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Intelligent Machines

THE Intelligent Machine is the practical result of some of the early academic studies in Artificial Intelligence. As in most practical versus academic comparisons the former often appear mundane when compared with the esoteric flavour of the latter. For example, the automatic inspection of pressed components compared with a computer program conducting medical or legal interviews is practical but prosaic. However, the one is an actuality and cost-effective while the other is a possibility for realization in the future and consequently un-costable. Our concern as engineers is with actual and costable devices useful to industry in the short term and which will have direct impact on the gross national product.

'Intelligent' in this context means the ability of an inanimate machine to operate, through sensory contact (visual or other modality), in an environment which is not completely defined, to accommodate task changes within that environment and to cope automatically with random variations in it without detailed instructions.

The late John Sargrove in his classic papers, published in this Journal in the late 'fifties and early 'sixties, preferred the term cybernetic (from the Greek:a steersman). However his concept did not then introduce the concept of self-teaching or self-adaptation which is explicit in many of the papers in this issue though he did anticipate the needs for such machines put forward again by the present authors.

The major step forward in capability since Sargrove's work has been the availability at low cost of the ubiquitous computer, particularly the microcomputer, and the advent of solid-state, rugged, camera devices. The latter make accurate measurement of objects possible without physical contact. This, combined with the logical and arithmetic capability of the micro-processor enabling it to perform intelligently removes the need for exact and costly placement of objects for inspection, assembly etc. Thus the concept of 'flexible automation' emerges, that is, automatic machines which are commissioned for a job capability of some generality rather than for one specific job. Recoverable or 'retrainable' equipment is essential if the automation of modest batch size production is to be implemented economically. Using such capabilities it is possible to foresee the manpower-intensiveness of piece-parts *inspection* and *assembly* becoming progressively automated to a level approaching the degree of automation familiar in *production* of piece parts. This is particularly relevant in medium volume, low unit cost, product areas where much of our GNP is produced in batch, and labour is both costly and capricious.

Long-term consequences and the motivation for the development of intelligent machines will be improved product quality and serviceability, encouraged by the overall product–lifetime–economic concepts of terotechnology. The overall function of 'manufacture' (from product inception to quantity production and service) also becomes that much more susceptible to systems thinking, another Sargrove concept. The adoption of ATE has already produced significant impact within our own and allied industries through application of 'design-for-testing' attitudes which can be adopted and carried over into the larger manufacturing areas of mechanical production. To marry up the various technologies, languages and attitudes of electronic, computer, mechanical and production engineers needed for the commercial development of intelligent machines is a challenging task calling for patience, strong nerves, dedication and money. However the rewards are likely to be considerable, and it can be done.

In product quality alone, the total 'cost-of-quality' to UK manufacturing industry (the greater part of which is the cost of rectifying or replacing equipment failing early in service) is of the same order as the profit margin, i.e. between 4 and 20% of turnover. A substantial fraction of the in-service losses could be saved by more effective Q.A. The major current weakness in Q.A. is the fallibility of human inspectors and their cost, and the first impact of Intelligent Machines is likely to be in this area. The impact will be no less in the areas of data capture and direct communication between man and computerized system through the spoken and written word. A myriad of un-anticipated applications will surely follow the emergence of a new capability—in this case the capability of machines to 'perceive' and 'react' to their immediate environment albeit simplistically (at first).

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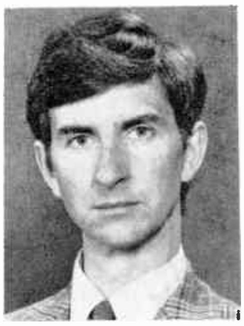

Alan Pugh (Fellow 1970, Member 1965) graduated from the University College of South Wales, Cardiff, in 1957 and held appointments with the BBC and Rolls Royce and Associates Ltd. Since 1961 he has been on the academic staff at the University of Nottingham and he is now a Senior Lecturer in Electronic Engineering. Dr Pugh was a visiting Professor at the University of Waterloo, Canada, for the whole of 1972 and his work on advanced robot techniques has gained him an international reputation through papers both published and read at conferences in many parts of the world; he is UK national coordinator for the International Symposia on Industrial Robots. He is a member of the IERE Papers Committee and of the Components and Circuits Group Committee and a year ago was appointed Chairman of the latter.

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Michael Underwood graduated in Physics from University College London in 1964. His Ph.D. in Communication was gained at Keele University in 1968 for work in speech synthesis and he then joined the Research Division of English Electric Computers which later became part of International Computers Limited. Subsequently he has worked on aspects of pattern recognition and information retrieval and he is currently responsible for a project investigating the use of speech for two-way communication with computer systems. He is author or co-author of a number of papers on speech processing, a committee member of the British Pattern Recognition Association and Honorary Treasurer of the Speech Group of the Institute of Acoustics.

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Intelligent machines —commercial potential

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SUMMARY

Artificial intelligence is defined and the components necessary for the mechanism of an industrial robot are discussed. The possibilities and constraints are assessed, leading up to a consideration of production aids which have an intelligent response. These fall into the classes of machine monitoring and visual inspection of fabricated parts, namely spindular objects and stampings and pressings. The second part of the paper discusses the application of intelligent machines in automatic personal identification, particular reference being made to signature validation.

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1 Introduction

Until the relatively recent advent of low-cost programmable logic—the microcomputer—attempts to model intelligent behaviour by machine has been limited to academic demonstrations of machines which can play games, e.g. chess,[1] navigate through simple but undefined terrains of randomly placed cubes, wedges, doors, etc.[2] and machines which can assemble a simple model from a stack of component parts.[3] These various studies and many others[4,5] have been characterized by their use of large computing facilities and their slow speed. In terms of normal human rates of perambulation and parts assembly, this is many times 'real time' in execution. Nevertheless these studies, lumped together under the collective term Artificial Intelligence (AI), have established that computing equipment *can* be programmed to cope with situations in which explicit *a priori* definition of the required response to possible situations is not given. In general from any given starting point the chain of actions leading to the required finishing point is not unique or defined. From this outline of AI it will be inferred that intelligence is defined as the ability of a non-biological mechanism to make contact with a rich environment, e.g. a games or 'real world' situation, and to react to it in a purposeful way. The domain within which the mechanism is to operate is of course defined by the experimenter as are the various tactical and strategic facilities which the mechanism has available to it.

In broad terms an AI mechanism has three components (Fig. 1):

(a) a sensory system for receiving input from the environment in which it is operating; this might be a keyboard input for a games situation, or a television camera and image analysis system for visual guidance;

(b) a central analysis and decision unit, and

(c) an effector, directed by the decision unit, which may be a physical manipulator for altering the perceived environment or, in games situation, an output printer or display.

The relative sizes of these three components depends upon the nature of the task. For example, chess playing is an analytical game making low demands on the sensory input and output effector, while the location, picking-up and placement of, say, a peg in a hole makes very much higher demands on the coordination of 'eye' and 'hand'.

While AI has grown as a topic and produced several scientific robots capable of assembling simple kits of parts, a breed of industrial robots (IRs) has emerged independently and found significant applications.[6] Of these the Unimate is the best known. IRs are mechanical manipulators with up to six degrees of freedom, controlled by a stored 'program' of movements and 'stances'. The 'program' consists of the recorded state of the various positions of the manipulator's 'joints' as a human instructor manually rehearses it through the

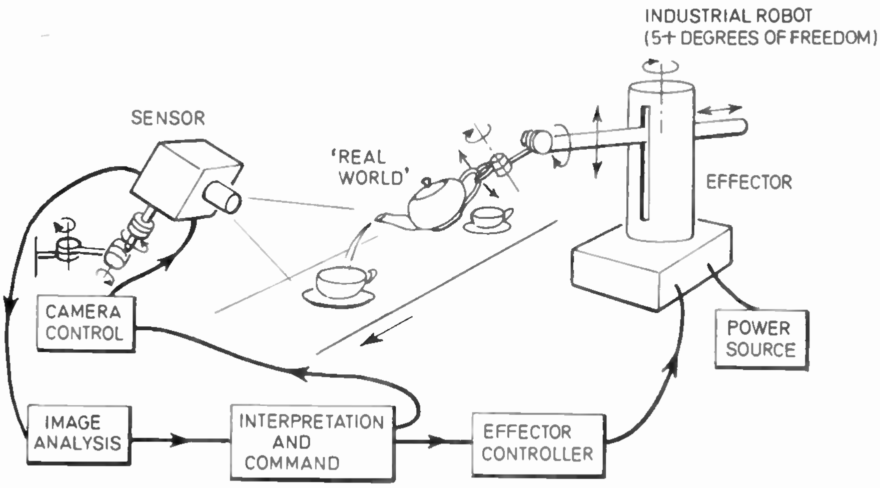


Fig. 1. Basic functional diagram of visually guided intelligent robot.

required routine of movements. The demonstrated movements are subsequently automatically reproduced from the stored information. This information may be either of a continuous path nature (when a complete path of movement of the manipulator is required), for example in paint spraying, or point-to-point, for example in spot welding where only a few fixed coordinate positions are required (Fig.2.)

Paint spraying and spot welding are, so far, the most popular and effective areas of IR applications. The techniques are also being used for gas cutting and seam welding, for machine loading and unloading, and materials handling.[7]

To date IRs use only primitive sensory inputs, e.g. simple go/no-go detectors which serve to initiate or control the sequence of a program. IRs are unable to react to minor changes in their environment, such as poor alignment or attitude of objects to be worked on. However, their use is increasing as their performance and cost effectiveness improves. They are generally acceptable to the work force, when sensibly introduced, as they are well matched to highly repetitive soul-destroying tasks calling for muscle power, repeatability and attention—but no intelligence.

The gap between the scientific and the industrial robot is immense. The former is led by the intellectual

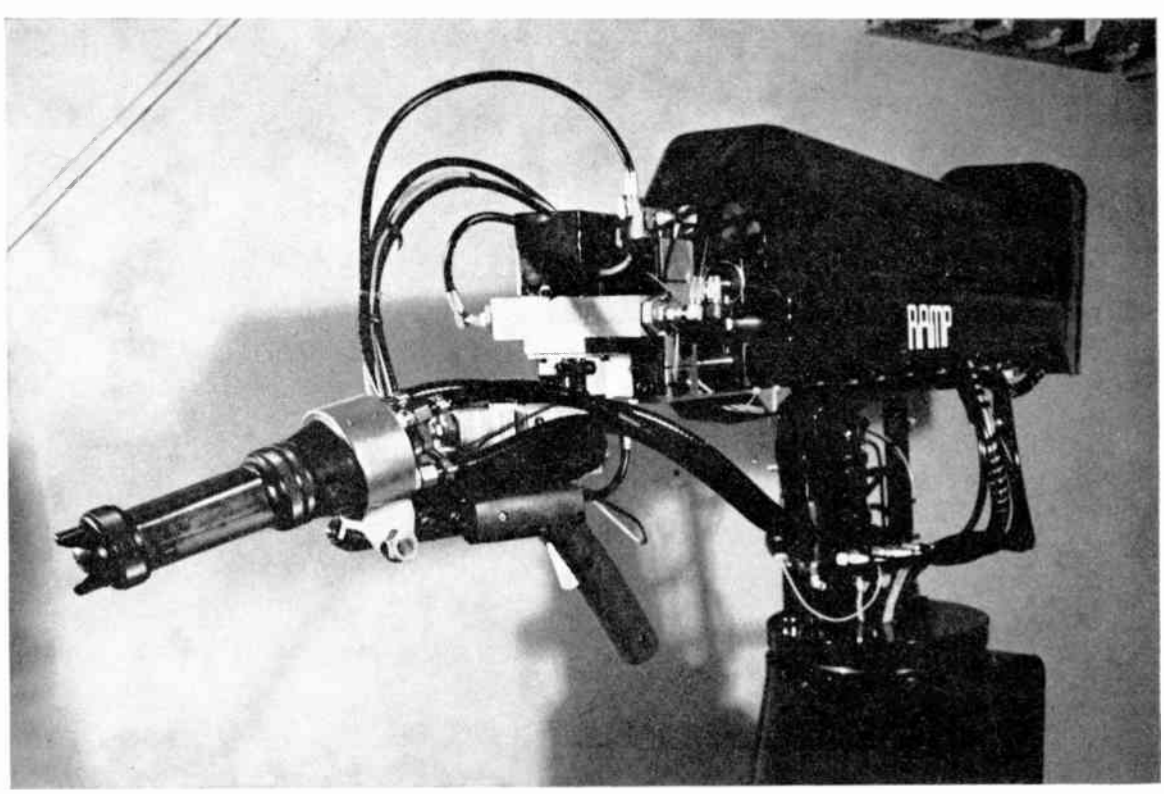


Fig. 2. RAMP automatic spray painting machine (*Hall Automation Ltd*).

challenge of developing artificial intelligence, a field which contains activities other than 'robot building', e.g. theorem proving, development of 'knowledge structures', programming language development, semantic modelling, speech understanding, and the like, but which often finds effective expression and test when combined in a scientific robot aimed at mimicking human behaviour.

The industrial robots are seen as part of the next major steps in automation—namely towards flexible or programmable automation for component handling and assembly.[8] They are complementary to numerical control and allied methods for *making* components. The major requirement of industrially applicable devices is, of course, their practicality and overall cost effectiveness. They are often viewed in isolation as man replacements, but should be viewed as part of a complete 'manufactory'. The benefits of more consistent products can then be included in the total cost equations.

Companion papers in this issue describe experimental devices aimed at solving particular manufacturing problems in batch production situations. This paper attempts to outline how modest computing facilities can be used to provide usable intelligent devices of commercial relevance in the rather disparate areas of product quality control and automatic personnel identification.

2 Need for Intelligent Machines

Ultimately we may see intelligent machines capable of performing many of the routine and monotonous jobs currently beyond mechanization, e.g. complex assembly, driving, mining, commodity deliveries, and so on, but for the present we have little concept of how these tasks can be achieved economically, i.e. cheaper than but as well as we can currently persuade a man or woman to do the job.

While the intellectual challenge of modelling intelligence is often difficult to resist (often because of the beguiling ease with which biological systems perform complex tasks), practical progress will probably be most effective if evolutionary rather than revolutionary attitudes prevail. This amounts to a recommendation that, for practical results, tasks of commercial significance but which are (apparently) relatively straight forward should be attacked. The very difficult or near impossible tasks will simply have to wait whatever the pressure for solution. Humility or objectivity is not a widespread attribute of imaginative researchers facing a challenging problem, particularly if the reward, financial or egocentric, for *attemping* to solve it is large. Equally over-dedication to a particular methodology can and has obscured more practical solutions. Indeed it should not be assumed that the solution to all existing manual assembly tasks necessarily requires an intelligent machine solution.

One of the earliest needs for practical and effective intelligent machines arose in the banking field in USA when the banks were faced with the mounting costs of cheque sorting due to increasing use of cheque accounts. The solution adopted to this problem, the E13B set of exotic character shapes to be found on most US and European cheques, illustrate two useful and pragmatic principles. Firstly, the situation is totally artificial, the whole system is a man-made artifact, and can be manipulated to ease the application of mechanical replacement; and secondly, given a manipulatable situation, it can be adapted so that the symbols are read mechanically by methods which do not reflect those used by human readers but exploit well-established engineering or signal processing techniques. In this instance conventional aesthetic character shapes and handwritten information were replaced by a set of symbols which can be conventionally read as two-dimensional character shapes but, additionally, mechanically read as a one-dimensional signal (differentiated vertical projection of the horizontal ink distribution) and immediately susceptible to classification by matched filter techniques.[9]

Inevitably the constraint that the symbols be readable both mechanically and by eye imposed compromise on the symbol shapes, resulting in some loss of legibility for both methods. It also required standards of printing, with specialized inks, never before demanded of the cheque printing industry. The increased cost of the new cheques was significant, in terms of paper quality (for improved mechanical handling), the additional printing costs, and revision of the bank chequing operation needed to exploit the new technology. However, the system which has been in use for many years now, was in the short term cost effective as an *overall system* and, in the longer run, is the only way in which the banks can continue to operate low-cost 'chequing-accounts'.

More advanced character reading systems have since been developed, culminating in the recognition of hand printed symbols,[10] which demonstrate an increasing capability for reading symbols poorly defined in size, position or shape. These variables, and others, occur in combinations which are too numerous to be explicitly stated or represented by statistical measures and the 'combinatorial explosion' is immediately met. Consequently heuristic methods have to be used. These systems use some form of character feature analysis such as line endings, branching, cross-overs and the like. The results of the analysis are inspected for spatial relationships between features which represent allowable characters. What is acceptable is not explicit but depends upon the relative sizes or position of 'chunks' of a character. This involves mechanical resolution of potential ambiguity for example between a poorly formed 6 or 0 which is resolved by the length and position of the upper stem relative to the loop.[11]

It was suggested earlier that attempts to develop intelligent machines should be honestly moderated by a realistic attitude to what is achievable—over-optimism leading to disillusion and loss of credibility. It is highly desirable that any speculative work and certainly any sponsored development work should be directed into channels where the *combined* chances of technical success and commercial pay-off, are high. While many challenging tasks for applied AI exist, ranging from independently perambulating planetary surface vehicles, through socially beneficial devices such as domestic robots[12] and automatic medical diagnosis centres, to games-playing machines, unless these can be commercially successful (and much work has been expended without significant commercial success), then more prosaic areas should be explored. Such areas should have some of the following attributes:

(a) Make a direct contribution to the gross national product.

(b) Improve the ease with which human beings can interact (i.e. communicate) with mechanized systems, for example by use of speech understanding machines.[13]

(c) Release human operators from jobs requiring only modest intelligence but of a tedious and/or dangerous nature.

(d) Demand unwavering attention over extended periods.

(e) Be approachable with technology within the state of the art.

This author's own rationalization of these requirements led him to accept commissions for the early investigation and development of production aids, particularly quality monitoring devices, and systems for the automatic identification of personnel—two rather different application areas for intelligent machines, which are described later in this paper. (Sects. 5 and 6).

3 Intelligent Machines as Production Aids

Of a net output for all manufacturing industries in the UK of £37B in 1975 the engineering industries (mechanical, instrument, vehicle and electrical) made a contribution of £12B. A large fraction of the production of these industries is based on batch production methods, batches ranging in size from a few hundred units, e.g. large motors and instruments, to tens or even hundreds of thousands, e.g. motor vehicle components, and nuts, bolts and other fasteners. In many cases the run length is short, limited to days or at most weeks so that special-purpose production (line) mechanization is not economically justified.

The number of products which are truly mass produced is rather limited, for example light bulbs, bottles and cans, and bread. To these we might add the production of continuous products such as gas and oil products in which the process from feedstock to delivered product is relatively easily instrumented under close automatic control. This is reflected in the dramatically high net output per head for oil-based products of over £22k compared to the engineering industries of approximately £5k. Consideration leads to the conclusion that production of free flowing materials poses many fewer problems in material handling, mixing, storing etc. when compared to the production of *discrete* items be they screws or motor cars. Concepts such as positional accuracy, orientation of components, surface finish and so on have little meaning in flowing materials and assembly is often achieved simply by mixing in prescribed proportions.

The manufacture of discrete items shows several distinct phases:

(a) The making of components, generally by mechanized and sometimes automated tools,

(b) putting together components to form assemblies or sub-assemblies, and

(c) finished product or sub-assembly inspection calibration and test.

Of these three activities (b) uses most manpower, particularly in the high-volume low-unit-cost areas of consumer durables, the larger fraction of our engineering output. Paradoxically a significant capability exists for automatic assembly[14] but is not used to an extent commensurate with the apparent capability available. While labour attitudes may have something to do with this, more fundamental reasons are apparent: these are, primarily,

the difficulty, with the existing technology, of correctly orientating or separating complex, thin or near symmetrical components (particularly non-rigid objects such as springs, gaskets etc.) and

the proportion of defective components included in parts for assembly which existing quality control methods have to accept for economic reasons.

These problems can be reduced through the use of machines with sensory input (a better appreciation of the requirements for automatic assembly in the design stage would also help to reduce these problems).

Intelligent machines can be applied at the point of assembly to inspect individual components for conformance to specification and to determine their position and orientation. A manipulator can then be directed to pick up acceptable components, orientate and assemble them, non-conforming components being rejected. Sensor-directed intelligent assembly robots have been demonstrated by Edinburgh University[3] and S.R.I.[15], Nottingham University[16] and Philips Research Laboratories.[17]

It may be natural to think of the direct linking of parts inspection, manipulation and assembly but this is not fundamental. There is a significant disparity between the work rates of electronic and mechanical processes which often prevents their efficient matching. Many component suppliers are required to maintain very low defect counts when manufacturing for other firms or other parts of their own organization and therefore require free standing automatic inspection equipment. The mechanical handling requirements for the presentation of parts for inspection can be relatively simple, quick and cheap if the inspection method can cope with only approximately positioned and orientated parts. Two approaches with which this author was associated are outlined later in this paper.

The availability of high-speed inspection machines, operating at a rate of several parts per second, makes 100% inspection of components possible with only a modest increase in cost.[18] These can then be supplied in lots of certified quality level. Quality levels better than 0·1% of defects would be possible. Existing manual methods of statistical quality control, SQC, operating on a sample testing basis, are well developed and documented, but are unable to ensure that batch quality level is better than 1% or so at acceptable cost. This level of quality (Acceptable Quality Level, AQL) is a reasonable match between quality control and the requirement of existing manual assembly methods. Relatively modest sample sizes are adequate to ensure AQL at around the 1–2% level but for levels an order of magnitude up on this close on 100% inspection is needed for batches up to 1000 units.[19] To achieve AQL of 0·1% using human inspectors required duplicated inspection and the cost of components becomes very high, many times that for AQL of 1%.

For automatic assembly to be effective AQL of the order of 0·1% is essential[14] in order that the resultant assemblies, of perhaps ten pieces, themselves have an acceptable AQL, and also to prevent frequent stoppages due to malfunction of the assembly device when attempting to feed or assemble faulty components.

Cost is a dominating factor when discussing the practical application of any new automation equipment. Appendix 1 outlines a simple analysis of the cost effectiveness of an automatic inspection machine costing approximately £15k amortized over three years, working on a one shift 220 days per year basis at a rate of 4 pieces per second. Assuming a return on investment of 15% per annum and acceptable mark up in component cost of 5 to 10%, then if such a machine requires no more than one operative in attendance half the time (a very pessimistic assumption) the use of such an inspection device is justified for parts whose value, before inspection, exceeds 0·5p each.

On the topic of costs, the total 'cost-of-quality' (C of Q) is worth considering. It is the sum of those design and manufacturing costs which go to ensuring product quality (i.e. fitness for use), plus the rework and warranty costs incurred when faults are detected at a later stage, often in the field. C of Q amounts to between 4 and 20% (according to industry) of the products ex-works cost.[19] The cost of quality, or the consequences of lack of it, is comparable to the pre-tax profit margin and is of the order of £1000M per annum in UK engineering industries.

About 60% of this cost is incurred in the field as replacement or rectification costs and is the direct result of ineffective quality control during manufacture (or in materials used) and is something of an indictment of the the existing methods. Fortunately our own, electronics, industry is rather better than most in this respect through the adoption, for example, of (intelligent) automatic testing procedures.[20] We are fortunate that we can use our own technology, leavened with computing techniques, to test our products. There is a literal compatibility between the products and the test methods and apparatus which makes testing relatively easy. However in most other industries our technology is alien or at best unfamiliar. The crossing of technology boundaries is one of the challenges and rewards (all senses) of introducing machines with a limited intelligence into other production engineering situations.

The above discussion has centred on inspection of discrete component parts, however methods are emerging, some capable of immediate implementation, for the automatic inspection and grading of materials, particularly sheet materials, metals, paper and plastics.[21,22] Applications often require the classification and hence source of surface defects in addition to assessing their area and number for material grading purposes. Automatic inspection equipment then becomes a quality control tool in production of commodities such as tin plate, coated paper, glass etc. Some of these production processes are continuous but have not been fully automated for lack of instrumentation capable of assessing (measuring is too precise a term) the type, extent and frequency of defects and blemishes which are often more psycho-physical and 'cosmetic' in nature than the bulk physical properties of, for instance, oil products.

4 Machine Monitoring

Up to this point components inspection has been discussed as a post-manufacture process, often performed after other processes, e.g. finishing or forming have been applied. There is, therefore, little direct control of the manufacture process which can be exercised as a result of the inspection process. For this purpose in-process inspection is required. While some success has been achieved with in-process gauging[23] for control of precision turning and grinding, little if anything is currently possible in other production processes such as casting, pressing and forming, extruding and so on. Optical methods cannot gain a clear view or would quickly be spoilt by the high level of swarf, lubricant, smoke etc. existing in and around the work area and are inappropriate. There is probably no general answer to this problem, however many material forming processes, such as punching, pressing, extruding, and some casting and moulding processes have a high energy or work rate. Such processes are short-lived and 'violent', and repeat with very little variation from cycle to cycle. The products of such processes can be indirectly 'inspected' by monitoring some aspect of the forming machine

Table 1. Some manufacturing processes which can produce characteristic 'signatures'

Process	Measurement or instrumentation	Faults detectable
1 Punching, pressing broaching, impact extruding and similar 'impulsive' metal forming processes	Accelerometer (vibration), strain gauge	Material mis-feed, tool damage Scrap between dies, tool losing 'setting'
2 Pressure casting and moulding	Pressure, mass-flow	Incomplete filling blockages, incomplete removal of product
3 Spot welding[25]	Current/voltage profile	High resistance weld, i.e. incomplete metal melting

behaviour which is characteristic of its operation.

Electrical signals which characterize a process can be obtained from a variety of mechanisms.[24] Table 1 lists some manufacturing processes, the form of 'signature' which might be extracted and likely causes of change in the 'signature' to which monitoring might be applied.

Continuous processes such as turning and grinding are unsuitable for this approach, though tool condition can be inferred from, for example spectral analysis of the tool 'chatter'.

Process signatures repeat closely (ignoring non-relevant signals from extraneous sources arising outside the 'active' phase of each cycle) while the process is functioning correctly but change markedly if the process changes due to a fault. Clearly the 'detector' has to be judiciously positioned in the machine to obtain a usable signal in which small changes can be detected. Figure 3 shows a vibration signature, while Fig. 4 shows Fourier analyses of this signature for good and faulty punch press processes.

In applications use the process signature would be 'learnt' by a computerized monitoring system while the machine executes a significant number of good operations under qualified supervision—probably the tool setter. During this phase the mean wave form of the signature and its statistical variation is determined. In the 'operational' phase the monitor examines individual signature waveforms, perhaps on a sampling basis, to detect any tendency for them to move away from the 'learnt' form. Gradual statistical trends would be reported periodically to supervising staff while any dramatic changes, indicating severe trouble, raises an alarm and halts the machine before serious damage is done. As the critical interval in most processes will occupy only a fraction of the total machine cycle then the monitoring equipment can be time-shared between several machines. By time-sharing between, say, fifty to a hundred machines, it is possible to produce monitoring systems at a cost of the order of £200 per individual

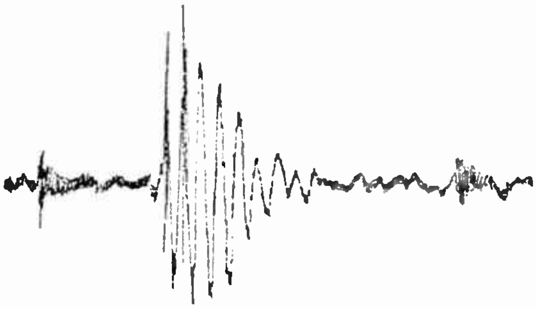
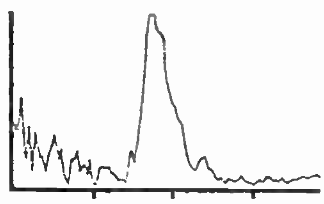
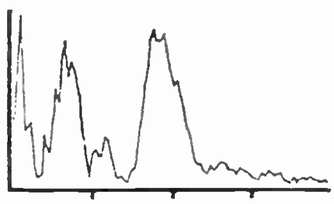


Fig. 3. Vibration 'signature' from a 10 tonne press.



(a) Normal operation



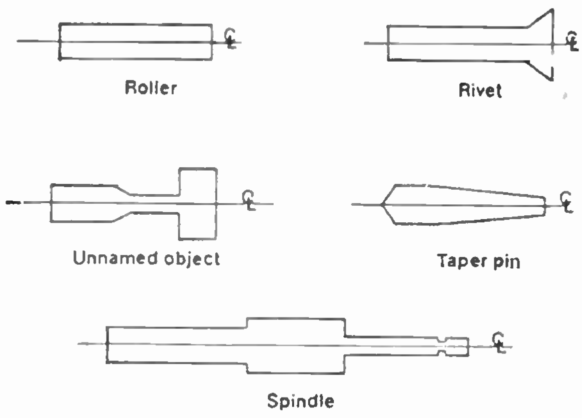
(b) Fault condition

Fig. 4. Spectral energy analysis of vibration signature.

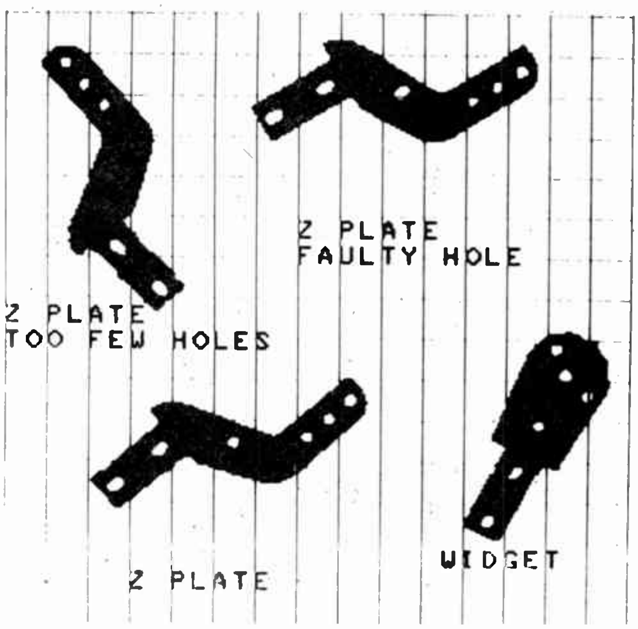
machine. Such monitoring systems also enable a precise inventory to be kept of pieces made, i.e. actual *production* cycles of machines, as distinct from machine cycles. Run-out of stock material would be immediately detected and reported. This in turn would improve the utilization of machines and economize on energy consumed. With such a 'self-teaching' facility monitoring systems can accommodate a variety of differing machines and processes of varying cycle time. Changing of the product requires only a 'retraining' of the monitor.

5 Visual Inspection Systems

The requirements of a system for visual inspection of component parts varies with their method of manufacture. For example, most turned components are axially symmetric and require accurate measurement of diameters and lengths. Accurate measurement cannot be avoided as dimensions are not well defined by the tooling which can go dull or out of set. On the other hand-stamped components produced from strip material are much more complex (Fig. 5) but, being produced



(a) A selection of spindular objects.



(b) Examples of punched components showing computer-labelled specimen and defective punchings. Definition of complete picture is 240×240 picture elements.

Fig. 5

from rigid tooling, do not show significant change in dimension except as a result of tool breakage, or failure of the stock material to feed correctly. These two classes of component require different aspects of their form to be checked in an inspection facility.

Turned components are usually spindular, i.e. have length significantly greater than their diameter and can relatively easily be placed in a groove and thus roughly aligned for inspection. A large proportion of stamped components are more or less flat, i.e. have a height much less than their width, and therefore have only two stable states, 'face' up or 'face' down. In general, stamped components have no dependable symmetry and therefore offer no inherent alignment properties. However, both classes of objects can be adequately defined in size and shape when viewed as silhouettes against a bright background thus giving a simple black/white image for examination not confused by surface colouration or markings. Distinctly different inspection methods have been developed to cope with the different types of components, but both using the 'self-teaching' principle so that rapid change of inspection task are possible.

5.1 Inspection of Spindular Objects

A simple method for inspecting roughly orientated spindular objects, has been developed at the National Physical Laboratory, London, and is now available commercially under the trade name of SCANAFORM.

Consider the objects in Fig. 5(a) from the point of view of solid geometry. Each is a collection of coaxial cylinders and frustra each individually specified by the lengths and diameters of the component solids. The whole ensemble is 'assembled' in a prescribed order. (An exact reversal of this order also describes the same object.)

Passing this object before a one-dimensioned photo-diode-array camera yields a quantized video signal representing the objects. The signal can be reduced to a simple numeric form suitable for computer manipulation by hardware shown in Fig. 6. This produces a stream of number groups corresponding to the number of the diodes at black/white or white/black transitions in the image. In general, there is an even number of such transitions in each scan, the odd numbered ones indicating white/black transitions, the evens black/white ones. The differences between the odd-even pairs indicating the width of each dark strip, and differences between even-odd pairs indicating the gap-width between dark strips, should there be more than one. Objects with holes will produce a multiplicity of dark strips in each scan through the object.

The difference between the elements of each (or 'outer') pair of numbers indicates the diameter (width) at one point on the object, while the mean of the two numbers corresponds to the position of the centre line. A step-transition, from one measured diameter to another, will indicate the completion of a segment. Any lack of straightness of the object will be reflected in the position of the centre line.

In practice various complications creep into this simple situation. In general, the first intersection of the leading edge of the image and the photo-diode array will not produce a true diameter due to surface roughness of the object, or to variation of the photo-diodes' sensitivity. Typically, one or more 'noisy' diameters are obtained initially. Although the measure of diameter obtained is equivocal, there will be no doubt that the image has reached the photocells and the length of the object (or segment) may then be measured by counting the number of scans which intercept the image. Later scans will be free of the initial 'edge effect' and will indicate the true with a limited intelligence are required. Electronic funds transfer and other automatic banking and access controlling facilities require good evidence of the authenticity of any client attempting to use a remote unsupervised interactive terminal. Existing methods are based on the presentation of a token, often a plastic card with magnetic stripe, supported by keying-in a security number. Such systems are not completely secure and systems are being developed which use a token which cannot be 'detached' from a client, even under duress.

This requirement has to exploit some personal characteristic, physiological or behavioural, which cannot be duplicated, mimicked or forged. Devices have therefore to be developed which can be used on a routine day to day basis which do not soil the client, are socially acceptable and yet which leave an audit trail for subsequent checking if necessary.

A number of possibilities exist, e.g. finger prints, voice prints, facial images or taxonomic measures of the hand. However, the most socially acceptable alternative is the conventional written signature. This has attracted attention in USA [27] and UK.

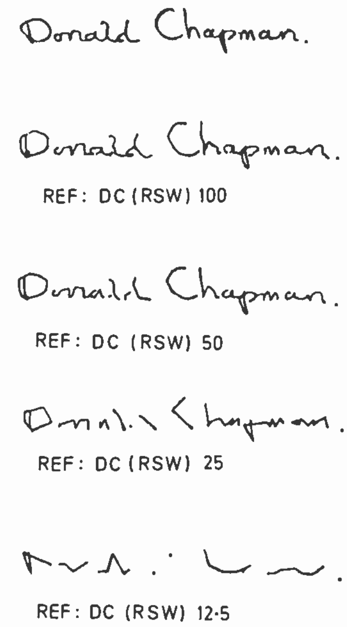


Fig. 7. Original signature and reconstructions at sampled rates of 100, 50, 25 and 12·5 coordinates per second.

6.1 Signature Validation

The major use for API by written signature is at 'points of transaction' where the client is present and can be required to produce his signature upon a given form. It is then a simple matter to present this form on top of a suitable pressure sensitive digitizer which encodes the movement of a writing stylus as it moves over its surface. Various suitable digitizers have been produced[28] which digitize the x, y position of the stylus point at least fifty times per second. This rate of digitizing is adequate to reproduce written signatures (Fig. 7) and contains not only the geometric locus of the stylus but also temporal information indicating the order and 'tempo' of the writing.

It is a relatively straightforward matter to extract a number of simple measures of a signature which are adequate to characterize it. Such measures include:

(a) Total time of writing.

(b) The number of discrete segments in the writing.

(c) Writing velocity and accelerations at selected points in the writing.

(d) Number and position of loops or other locatable features

A large number of potentially useful measures can easily be invented and derived from the basic spatial and temporal encoding of a signature (or other piece of writing). The cleverness in the design of such systems resides in the selection from a large candidate-set of a small but sufficient number of parameters to frustrate attempts to gain illegal access with a forged signature while not making it difficult for genuine clients to obtain acceptance. This has been achieved in the VERISIGN system demonstrated at NPL.[29] (Fig. 8.) The exact details are not relevant here except to illustrate how such systems behave intelligently in an unspecified task environment.

The task is validation of signatures given a number of useful property descriptions which are known *a priori* to be adequate for the task. There are an essentially unlimited number of signatures in various scripts which could be offered in a practical application. There is, therefore, no attempt to *recognize* signatures but only to *verify* that a signature offered at some point is sufficiently like a previously authenticated signature to be accepted as the same.

Consequently the system has to operate in two phases, learning and use, as already described for parts inspection systems but with one or two extra facilities. In this application we are dealing with a broadly reproducible but non-rigid object with undeniable and unique identity from sample to sample. Each signature exhibits a statistical variation and may also show a long term systematic variation.

Clients admitted to use the system initially provide a number of signatures from which the value and statistical variation of the property measures is estimated. In statistical terms a simple process but in practice there are a number of problems:

(a) Clients are unfamiliar with the apparatus.

(b) It is not practical to ask clients to sign more than about five times without some diversion to prevent boredom or annoyance.

(c) Sample signatures usually have to be collected at a single 'session' when the client is admitted.

As a consequence of (a) an initial set of five samples may contain abnormal or fragmented signatures, or the statistical spread of the samples may be excessive. The learning phase of the system therefore assesses the given group of signatures to determine their 'compactness' by comparing the property measures from individual signatures with the mean and deviation for the offered set. Any bizarre signatures are thus detected and discarded and a replacement sought from the client. This process is repeated if the deviation is 'excessive' until either this deviation is confirmed by further samples or the deviation contracts to an 'acceptable' level. These are clearly heuristic methods justified only by the eventual system performance and which certainly violate the best statistical estimating procedures. The qualifying terms 'excessive' and 'acceptable' were based upon the statistics derived from a large population of signatures. The overall variability of a client's offered signatures when normalized by the population statistics yields a measure which indicates the vulnerability to forging of his signature. This vulnerability factor can be used, in practice, to monitor a client's consistency of behaviour and also to moderate the value of any transaction which can be allowed automatically without recourse to additional evidence or higher level decision. The extracted parameters of a client's signatures once accepted are stored (possibly on a magnetic stripe on a credit card).

In active use a claimed identify is validated by comparison of measures extracted from a written specimen signature with the stored statistics. The degree of match obtained is an indication of the validity of the proffered signature. The degree of mis-match which is tolerated may then be related to the value of the transaction sought. Up to three attempts have been allowed to achieve an acceptable match after which, if all fail, access is refused and assistance summoned.

In experimental trials it has been found that while achieving complete protection against deliberate forgeries, about 4% of transactions were failed but that these failures tended to concentrate on a small number of the users. There is a finite chance that any arbitrary writing could be found acceptable since the measures extracted, from a signature are not necessarily unique. By comparing all possible clients' parameters with several thousand other signatures this chance confusion was found to be of the order of 1 or 2 parts in 10^4. By adjustment of the threshold of acceptance used it is clearly possible to trade off the level of protection to forgeries offered against the false rejection rate.

In practice it was found that most clients became more consistent from transaction to transaction but that there was also a long term, possibly habituation, effect, which required the VERISIGN system to adjust the stored statistics automatically to accommodate this drift in client behaviour. Again this was taking liberties with conventional statistical methods but was demanded in the practical situation to accommodate human behaviour.

Applications are being considered for such systems in both banking and access control situations.

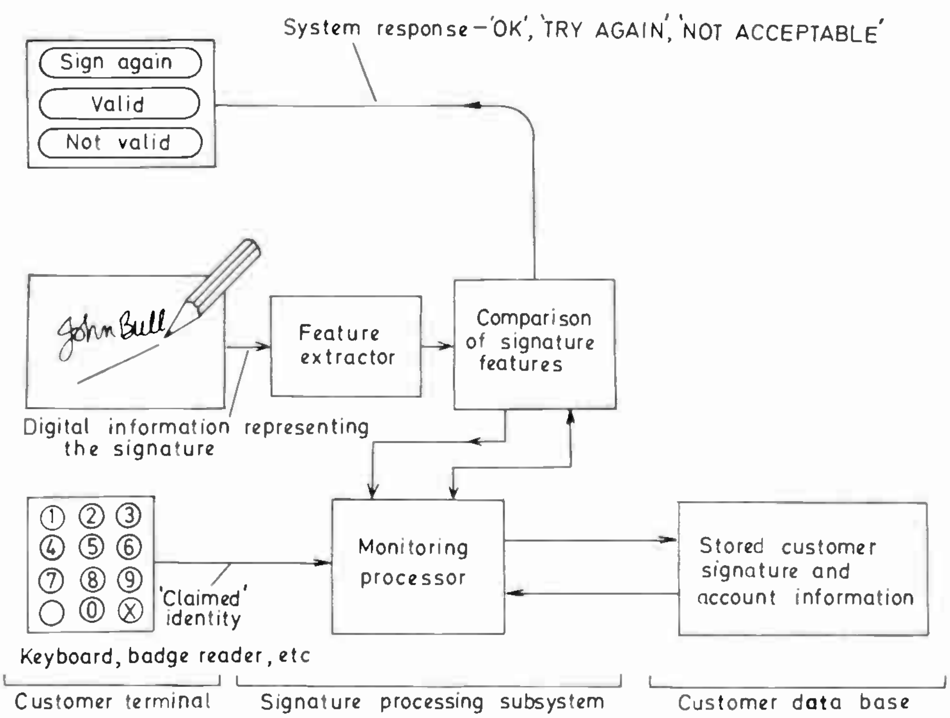


Fig. 8. Basic system configuration for VERISIGN—the exact location of the various components will depend on the particular application.

7 Further Possibilities

The two very different types of intelligent machines described are characterized by the ability of the mechanisms to automatically adapt, by 'self-teaching', or 'learning' to changes in specific tasks or objects within a broadly defined range of operation. The dimensions or shapes of objects for inspection are not defined beyond the generic definition of spindular or shallow pressings or stampings; likewise the repertoire of signatures to be encountered by VERISIGN is not knowable *a priori*, and it has proved capable of dealing, without modification, with Middle and Far Eastern writings as easily as the Occidental cursive script for which it was intended. These devices, and others described in this issue, were fundamentally designed to be self-adaptive so that they can accommodate changing situations with minimal instruction.

What lessons can be learnt from these modest beginnings and, if they are beginnings, where is further development likely to lead? In the short term, of course, practical cost effective applications of such methods have to earn their spurs in competition with established methods and in the face of inevitable conservatism. However SCANAFORM, as recently introduced commercially, has excited considerable interest. It is perhaps significant that this particular machine is being marketed by an established supplier of various types of gauging equipment (Thomas Mercer Ltd.), as an evolutionary step in automatic measurement capability and not as a revolutionary introduction of a new technology (and certainly not by eccentric scientists!).

In the longer run devices are needed for checking more complex assemblies of components. Full three-dimensional shapes could be visually checked for completeness with the possibility of checking objects having appendages, e.g. operating levers on car door locks, which have no unique positions but whose relative attitudes and positions are significant. The possibility, probably before three-dimensional objects are tackled, of 'flat' assemblies of components of distinctly differing colour or reflectance can be foreseen.[30]

However, it is likely that progress will be made more quickly through concentration on achievable advances in the technology matched by identified needs rather than by dramatic leaps, though application or reapplication of existing art in new fields might appear to be dramatic.

Now that the cost of the microcomputers and solid state input sensors has dropped, many more applications can now be economically met by intelligent machines. A new technology is now applicable, in quality control particularly in small to medium batch runs, and in field of human interaction with machines —going far beyond the establishment of bona fides.

8 Conclusion

Given the existing state of the art in AI research, commercial pressures for improved product quality and utilization of resources, and continuing pressure to reduce production dependence on manpower in low grade repetitive jobs, some application of AI techniques in the form of intelligent machines is seen to be possible in the early development of machines which can accommodate variable or ill defined tasks. The cost-of-quality is comparable with the profit margin. A majority of this cost arises through a lack of quality causing costly failure of equipment in use and there can be no doubt that improved methods of quality control and management are needed. Intelligent machines are particularly relevant in the limited production run situation in which production equipment has to be 'universal' in nature and easily reapplied—the essence of programmable or flexible automation. Such equipments will need increased 'sensory' contact with their tasks and to be self teaching or adaptive, thus minimizing the need for skilled manpower to 'reset' them for successive jobs; jobs which may only run for a few hours or even minutes.

Such technology is emerging and some is available commercially. Its future is limited more by a lack of appreciation of the capabilities which are now available with low cost processing power and sensory devices than by the state of the (electronic and data processing) art. The future for intelligent machines is promising in many fields, not least of which are likely to be production engineering of high volume low unit cost consumer products and control of access to sensitive or valuable commodities, information or money, to name but two.

9 Acknowledgments

While the author must accept responsibility for this paper he cannot pretend that the ideas are his alone and grateful acknowledgment is made to many contacts in industry and academies too numerous to mention and especially to former colleagues in the National Physical Laboratory where the works briefly described in this paper, and not generally published, were undertaken. This paper is published with the permission of the Department of Industry.

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11 Appendix

Approximate analysis of costs of inspection with automatic parts inspection machine.

1 Cost of facility

Cost of machine say, £15k amortized in 3 years ..	£5k/a
Cost of finance at 15% ..	£1·5k/a (average)
Cost of accommodation at £30/m² on 3·3m²	£100/a
Cost of supplies, 1 kW at 1·5p/kW h	£22/a
Cost of skilled operative ½ man-year at £4·5k/a + 200% overheads	£6·75k/a
	£13·4 k/a
Annual cost including Allowance for insurance, service etc., say	£15k/a

2 Throughput of facility

Specification of machine; 4 parts per second	
Single shift, 220 days per annum Maximum possible throughput	$2{\cdot}53 \times 10^6$ parts/a
Whence minimum on-cost for inspection	0·06p each
If utility of facility is 60% the on-cost is	0·1p per piece

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Machines that understand speech

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SUMMARY

The ability to use language to formulate abstract concepts and to communicate these concepts to another human being must rank as one of the most significant aspects of intelligent behaviour that a human being can demonstrate. Speaking is the technique that has evolved to enable this communication to take place quickly and efficiently between two people in close proximity to one another. Consequently machines that understand speech are usually considered to be intelligent. The designers of the early machines for recognizing speech treated it as a set of patterns that could be processed by conventional pattern classification techniques. This work has led to the design of commercially available machines that respond to a limited range of isolated words in controlled conditions. More recent attempts at designing speech understanding machines have been based upon the linguistic nature of speech and employ linguistic and semantic modelling to aid recognition. Whilst the performance of these systems is vastly superior to the pattern classification type of machine, it is still very limited when compared with the speech understanding capabilities of a human being. This paper reviews the problems and current state of the art in machine understanding of speech.

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1 Introduction

It is generally agreed that man is the most intelligent member of the animal kingdom. Whilst there are a number of factors that distinguish us from other animal species, the most significant one must be the highly developed powers we possess for using language. Language is the means by which information (i.e. a *meaningful* message) is passed from one animal to another. The ability of animals to communicate with one another is concerned mainly with primitive functions, largely related to the survival of the animal. At the other extreme, man is able to represent and communicate the most abstract concepts, and speech has evolved as the most natural means of communication between people. It is also the means by which we develop our linguistic skills, the development of additional (and particularly more intellectual) skills being itself dependent upon a certain degree of linguistic proficiency. From this it should be clear that speech cannot be considered as an isolated phenomenon; it is intricately related to natural language and man's whole functioning as an intelligent animal. With this view of speech in mind, it is hardly surprising to find that a machine of considerable complexity would be required in order to recognize speech as capably as a man.

This paper is concerned with examining the point that has been reached in designing machines to understand speech. For these purposes, a machine will be considered to have recognized or understood a spoken message if the receipt of that message causes the machine to react in the way that the speaker intended; for example, the message may be a single word that causes the arm of a robot to move. The paper is organized in the following manner. Section 2 is a brief discussion of the nature of speech and the information conveyed by the speech signal. An essential part of every machine to understand speech is concerned with the physical analysis of that signal. Some of the techniques for doing this are described in Section 3. A distinction between three types of speech understanding machine is made in Section 4, and some of the problems in their design, implementation and use will be discussed. Section 5 contains some remarks about the future developments in speech understanding machines.

2 The Nature of Speech

In formulating a spoken message, a speaker has a number of choices to make. For example, he can choose the specific concept he wants to communicate, the words that make the message and the way in which he will speak it. Having made certain choices however, there are a large number of rules or constraints that govern the successive transformations of his thoughts into a pressure waveform that is propagated through the air to one or more listeners. This is illustrated diagrammatically in Fig. 1. If these rules are not obeyed, it is likely that the message will not be understood. Likewise the listener must also be aware of the rules and constraints,

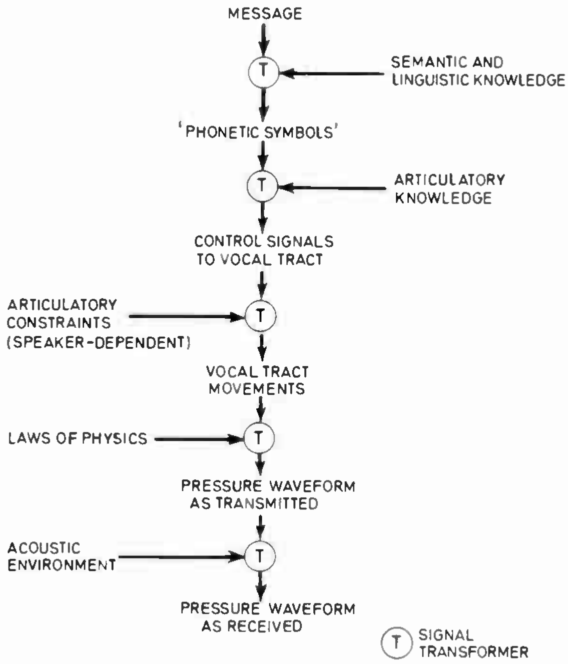

Fig. 1. Simplified diagram showing some of the influences on the generation of a speech signal from a conceptual message.

or he will not be able to understand the signals he receives. Not only must the speaker and the listener understand the same language, but they must both have some knowledge in common in order to be able to communicate effectively. For example the word 'gate' has different semantic associations for a farmer and a logic designer.

Although the way in which human thoughts are represented and manipulated is still unknown, it is apparent that the pressure waveform in the air can only be loosely related to the thoughts because of all the transformations the message has to undergo. The waveform can be regarded as an intricately encoded version of the thoughts. The process of encoding and decoding can only occur by virtue of the large amounts of knowledge possessed and used by both the speaker and listener. The work on designing machines to understand speech during the last 25 years has shown that machines too will need to employ such knowledge in order to understand speech with the same facility as a human being.[1] The representation of knowledge about the real world and its use by a machine still presents a significant challenge to those working in the field of machine intelligence.

Unfortunately for the designers of speech recognition machines, the speech signal contains information about many other aspects of the speaker and his environment. For example, a listener switching on his radio receiver can very quickly answer the following questions about what he hears.

(i) Is it speech? If so, is it in his native language?
(ii) Can he understand what is being said?
(iii) Does the speaker have a pronounced regional accent? If so which one?
(iv) Does the voice belong to someone he knows, or has heard before?
(v) Is the speaker a man, woman or child?
(vi) What is the nature of the acoustic environment of the speaker, e.g. quiet, noisy?

It is as though there were a number of separate information sources each contributing to the overall signal the listener hears. Not all these sources are independent of one another and this presents the designer of a speech recognition machine with a formidable task. To date the most difficult problem has been to separate those elements that convey information about meaning from those that convey information about the speaker. This problem has not yet been adequately solved. Some attention has also been given to the complementary problems of recognizing the speaker as opposed to the message. The problems and current achievements in this area are reviewed by Atal[22] and Rosenberg.[23]

So far we have discussed the general nature of speech and why it might be difficult to design a machine that would understand it. It is worth discussing the reasons for building such a machine.[2] One reason is that the difficulty of the task constitutes an intellectual challenge. A corollary to this is that the attempts to design such machines will enable us to learn about human speech processes, by comparing human and machine performance. A more practical reason is to be able to use speech to communicate with machines, particularly computers. Some situations where speech may be used are shown in Table 1.

Most data input to computer systems is entered manually. If a person's hands are already occupied, speech provides an alternative channel for the data input. Moreover, unskilled users of keyboards are able to input data faster and more naturally using speech than they are with their hands.[1] At present, computer-based information systems are used by comparatively few people. Developments in information processing technology are leading to more powerful information systems

Table 1. Situations where speech communication with computers may be useful

Situation	Advantage of Using Speech
Operator's hands or attention are occupied	An alternative channel of communication.
Unskilled users	Faster than keying and more natural to use.
Remote terminals	Speech is natural to use via the telephone and does not require special terminal equipment.
Handicapped people	An alternative channel of communication.

offering a wider range of services. Speech communication with such systems via the telephone would make them readily available to a much greater number of users.

In all these cases, the objective is not that a man should be able to hold a completely natural conversation with a computer, but rather that some limited use be made of spoken communication, e.g. the input of isolated spoken words. Inevitably this places restrictions on the user and the way he can interact with the machine. The use of speech will not solve all the problems of the man-machine interface. Indeed until machines have the same capability to recognize speech as humans, there will be significant human factors problems associated in matching these comparatively simple machines to men. Even when spoken communication with computers is better understood and applied than it is now, there will still be a need for other forms of communication (depending upon the application) in just the same way that some circumstances require written communication between people.

3 Speech Analysis

An essential part of any speech recognition machine is concerned with the physical analysis of the speech signal. The main function of the analysis stage is to transform the speech signal into a number of parameters that adequately describe the speech signal and enable the appropriate information-bearing elements to be extracted. The data rate of the signals produced by an analyser is usually considerably less than that of the speech signal itself (around 60,000 bits per second for p.c.m. telephone quality speech) and so it is important that relevant information is not lost in the analysis process. A useful check on whether significant information has been lost in analysis is to use the output of the analyser to synthesize a speech-like waveform. If the original and re-synthesized waveforms cannot be distinguished by a human listener, no significant information has been lost. However, if re-synthesized

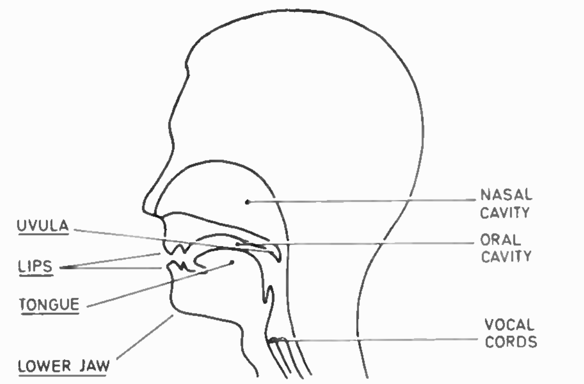

Fig. 2. Cross-section of the human vocal tract. The names of the articulators (the movable parts) are underlined.

versions of two different words cannot be distinguished by ear, it is very unlikely that any machine could recognize them as different words. A large number of techniques for speech analysis have been described in the literature.[3] The emphasis in this Section will be on the requirements for analysis techniques, rather than on the techniques themselves.

The speech waveform is produced by the air stream from the lungs being modified by the vocal cords and the resonant cavities of the throat, mouth and nose. A number of different classes of speech sound are produced according to the way in which the organs of the vocal tract are controlled (see Fig. 2). In voiced or vowel-like sounds, puffs of air produced by the vibrating vocal cords excite the resonances of the air in the vocal tract. The resonant (or formant) frequencies are determined by the position of the articulators, i.e. tongue, lips, etc. (and manifest themselves as dark bands in the spectrogram in Fig. 3). Unvoiced sounds, e.g. /s/, /f/,† are produced

† Characters enclosed by // are phonemic symbols. For example /s/ is the first sound occurring in the word 'speech'. The pronunciation of all the phonemic symbols used in this paper is self-evident.

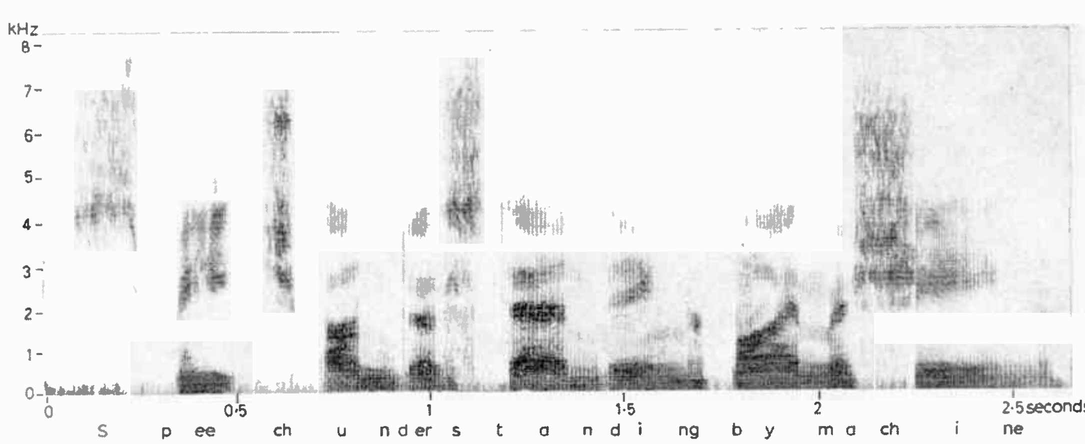

Fig. 3. Spectrogram of the phrase 'Speech Understanding By Machine'. During voiced sounds, the formants are indicated by the dark bars running across the spectrogram. Unvoiced sounds a recharacterized by the noise-like segments with frequency components extending to above 7 kHz.

by forcing air through a narrow gap in the vocal tract, the resultant turbulent flow giving rise to sounds with characteristic frequency components. Some sounds are produced with a mixture of voiced and unvoiced excitation, e.g. /z/, /v/. Stop sounds or plosives, e.g. /p/, /b/, /k/, are produced when the vocal tract is closed at some point. When the obstruction is removed, there is a sudden release of air, accompanied by a rapid change in formant frequencies as the articulators move to a new position. In English, the characteristics of the sounds we hear are determined primarily by the positions and movements of the articulators.

If we consider the speech signal in the frequency domain, its spectrum is the product of the source spectrum and the transfer function of the vocal tract. A primary objective of speech analysis for recognition is to extract the vocal tract transfer response from the composite signal. In practice, this separation is not a trivial task, whether it is approached directly in the frequency domain or by some related technique in the time domain.

Classical signal processing techniques like Fourier analysis, cepstral analysis and autocorrelation have all been used in speech analysis[4] on the assumption that the parameters of speech do not change significantly during short periods of time. The best results have been obtained when the techniques have been modified or applied in a way that takes account of the special properties of the speech production process. One technique that has been used extensively in recent years is that of linear prediction.[5] This technique produces the design for a filter which is equivalent to the transfer function of the vocal tract.

Whilst these elegant mathematical techniques produce parameters related directly to the acoustics of speech production, the amount of computation involved either requires special analysis equipment or cannot provide real-time operation—an important requirement for practical speech recognizers. Consequently, fairly extensive use has been made of simpler techniques which can be implemented more readily. Analogue filter banks (giving an approximation to the short-time spectrum),[24] zero-crossing techniques[6] and measurements based upon the asymmetry of the speech signal[7] have all been described in the literature. Some degree of speech recognition performance has been achieved with all these measurement techniques. Two important factors should be taken into account when deciding which analysis technique should be used. Firstly, the analysis technique should be appropriate to the quality of the speech signal being received. Thus it would be unwise to apply to telephone speech a measurement technique that was sensitive to spectral balance or phase shift. Secondly, there needs to be a balance between the resources allocated to the analysis and those concerned with the subsequent processing and recognition. As in 'Hi-Fi', the performance is limited by the weakest link in the chain.

4 Types of Speech Recognition Machine

In order to describe speech recognition machines in more detail, three types of machine will be considered (the types are similar to those described by Reddy[25]). The distinctions are made on the basis of the techniques employed in the machines, and the way in which they are organized. The three types of machine are:

(a) Isolated word recognizer (IWR). This approach constrains the user to speak his words in isolation so that word boundaries can be detected by some simple criteria. The words are then usually recognized as discrete patterns. Although this is a limiting approach, it does represent an important class of machines as the first commercial systems employ IWRS.

(b) Connected speech recognizer (CSR). This type of machine recognizes connected speech conforming to a rather rigid syntax. Machines that recognize limited strings of digits fall into this category as well as large vocabulary systems. The pattern-matching approach used for IWRS cannot be used and it is common to convert the measurements into some symbolic form prior to recognition. These machines attempt to recognize every word in the input string (cp. SUS).

(c) Speech understanding systems (SUS). The method of operation of this type is much more akin to human recognition. By using syntactic, semantic and other sources of knowledge, this class of machines functions by attempting to understand the intent of what has been said, rather than recognize the individual words that have been spoken. This requires a SUS to generate and test hypotheses about the spoken message.

It is extremely difficult to compare the performance of different speech recognition machines, as the conditions under which the results have been obtained vary considerably. Moreover, figures of percentage correct recognition alone do not convey sufficient information. Two machines with 90% correct recognition are not necessarily equivalent. In one the errors may be evenly distributed; in the other only two word classes may be confused but badly so. Which machine is better will depend upon the use to which it is put. The approach adopted in this paper will be to give typical overall results. For more detailed information, the reader is referred to Martin[24] and Reddy.[25]

4.1 Isolated Word Recognizers

One obvious question is at what level(s) should speech be recognized. At one linguistic level, English has about 40 distinct sounds or phonemes.† In principle, phoneme

† It is important to distinguish between phonetic and phonemic descriptions of speech. A phonetic representation enables the nuances of pronunciation (position of articulators) to be described for all languages. For any given language, certain differences in pronunciation may not change the meaning of any word in that language. The phonemes of a language are that minimal subset of grouped phonetic elements that enable differences in meaning only to be described.

recognition would enable any spoken message to be recognized. The designers of early phoneme recognizers soon found that the theoretical advantage was outweighed by severe practical limitations.[16] Firstly, the boundaries between phonemes are not easy to detect. This arises because speech is produced as a continuous signal and the sounds flow into one another in the same way as characters in hand-writing. Secondly, because of the inertia of the articulators, the measurable properties of the phonemes are affected by the phonetic context in which they appear. See for example the 'ee' sounds in the words sp*ee*ch and mach*i*ne in Fig. 3. A more fundamental limitation is that the phoneme is basically a linguistic concept, and requires linguistic knowledge to be invoked in order to establish which phoneme has been spoken. This has been found to be beyond the capability of a simple machine.

A higher level of representation is the word, and this has been found to be a convenient concept with which to work. In the same way that it is difficult to detect phoneme boundaries, words cannot be readily separated in continuous speech. (Significant pauses normally occur only at phrase or sentence boundaries.) However it is relatively easy for people to learn to speak isolated words (we often speak this way in order to make ourselves understood in very noisy environments) and a significant amount of work has been carried out on designing machines to recognize this sort of input.[8,24] There are a number of advantages in working with isolated words. Firstly, word boundaries may be detected comparatively easily using simple energy measurements because a word is preceded and followed by silence. In practice, the silence is not absolute, and it may be necessary to use additional measures to distinguish words from background noise, breath noise etc.[9] Secondly, the context of the sounds within the words remains constant and therefore the measurable properties of isolated words are relatively stable for an individual. This means that the measurements describing a word can be used as the input to a conventional pattern classifier, which can be trained to distinguish between several classes of pattern. A typical machine is illustrated in Fig. 4 and consists of analyser, pre-processor (or feature extractor) and classifier. The functions of these stages will now be described more fully.

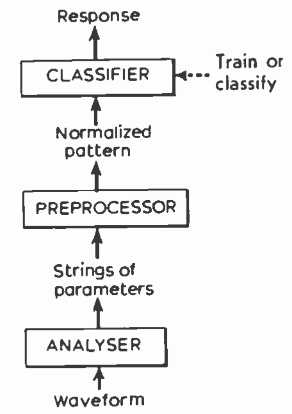

Fig. 4. Block diagram showing the major components of a typical isolated word recognizer (IWR). The functions of the components are described in the text. Note that the flow of data through the machine is in one direction only.

Most of the speech analysis techniques referred to in Section 3 have been used for isolated word recognition. It is worth noting that it is not essential for the analyser section of an IWR to produce measurements that are uniquely related to the acoustics of the vocal tract, e.g. formant frequencies. It is important that whatever aspects of the speech signal are measured must be consistent measures that enable words to be recognized.

Statistical pattern classification techniques[10] normally demand that each pattern is described in terms of a fixed number of measurements. Most analysers produce measurements on a regular sampling basis (samples taken between 10 and 30 ms apart) and therefore the number of samples produced for a spoken word is proportional to the length of that word. One of the functions of the pre-processor is to time-normalize the measurements so that a fixed number are produced irrespective of word length. Although word length may be an important cue in distinguishing some words, there is a considerable variation in the absolute length of a word, particularly when utterances of several speakers are compared. The time-normalization process may be carried out linearly or non-linearly. Linear time-normalization has the advantage of simplicity, but is very sensitive to the correct detection of the beginnings and ends of words. The missing of weak sounds, e.g. the /f/ in 'four', or the inclusion of noise bursts or breath noise, may mean that a word is grossly misregistered. Steps are usually taken to ensure that such effects are minimized. This may involve the recognition of certain noise patterns so that they may be removed, e.g. noise bursts may be distinguished as short duration signals separated by comparatively long periods of silence.

The other important function frequently performed by the pre-processor is to extract certain information-bearing elements from the measurements. These elements or features are chosen to be as invariant as possible to such factors as individual speaker characteristics. Automatic techniques for choosing features have not been very successful, and features are normally chosen in an iterative 'cut and try' manner using the designer's knowledge about speech and speech signals.

The final stage in recognition is the classifier. Most researchers have used trainable classifiers.[11,24] During the training phase, the classifier is presented with sets of features corresponding to known words in the vocabulary. These data are used to establish templates for each word or to construct probabilistic models. During recognition, a set of features from an unknown word is presented and the classifier calculates the most likely class to which the spoken word could belong. As the classifiers calculate the most likely class, they have a certain power to generalize, i.e. to tolerate variations in the nature of the input. In order to discriminate against words which are not in the vocabulary, or extraneous word-like noises, e.g. coughs, it is usual to employ threshold criteria that ensure that the pattern is sufficiently like one and only one of the words in the vocabulary.

An alternative approach to isolated word recognition employs non-linear time normalization. Recognition is based upon the amount of temporal distortion that has to be applied to the measurements in order to match the word to each of a set of reference patterns.[12] The indications are that there is little to choose between the performance of machines using the two types of time-normalization for vocabularies composed of digits and simple words.[13]

4.1.1 *Factors affecting performance*

There are two factors that have been found to have the greatest effect on recognition performance: the choice of words in the vocabulary and the number of different speakers tested. The choice of words in the vocabulary is a more critical factor than vocabulary size. A vocabulary containing 'aee', 'bee', 'cee' etc. may be recognized less well than one containing a larger number of acoustically dissimilar words. For most applications, it is possible to choose the words to be readily distinguishable from one another. Where acoustically similar words have to be used, it may be possible to use the syntax or structure of the application to restrict the number of words that can be distinguished at any instant.

The more significant problem is associated with the number of speakers. One solution (and this is used in commercial systems) is to train the recognizer separately for each user, and store the resulting templates. Before using the recognizer subsequently, a user would follow a simple logging in procedure which recalls the appropriate templates for his voice. This approach is entirely satisfactory where there are a limited number of users who make frequent use of the machine. The first applications of speech recognition have been in those situations where the use of the machine forms a significant part of a person's daily work. Typical applications so far are where a person's hands are already occupied and spoken communication provides the means for entering data or controlling machinery, e.g. inspection of manufactured items, programming numerically controlled machine tools, automated materials handling.[24]

There are a number of important factors that have to be considered in comparing the performance of word recognizers. The major factors are vocabulary size, type of microphone, number of speakers, accuracy and response time. The most advanced IWRS reported (see Ref. 25) seem capable of producing less than 2% errors in noisy environments for vocabularies between 30 and 200 words spoken by several speakers. The response time varied between approximately real-time and 30 times real-time.

4.1.2 *Correction of errors*

In any practical system, there needs to be a way of correcting errors. One way is to provide visual feedback of the recognized word and to have a control word in the vocabulary e.g. 'cancel' or 'erase' that allows a user to tell the machine a mistake has been made. When the control word is recognized, the user repeats the word that had been misrecognized. A simple exclusion strategy ensures that the machine does not make the same mistake again immediately. For operation in 'speech-only' mode, automatic speech response would be used for the feedback.[17] Although much work has been done in reducing the error rate in IWRS, it is not known what error rates or response times a user will tolerate. In normal conversation, particularly via the telephone, people frequently mishear words and have to be corrected—yet they think nothing of it (they may not even notice it) and continue to use the telephone. The best way of discovering how tolerant people are to imperfect and slow IWRS is by performing experiments with IWRS in real-world applications.[24]

4.2 Connected Speech Recognizers

Whilst there are real-world applications of isolated word recognizers, there is no doubt that they would be more convenient to use if they could accept a more natural form of input. In this paper, a connected speech recognizer is considered as a machine that will accept connected speech that conforms to a rather rigid syntax. Thus it includes machines that recognize limited strings of words (e.g. digit strings) as well as large vocabulary machines that recognize statements in some artificial command language. The essential point that distinguishes these machines from speech understanding systems is that CSRS attempt to recognize every word in a spoken message using measurements derived from the input signal, and rigid syntax rules.

The main reasons as to why connected speech recognition is difficult have already been referred to, namely the difficulty in deciding where one element (be it word or phoneme) ends and the next begins, and the way in which the acoustic characteristics of sounds and words depend upon the context in which they are spoken. In extreme cases an individual sound may be shared between two words, e.g. there is only one /n/ sound at the boundary of a spoken 'one nine'. The techniques employed in IWRS cannot be effectively applied to even the recognition of simple digit strings. For example, if each 4-digit sequence were to be recognized as a pattern, it would be necessary to hold ten thousand reference patterns. The concept of a reference pattern or template for each word can still be used where the vocaulary size is comparatively small. The recognition process consists of progressively matching (in an elastic manner) the measurements from the input word string against each of the reference patterns until there is a close enough match with one of them.[14] This yields a possible beginning to the next word in the string and so the process can be repeated. A significant factor in the success of this technique is whether or not the number of words in the string is known. Difficulties arise when the vocabulary becomes larger and words start to have syllables in common.

The more usual approach in CSRs is to convert the measurements from the analyser into a string of symbols. The symbols used are frequently phonemic in nature, i.e. related to the sound classes used by linguists. The generation of the symbol strings is performed by examining the measurements from the analyser, grouping them into acoustically similar segments and labelling the segments. Recognition of the words is then carried out using a matching process with a phonemic dictionary. As the beginnings and ends of words are not known, the process usually proceeds in a left-to-right manner until the first word has been identified. Matching for the second word can then begin. The occurrence of shared sounds means that in some cases it is necessary to back-track along the symbol string when a word has been detected. The greatest difficulty with this approach is that each of the stages (segmentation, labelling and matching) are subject to errors and uncertainties. Consequently it is necessary to allow alternative word matches to proceed. Recognition of the string of words is carried out using tree-searching algorithms and appropriate similarity measures in order to establish which sequence of words is most likely.[15] Although the allowable syntax of the words in the string is used to restrict the number of possible matches that have to be attempted at each point, the whole process is iterative and requires large amounts of computation. A number of systems[25] were built in the early 1970s as fore-runners to speech understanding systems and operated at between 10 and 100 times real-time, with vocabularies of between 25 and 250 words. The word accuracy was between 55% and 97% correct with sentence accuracies of between 31% and 81%. The correction of errors in a CSR is likely to be more difficult than in an IWR as a user has to specify which word(s) in a sentence is (are) in error. Little appears to have been published on this aspect.

4.3 Speech Understanding Systems

The early attempts at connected speech recognition showed the impossibility of designing machines that work at the phonetic level only.[16] CSRs were more succesful by working at more than one linguistic level and employing a few sources of knowledge to aid the recognition process. Speech understanding systems employ several additional sources (particulary task-dependent ones) in order to achieve a performance comparable to human beings. It is common experience that some utterances are grammatically incorrect or badly-formed, yet the message conveyed by them may be quite clear to a human listener. A speech understanding system is designed to mimic the human capability of understanding the intent of a message rather than recognizing every word within it. In order to do this it may be necessary for the system to keep track of the context from a number of sentences so that ambiguities within a particular sentence may be resolved. The accuracy of a SUS has to be judged in terms of its response to the message rather than by the number of words recognized correctly.

Table 2. The objectives of the 5 year ARPA project compared with the best performance achieved. (From Klatt)[27]

Objectives (November 1971)	Achieved (November 1976)
Accept connected speech	Yes
from many	5 (3 male, 2 female)
co-operative speakers	Yes
in a quiet room	Computer terminal room
using a good microphone	Close-talking microphone
with slight tuning/speaker	20–30 sentences/talker
accepting 1000 words	1011
using an artificial syntax	Average branching factor = 33
in a constraining task	Document retrieval
yield < 10% semantic error	5%
in a few times real-time	80 times real time
on a 100 m.i.p.s.† machine.	on a 0·35 m.i.p.s. PDP–KA 10 using 256 K of 36-bit words costing $5 per sentence processed.

† 1 m.i.p.s. = 1 million computer instructions obeyed per second

Most of the work on speech understanding systems has been funded by the Advanced Research Projects Agency in the United States since 1971. The major objective of the five year research programme (costing $15M) was 'to achieve a breakthrough in speech understanding capability that could then be used in practical man-machine communication situations'.[1] It is too soon to know whether this objective has been reached. As the ARPA-funded work provided the impetus for speech understanding systems (as opposed to any other form of speech recognition work), it is appropriate to describe SUS solely in terms of the ARPA work, particularly as very little work on SUSs has been reported outside the USA.

To meet their objective, ARPA funded the development of several speech understanding systems, the specifications of which are shown in the left-hand column of Table 2.

The major design decisions in building a SUS are concerned with how the system should be organized so as to use the information from the different sources (e.g. articulatory, phonetic, lexical, syntactic, semantic or task-dependent) in a computationally efficient manner. The problems arising in CSRs from having imprecise representations of the signal at every level of processing are compounded in a SUS by the additional knowledge sources involved. Although the major contractors on the

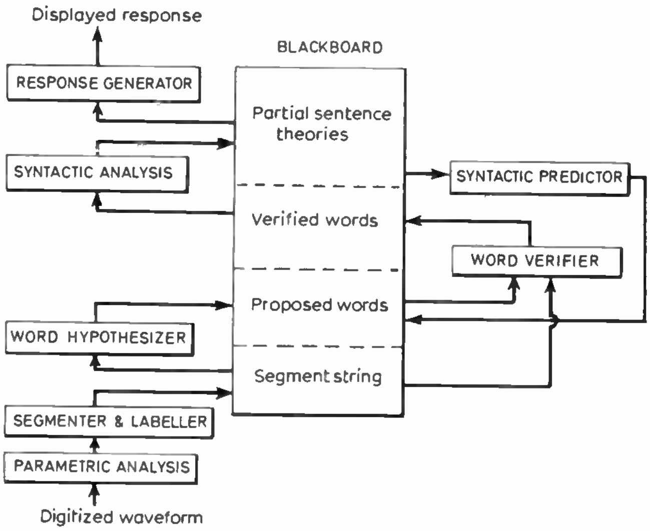

Fig. 5. Block diagram of the Carnegie Mellon University speech understanding system *Hearsay II* (From Ref. 27; also described in Ref. 15). In this system the 'blackboard' is a data structure that enables the processes (in rectangular boxes) to communicate with one another. Although the main flow of data is upwards, there is considerable amount of interaction between the processes. (Compare this with the simple organization of the IWR in Fig. 4.)

ARPA work all had the same objective, the system organizations used were quite different.[25,27] In one approach (see Fig. 5), the system is organized as a parallel set of independent processes capable of generating hypotheses and communicating via a 'blackboard'—a structurally uniform global data base.[15] Processes are called up to reject or validate hypotheses produced by other processes. Processing continues until only one hypothesis remains with adequate support from all the processes. In another approach, the hypotheses are generated according to the syntax alone. A third system is organized as a large state transition network, and avoids the need for any sophisticated acoustic to phonetic decoding rules by using acoustic segments defined directly in terms of analysis measurements.

The comparison of the advantages and disadvantages of the different approaches taken by the ARPA contractors is likely to continue for some time.[27] Most of the systems had not been operational for long by the end of the contract. In addition, the contractors used different tasks making comparison more difficult. (The tasks were all concerned with computer-based data management systems: document retrieval, travel enquiries and facts about ships.) The systems were able to answer such questions as 'How many articles on psychology are there?' or 'What is the plane fare to Ottawa?'. The sentence recognition for the systems ranged from 24% correct to 95% correct. The performance of the best system is compared with the project objectives in Table 2. Two points should be noted. First, a significant amount of training and manual intervention was required to tune the system for each speaker. Secondly, 95% correct sentence recognition was achieved only by constraining the allowed syntax severely. This degree of constraint (average branching factor of 33 means that on average 33 different words had to be considered at each syntactic node) was judged to make it difficult for a user to produce syntactically correct sentences.[27] The effect of having a more natural syntax was to reduce the number of sentences recognized correctly.

5 The Future

The performance of the most advanced speech understanding system yet built is markedly inferior to that of a man when judged in terms of factors like vocabulary size, range of speakers and complexity of sentences that can be understood. This arises because we do not yet know enough to be able to design such complex systems effectively. However, it is not necessary to have machines that are as good as men before there are real-world applications for speech recognition machines and we are now beginning to see some practical results of the research of the last 25 years.[24]

For those machines that we do know how to build, the technology with which to implement them more cheaply is now becoming readily available. The use of inexpensive but powerful microprocessors is likely to have a great effect on the cost of isolated word recognizers and this will increase the number of likely users of such machines. At present, our experience of using these machines is limited, and the ready availability of IWRs will enable their practical advantages and disadvantages in a wide range of applications to be quantitatively assessed. In addition to applications in data capture and machine control, it is likely the IWRs will be used in situations involving two-way speech communication, e.g. communication with computer-based information systems. (Speech response techniques to achieve this are already adequately developed.)

The next development in commercial speech recognition machines is likely to be the appearance of machines that will understand strings of words, thereby removing one of the major limitations of IWRs. The future for large vocabulary CSRs and SUSs is less certain at this point. These systems are very complex, and complex systems are always likely to be expensive irrespective of the technology used to build them. It remains to be seen whether there are applications for such systems where the convenience gained outweighs the cost.

Speech understanding systems are currently at the pioneering stage; there are many problems that remain to be solved at all stages in the processes involved. The solution to these problems will require research in many related areas. Perhaps the most daunting task is in the organization of such complex systems. Developments in this area will be of significance to the design of all intelligent machines, and not just machines that understand speech.

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A preliminary review of the ARPA Speech Understanding work appears in:

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The prospects for sensory arrays and microprocessing computers in manufacturing industry

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SUMMARY

A brief survey which discusses the most relevant industrial robot projects incorporating sensory feedback, provides a background for the main contribution. A cheap and reliable sensory system which can be readily adapted to the task of component part orientation, is seen as an immediate need. Line-scan cameras coupled with a microprocessing computer are the basic ingredients of the proposals which are founded on a considerable history of intelligent automation research at the University of Nottingham.

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1 Introduction

The availability of extensive computational power in the mid-1960s, coupled with high capital investment in space exploration within the United States, provided a fruitful environment for the initiation of projects involving sensory feedback with a degree of artificial intelligence. Initially, the two main centres of activity were at Massachusetts Institute of Technology (Project MAC)[1] and Stanford Research Institute.[2] Both of these projects were unbounded by complexity and received generous financial support The most aesthetic output from this work was the famous 'SHAKEY' robot or automaton produced by the S.R.I. group.[3]

The 'SHAKEY' robot is a self-contained vehicle comprising stepping-motor drive coupled with a steering facility. Sensory feedback is provided by a television camera and optical range-finder although there is also primitive tactile feedback to detect contact with objects. Two-way radio communication links the on-board controller and drives with a remote PDP-10 computer. The automaton is capable of executing primitive tasks associated with its environment such as navigation without instruction and the recognition and manipulation of defined shapes or structures. This project was the first to give a dramatic demonstration of the capabilities of this technology even though it revealed the enormous problems of replicating the most elementary human functions.

In the United Kingdom, this same kind of research activity was executed within the Department of Machine Intelligence at the University of Edinburgh.[4] Of the two projects completed at Edinburgh, the second provides a most impressive demonstration of 'intelligent' mechanical assembly using basic shapes associated with a common object. For example, the wheels, axles and body of a toy car can be assembled from a disorganized heap of component parts. This system incorporates two television cameras, one mounted on the manipulating structure and the second mounted outside the work area. The computational effort is provided by an ICL 4130 computer coupled with a Honeywell DDP 316 satellite computer. In common with the 'SHAKEY' project, the computation requirement is extensive and occupies long periods of time.

Japanese effort in this field features the Hitachi Company as being in the most prominent position. Their HIVIP Mark I project[5] provides another variant with the system being able to interpret primitive structures from line drawings and then to select shapes which are assembled to realize the structure illustrated on the line drawing. This machine incorporates two television cameras, a manipulator and a HITAC 7250 computer.

The activity of these various research groups was substantially concurrent over the period until 1972 with an element of cross fertilization between the international centres. However, the initiative in this kind of research remains with the United States.

2 Intelligent Robots

Whilst a clear application existed in space exploration for some form of automaton, the most obvious immediate applications lay in the industrial environment. However, the mere thought of massive computers and computation time running into minutes is sufficient for an industrialist to recoil with horror! Fortunately, the industrial environment is one of organization with the piece parts being identical to each other and regular in shape. These facts allow a dramatic reduction in computational requirements both in magnitude and time.

Driscoll[6] made a classification in 1972 of intelligent robots based on the existence of industrial robots when realized as a means of universal automation. These Driscoll postulated as 'generation 1' robots but further postulated 'generation 2' robots, or 'blue collar' robots as being 'automatically programmable mini-robots or lightweight factory manipulators with minicomputer or multiprocessor control, multiple arms and hands, and interactive sensors.' These 'generation 2' robots would be followed, in the 1980s, by 'generation 3', artificially intelligent robots incorporating the features described in the introduction.

Since 1970, there have been a number of research groups exploring the possibilities for 'generation 2' machines. One of the earliest groups in this field was based in the United Kingdom at the University of Nottingham where the 'SIRCH' robot became operational in 1972.[7,8] This machine uses a single television camera mounted vertically to provide a semi-eye-in-hand capability for examining its working surface. A 2-state video signal is used with a sampled array of 128×128 picture elements which occupies 1 kiloword of store in a Honeywell DDP 516 machine. The analytical routines have a simple structure which allows picture processing in times between 0·3 and 3 seconds according to the complexity of the interrogated part. The complete software package (including data) is accommodated within 6 kilowords of computer store. This clearly demonstrates the dramatic reduction of computational effort required in machines of this concept.

Other machines of this type have emanated from Japan with Hitachi featuring prominently once again. This company has produced a visually interactive system very similar to the 'SIRCH' machine which incorporates a moving conveyor on which the objects are assembled for visual interrogation. In this project the picture data array size is 64×64 which is quite adequate for many industrial applications. Perhaps the most impressive project executed by Hitachi is their Hi-T-Hand tactile 'insertion' machine[10] capable of inserting shafts into holes with a mere 20 μm clearance. This it does with speed and precision using a compliant head incorporating strain-gauge feedback. The application area for the Hi-T-Hand is the automatic insertion of ball-bearings into motor housings for which it appears highly suited.

The other Japanese company which has made a significant contribution is Mitsubishi[11] who have experimented with an eye-in-hand robot. This device has been applied to the task of retrieving motor brushes from quasi-random presentation for insertion into brush holders. In this case the brush has a braided copper 'tail' which adds to the problem of part presentation.

In addition to these research projects which have been highlighted, there are a great number having a lower industrial significance. The majority are under development in Japanese laboratories where there is a clear innovative ability amongst the respective research groups. Whilst each of these projects is interesting and has some relevance to intelligent robots they cannot be classed as 'generation 2' industrial robots.

3 Towards Industrial Application

The authors know of only two cases where intelligent robots have been applied to shop floor manufacture.

Hitachi[12] are using a visually interactive robot to locate bolts on a mould for the manufacture of concrete piles. This system uses a much simplified form of visual sense without the resources of a stored program computer. Consequently it falls somewhere between 'generation 1' and generation 2' systems and in fact the non-integer numbering of 'generation 1·5' is sometimes used!

The second known application is in the United States in the G.T.E. Sylvania plant at Ottawa, Ohio.[13] This is a much more ambitious system using a commercially available industrial robot fitted with an elementary optical displacement transducer which is used for tracking carriers on a conveyor. The robot is mounted on rails and the whole system is controlled by a PDP 11 computer. The requirement is to transfer television picture tubes between two conveyors where the transfer is completed whilst the robot is in motion. The technological mixture in this application is different from the Hitachi system in that a primitive optical sensor is used with a stored program computer. Again this falls into the 'generation 1·5' category.

While the above applications come close to the 'generation 2' specification, the industrial development has been rather slower than anticipated in 1972. One of the fundamental problems with these systems is communication with the device; the versatility required from intelligent robots must be matched by the ease of programming or training by the industrial operative. This, coupled with relatively high cost, has impeded the early application of complex robot systems. An interesting experiment is being carried out at the Stanford Research Institute[14] where voice communication is being used to instruct a robot at the shop floor level. This avoids the need for the operative to use a keyboard interface and appreciate a mnemonic language. The outcome of these experiments will be most interesting.

Over the past four years, there has been a revolution in computational technology with the availability of microprocessing computers. This, coupled with solid-state imaging arrays has brought the 'generation 2' robot a lot nearer reality. There is much which can be achieved by integrating visual sense with a degree of flexible computation without the need for extensive mechanical manipulation. Devices capable of inspection or orientation can be conceived around solid-state arrays and microcomputers in such a way that they can be realized as batch-produced systems.

At the University of Nottingham, the problem of component orientation is being investigated with such a system with the object of replacing a specially 'tooled' mechanical orientation device (such as a bowl feeder) with a software 'tooled' general-purpose device. The orientation of a part can be detected using quite simple algorithms[7] and this information can be used to interrogate the orientation of components which are presented at random to a sensory array. By implication, a primitive degree of inspection is inherent in this process which provides an additional attractive feature. In such a system as this, it is the intention to use the component profile itself to program or train the system and to retain the component parameters peculiar to the geometry in programmable read-only meory.

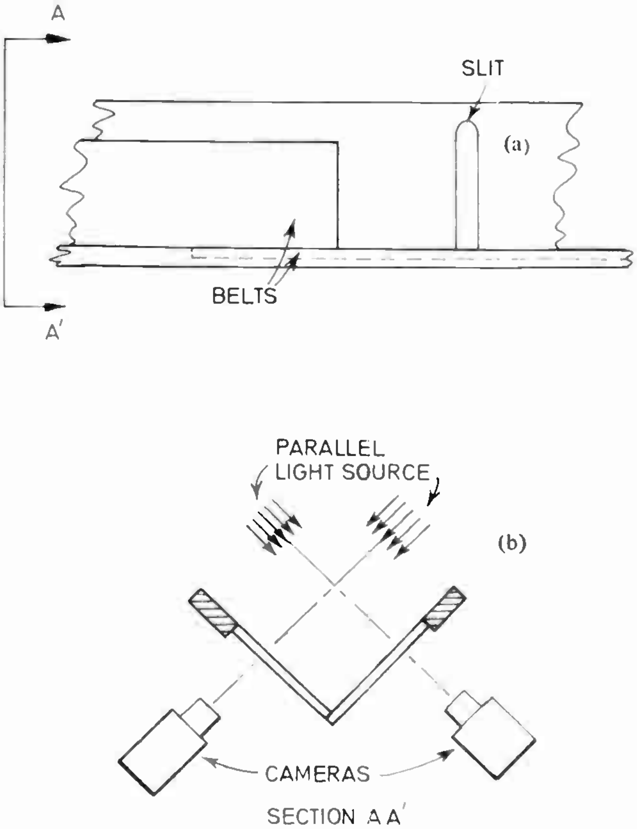


Fig. 1. Diagramatic arrangement of the transportation system.

4 Nottingham Prototype Inspection Machine

The prototype consists of three main components; the mechanical arrangement, camera input/interface and Intel 8080 microcomputer, which forms the heart of the system. The following Sections deal with a description of these hardware components and the software used to provide a rudimentary inspection process.

4.1 Mechanical Arrangement

Figure 1 gives a diagrammatic illustration of the machine configuration. It consists of a conveyor belt which is mounted on a back plate moving past a slit in the plate. A line-scan camera and a parallel light source are mounted either side and perpendicular to the belt motion. Parts are fed by conveyor past the slit in the back plate which is illuminated by the parallel light source. The camera, which contains a linear 128 photodiode array, scans the slit vertically as the part is moved horizontally past the slit. Consequently a two-dimensional picture is generated, whose axes correspond to the electronic axis of the camera (vertical) and the mechanical movement of the belt (horizontal).

Two cameras can be used to facilitate the inspection of components in three dimensions. This is achieved by mounting the cameras and corresponding slits on orthogonal axes which are separated by a small distance to allow for the installation of two drive belts (Fig. 1). Picture data representing two-dimensional information are correlated to achieve three-dimensional analysis.

4.2 Camera Input and Interface

The camera system uses a self-scanning array mounted behind a lens assembly in a small camera case, together with an associated array sampling unit. The linear array comprises 128 photodiodes which are accurately spaced at intervals of $1{\cdot}6 \times 10^{-3}$ cm.

The photodiodes are sampled sequentially to produce a video signal which is an electrical analogue of the light intensity distribution along the array. This is achieved with a commercially available recharge and driver signal processor unit, which is mounted remote from the camera array and lens assembly.

If the profile being monitored, through the back plate slit, is moved, repetitive interrogation of the array provides an area scan of the moving component. The process of array or line-scanning is repeated 128 times, generating a matrix of 128×128 possible picture points of square aspect. The chosen size of 128×128 provides continuity between the SIRCH robot and the new machine. This size was originally based on choice of video sampling rate and allocation of store capacity for data.[17]

The camera processor unit signal is further processed by a hardwired electronic interface to convert the analogue signal into a form which can be presented as input data to the microcomputer. The input data provide information relating to the component profile and are discussed in the following Section.

4.3 Consideration of Data Transfer and Storage

The 128 × 128 matrix of the SIRCH robot scene is packaged into 16-bit words,[15,16] each line comprising 8 words; the total storage requirement for one picture being 1024 words (1 kiloword). The Intel microcomputer is an 8-bit machine and therefore for the same size matrix 2 kilobytes of store is required if the same method of data storage were to be used. This would detract from the concept of using a microprocessing system and a more economical method of data storage has been introduced. As with SIRCH, the video information is first thresholded by the interface to provide a binary signal (Fig. 2). Most of the information in this thresholded signal is redundant, since maximum information content is given by the position of gradient changes along the scanned line. These changes correspond to black to white or white to black transitions indicating the position of edges of the inspected component part. The operation of edge detection is performed by the interface which presents this information to the microcomputer. Line-scanning is repeated 128 times and an outline of the component is produced with interior features (holes), if present. Such a process reduces the overall amount of storage needed for the picture, resulting in a storage requirement directly related to the complexity of the part under interrogation. In consequence, this method of storage reduces picture storage requirements to a point where memory cost is directly related to component complexity.

4.4 Microcomputing System

The microcomputing system is equipped with 4 kilobytes of programmable read-only memory, p.r.o.m. and 4 kilobytes of random access memory, r.a.m. Input/ouput operations use standard programmable I/O devices. The I/O facilities provides conventional teletype control and display, a large storage display unit for displaying images and small hand-held keyboard facilities for system control. A real-time clock is incorporated for component transport velocity measurement, although an alternative method of velocity measurement has been devised in which the velocity of transportation is computed directly from the leading edges of the component structure and is reported in an earlier publication.[15]

Software for the system is written in 8080 assembly language and contained within 4 kilobytes of p.r.o.m., while data variables and picture information are contained within 1 to 1·6 kilobytes of r.a.m. depending on the complexity of the component under investigation. The 'pre-processed' data from the interface, comprising position (diode number) of picture gradient changes along a scanned line, is stored in r.a.m. in a stack. The stack contains data relating to edge positions of individual line-scans supplied by the interface, together with line number allocated by the microprocessor when taking in the 128 lines of the picture matrix. The stack structure has been adopted to provide the compact data storage system required from the earlier considerations of Section 4.3.

(a)
(b)
(c)

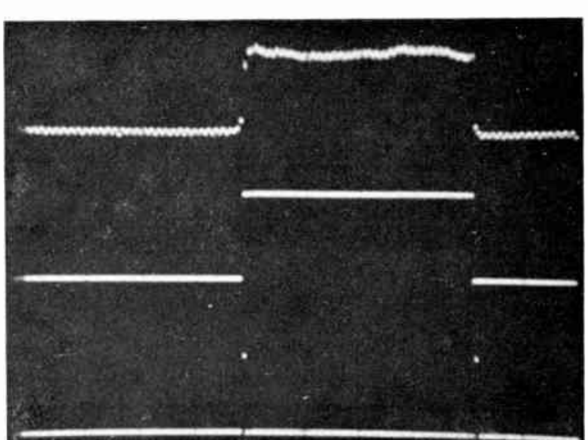


Fig. 2. Waveforms showing (a) camera video output, (b) thresholded video signal, (c) edge position signal.

5 Operating Modes

The machine is commanded to execute various operations from a small hand-held key-pad. Operations are split into two main sections, DESCRIBE and COMPARE. In the description phase, parameters from a scanned 'master' part are extracted, to classify the presented 'master' part; during the comparison phase the candidate part parameters are inspected and compared with those of the master part. Subordinate to these sections are various routines to perform the input of visual information and camera selection.

5.1 Describe Phase

This phase involves the extraction of various parameters of the part under interrogation. These parameters allow the determination of orientation and acceptability of future similar parts which are scanned during the COMPARE phase.

The parameters extracted for part classification are area and perimeter, interior detail and external discontinuities. In addition, sample points are also extracted for a grid comparison.

5.1.1 *Grid point extraction*

A rough comparison facility is incorporated into the system to allow for a higher success rate in further candidate part inspection. The technique involves placing a grid or mesh over the master part profile (see Fig. 3). An array is assembled which contains the corresponding intersection points between part profile and grid lines. During the comparison phase, the data held in this array are used as a simple test to detect gross deformation of the compared profile from that of the master profile and to provide a tentative indication

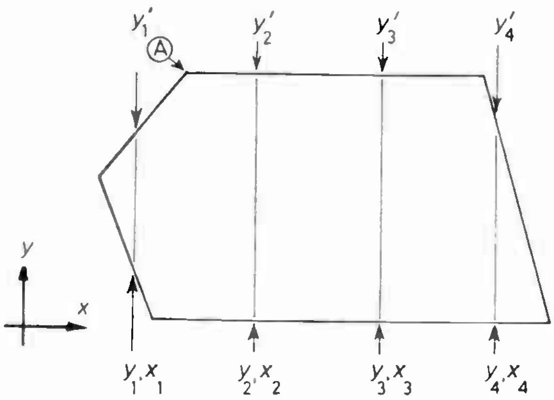


Fig. 3. Grid positioned over a component part.

of the compared parts orientation. The horizontal positions of the vertical grid lines are set at predetermined positions but for known difficult parts the operator may interact with the system using the key-pad and a display unit to position new grid lines in high priority positions.

5.1.2 *Area and perimeter*

Here the master part profile is examined to compute the area and perimeter of the part. These are determined simultaneously during this procedure. The perimeter is computer by summation along the outline of the part, using the difference between vertical co-ordinate position of points along neighbouring vertical lines (Fig. 4), while the area is computed by summation of difference in vertical co-ordinate positions of points on the same vertical line for each line-scan of the component profile. Referring to Fig. 4 area and perimeter are computed using the following summations.

$$\text{Perimeter} = \sum_{0}^{n=N} \{|y_{n+1} - y_n| + |y'_{n+1} - y_n'|\} + |y_0' - y_0| + |y_N' - y_N| + (2 \times N)$$

$$\text{Area} = \sum_{0}^{n=N} (|y_n' - y_n|)$$

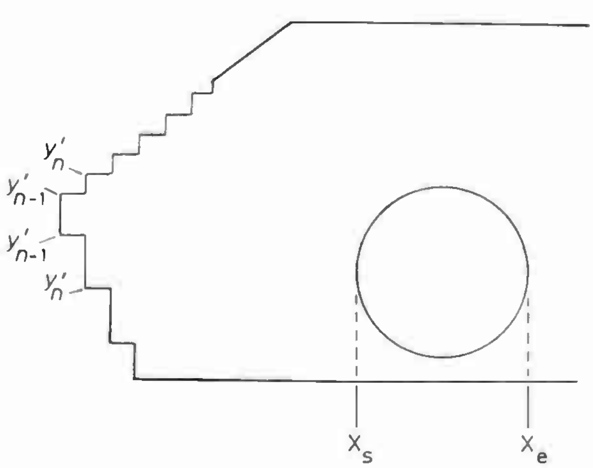


Fig. 4. Quantization of component profile.

5.1.3 *Interior features*

The master part is further classified using information on its interior, typically a hole. During the 'describe' phase the interior of the part profile is examined noting presence of internal features and their respective positions in terms of line number. In Fig. 4 a perforation would be found and its start and end line numbers stored as x_s and x_e. The scanning process for features is relatively simple relying on the number of edges or transitions along a line. A line-scan of a part with no internal features (for example, Fig. 6a) will produce only two points along the line, while a line-scan of a part with a hole (for example, Fig. 7a) will produce four or more points. The process of inspection for internal features involves searching through the stack held in r.a.m. for lines with four or more edge points. The 'overlap' of two holes one above the other would be indicated by six points which is also handled by the analysis program. The above assumptions rely on the scanned profile of the master having no noise content and since the system is not an ideal one, an algorithm is built into the program to reduce the sensitivity of the detection process to noise.

5.1.4 *Discontinuity gradient changes*

The scanning of the parts of Figs. 3 and 6(a) would produce no data concerning interior features and in these cases the part profile is further examined for 'discontinuities'. These are regarded as positions at which straight line sections longer than a specified limit rapidly change gradient; this would occur at point (A) in Fig. 3. The process involves examining the outside edges of the part to detect the straight line sections, then to determine whether the gradient change passing from one section to another is greater than a specified tolerance. On detecting such a point, its line number and position along the line are stored. This process is repeated a second time looking for another 'discontinuity' and the subsequent co-ordinates stored.

5.1.5 *Summary of 'describe phase'*

During the describe phase the part for examination is transported past the line-scanning camera and its profile transferred into the system memory where it is stored in a stack. The part profile is interrogated by the methods outlined above to extract the relevant parameters needed to characterize the part which are themselves stored in memory (r.a.m.). These extracted parameters may also be displayed on a teletype allowing the data to be programmed into a p.r.o m. at a later stage. When programmed with these parameters the p.r.o.m. may be substituted for the section of memory used to store the master parameters facilitating only one describe phase, since once in p.r.o.m. there is a non-volatile record of these parameters. In addition, the describe phase may be executed a second time to accommodate for a master part with two stable positions,

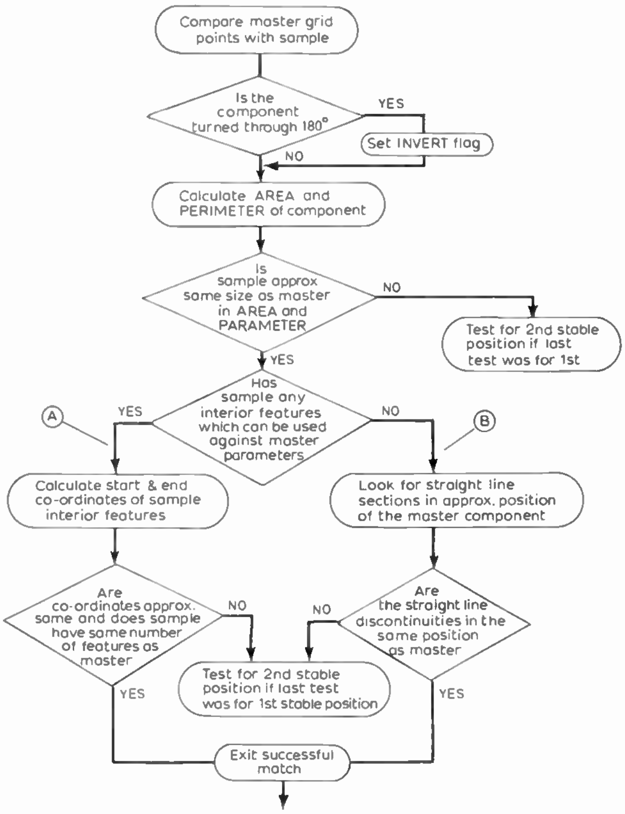
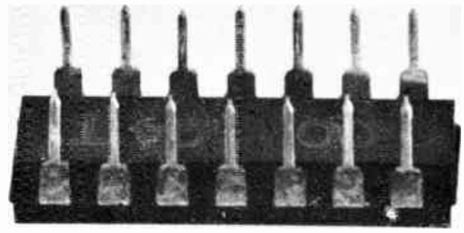
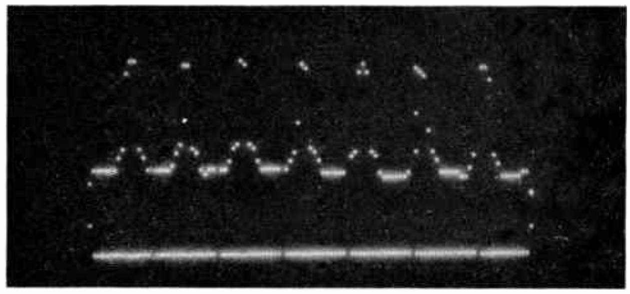


Fig. 5. Flow diagram of the comparison phase.

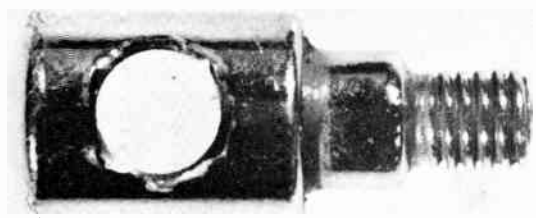


(a) Dual-in-line integrated circuit package.

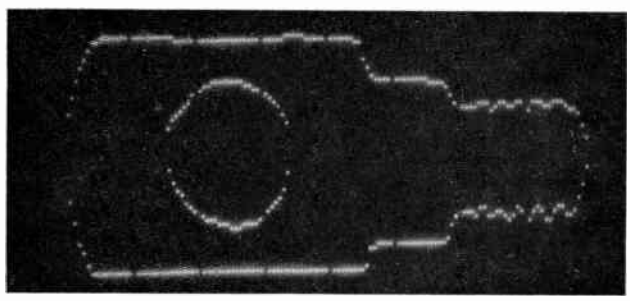


(b) Scanned profile of integrated circuit package resting with the pins uppermost.

Fig. 6.



(a) Bicycle brake adjuster lug. (By courtesy of T. I. Raleigh Ltd., Nottingham, England).



(b) Scanned profile of brake adjuster lug lying on one side which clearly shows the hole and screw thread.

Fig. 7.

the classification method being exactly the same. Indeed additional stable states can be allowed, the only real limitation being that of memory size for parameter storage.

5.2 Comparison Phase

The compare phase involves the comparison of sample part parameters with those extracted from the master during the describe phase. The technique utilizes the application of modified interrogation software outlined in the describe phase, once the sample part profile has been transferred to memory. The process of comparison is outlined in the flow diagram of Fig. 5.

5.2.1 *Grid comparison*

Grid comparison is the first test the sample part undergoes to determine its candidacy. The first of the master grid lines is retrieved from store and the sample examined at this line number to determine whether edge positions along this line match those of the master to within a certain tolerance. If successful, comparison continues until all grid lines have been examined and compared. However, if during the comparison a mismatch is found, then the sample part is not regarded as a non-candidate. The part may have been rotated through 180° and to accommodate this valid alternative, the master data are manipulated to allow for a 180° comparison test. A mismatch occurring during this second comparison indicates a non-candidate part for this stable position. In this case the process is repeated to determine whether the part is in the second stable position indicated during the teach phase. Assuming a match is achieved, then on exit from the routine performing grid comparison, the probable stable position and orientation of the sample part will be indicated to within 180°.

5.2.2 *Further comparison*

The grid comparison technique will determine the probable orientation of the part, and this initial decision is further tested using the remaining master-sample comparison data. Area and perimeter are well-known orientation independent parameters which are next used in comparison to indicate any gross deformation. At this stage a decision is made involving interior features or discontinuities for comparison. If there are interior features to the master part then path (A) is taken in the flow diagram (Fig. 5). A suitable candidate part should have a similar perforation starting and ending at approximately the same co-ordinates as that of the master in Fig. 4 or at co-ordinates corresponding to 180° inversion. These same constraints will also be true for the other path (B) taken if no interior features are indicated on the master part. The comparison process can be repeated to examine for the second stable position; in this way we can allow the inspection for orientation of up to four differing positions of the same master part.

```
*MASTER DATA
 GRID (POS) (LINE)
      03 37 8B
      03 0A 2B 37 A2
      03 37 BB
      04 2D C9
A=14A7 P=0344                /AREA AND PERIMETER
H=1                          /NO. OF HOLES
```

(a) Numerical data (hexadecimal) arising from the DESCRIBE phase.

```
*SAMPLE DATA
 GRID (POS) (LINE)
      03 39 8B
      03 0B 2D 38 A2
      03 38 BB
      06 2F C9
A=1503 P=0351
H=1

[PART OK
->
```

(b) Numerical data arising during comparison of candidate component with master together with the decision of the operating system.

Fig. 8.

6 Concluding Remarks

We have given an illustration of the level of hardware and software complexity which would find industrial acceptability at the present time The computational hardware is now reduced in size to a point when it can be packaged as a conventional circuit card. This, coupled with the use of programmable read-only memory for storing the operating system, removes the need for intimidating computer peripherals. The industrial user is not required to suppress any inhibitions he might have concerning the introduction of computers on the shop floor. Provided that care is taken in the presentation of hardware suitable for shop-floor use and adequate support is available, there is good reason to believe that this technology will provide the break-through necessary to enter the 'generation 2' industrial robot era.

Operation of the system at present is confined to two-dimensional analysis. Facility for three-dimensional capability is incorporated in the software but to date effort has been directed towards developing fast effective software for analysis of the two-dimensional information. This sequence of development was chosen because most of the software for two and three-dimensional analysis is common. The overall system only requires software to correlate the separate data from each camera to provide three-dimensional capability.

The results achieved to date with the system described are most promising. A simple line-scan of the components of Figs. 6(a) and 7(a) using the system outlined provide the profiles of Fig. 6(b) and 7(b) which clearly offer very reasonable representations of these components. Processing times for determination of candidate component and orientation range from 200–500 ms depending upon the complexity of the interrogated component. A teletype print-out of area, perimeter and grid intersections for the component of Fig. 7(a), as determined during the 'describe' phase, is reproduced in Fig. 8(a). The numerical data arising from the same component during 'comparison' is listed in Fig. 8(b) together with the decision of the operating system. Although some sections of the operating system need further development, the power of the system is clearly in its own relative simplicity. Development will continue to the point when an industrially acceptable unit is available for demonstration.

7 Acknowledgments

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automation, or is able to be easily changed from task to task—thus permitting economic justification for smaller quantities (batch production).

Any automation can only be justified if sufficient parts are being made to cover the costs of the automation machinery itself. One can, arbitrarily, define limits, in terms of quantities, for batch production, and one may think of the region between one thousand and a few hundreds of thousands of pieces. This is the area of application where intelligent flexible automation can help most. For very small quantities model-shop principles of production will continue to apply, and 'Detroit style' hard automation will certainly remain valid for mass production).

The fact that the basic system, which will be quite expensive, can be used for several consecutive tasks, which may be unrelated, may allow automation to be economically and effectively applied to short production runs. Most of the system will be used over and over again. This could mean that the accountancy methods used for the justification of production machinery purchase may have to be modified. The cost of a given intelligent flexible automation system may have to be spread over several unrelated products, or over a longer period than is customary at present.

Characteristics necessary in industrial automation are low cost, high reliability, ease of maintenance, high speed, and, if possible, an applicability to as wide a range of products as possible without extensive retooling. It is of no practical benefit making an advanced intelligent assembly machine if the machine takes several hours to complete a task which can be done by man in a few seconds or a few minutes. There is a constraint on speed and in practice the maximum time that can be spent on any one operation in batch production of the sort of size mentioned, must be between 0·1 and 10 seconds.

It is important to emphasize that the major part of the control of flexible automation resides in computer programs rather than in the mechanical design of the automation machinery.

The characteristics and performance of the system are determined primarily by this software in the controlling computer. In all software writing, modularity and ease of use is important. In software for this kind of automation it is crucial and in particular it is essential that the software is structured in such a way that changes in function can be easily made at shop floor level. To use such systems an equivalent of the tool setter on an automatic lathe is required—but this individual must be capable of 'setting' the software to achieve the required task goal as well as setting the mechanics.

Because software effectively defines the functional capability of the system, it is possible to use the same machinery for operations on a range of different, but similar parts—just by changing the programs or program parameters. In some circumstances it may even be possible to work on different tasks with little or no changeover time simply by switching to other software. In practice this may not always be possible as it may be necessary to change some tooling, the manipulator grippers or special jigs, for example.

The set-up time for new tasks should be very much reduced, particularly if one uses the concept of 'teaching by showing', which is one in which a human operator 'shows' the system the task to be performed. Depending upon the intelligence of the system the human teacher may have to give more or less detail in his training demonstration. For relatively unintelligent systems great detail will be needed with full specification of part and operation to be performed. The exact sequence of operations will have to be defined, together with an exact specification of paths to be followed by the handling devices, or at the least a number of 'set points' along the paths. The system may then interpolate between these set points. Most of the currently available robot handling systems can be programmed in this way by 'leading' the machine through the required operation—under human control—and probably at slow speed. The system stores information about the path and sequence of operations, and at the completion of the teaching sequence can play back the operation—often at much greater speed.

It is now becoming feasible to define the requirements of a task to an intelligent machine in much more general terms—the basic function and perhaps the final end-points, together with demonstrations of 'good' (i.e. acceptable) and 'bad' pieceparts and positions, and to leave the machine itself to determine the best strategy in detail for the whole operation. The action of the machine may be 'modulated' by details of circumstance, observed via sensors, so that the course of each operation may vary whilst the final objective is being reached.

At this point it is perhaps appropriate to draw a distinction between the world beloved of workers in A.I. (Artificial Intelligence) and that of I.A. (Intelligent Automation). The A.I. workers strive for generality, using generally positioned cameras, and as little as possible *a priori* knowledge specific to the particular situation. In contrast, in I.A. one must use as much information as is available about the precise circumstances and components that one is involved with, and, if it helps, it is quite permissible to use tricks, such as special lighting or two strictly orthogonal television camera views.

Since flexible automation machines are likely to be equipped with visual sensors, it is possible to conceive of a mode of operation in which the machine makes a move and either 'looks' during the move, or observes after the move, and, based on the visual input, applies corrections to the actual or subsequent operations. This visual 'feedback' allows operation in a null method, and like all feedback, permits high accuracy from the use of perhaps only medium accuracy machine components. In addition it may no longer be necessary to specify such high accuracies either in the position of piecepart or machine, which are currently sometimes needed more to allow automatic assembly than for any functional need in the component itself. As an example, the exact position of a fixing—perhaps a nut and bolt—may not have to be nearly so precise as the dimensions of a shaft, which has to fit closely into a bearing, and yet for ease of automatic assembly in current practice the fixing position may be defined to an accuracy out of all proportion to the functional needs.

Vision is certainly not the only sense needed. To screw a bolt into a tapped hole may be done in two stages. First the bolt and hole have each to be individually located and brought together. This can be done using vision sensors for control. Once the bolt is positioned at the start of the tapped hole, vision is of little use—either for man or machine—as it may be physically impossible to see enough of the situation in which the bolt is being inserted. In any case it may not be possible to derive sufficient precision from the analysis of the visual image to control the action of screwing the bolt home. For this purpose it is essential to use tactile sensing—force feedback—together with a degree of controlled compliance in the gripper or manipulator 'wrist'.

3 Requirements for a Sensorily-controlled System

A system that is to do a task in a way which is modified by the circumstances in the real environment in which the task is actually done, must contain four essential sequential activities:

(a) It must observe the environment—this involves the use of sensors—television cameras, tactile sensors, 'force' and proximity detectors—as well as simpler devices such as micro-switches.

(b) It must process the sensor data to extract from it significant information about the task in hand. The sheer quantity of data produced by television cameras is enormous and can be an embarrassment to a computer. Thus the data on the system environment has to be selective and the volume of this significant information will be much less than the total initial sensory data.

(c) It has to form a plan of action by comparing the requirements of the task with the situation as observed. This comparison may well lead to the formulation of sub-goals, and hence sub-tasks, the completion of which lead finally to the achievement of the main task objectives.

(d) It has to issue the detailed command signals to the effectors—the actual mechanical manipulators, which will carry out the sub-tasks leading to the final desired result.

Each of these activities represents a significant field of endeavour.

3.1 Sensors for Flexible Automation

An important characteristic of flexible automation is the ability of the system to control its behaviour according to the observed environment in which it finds itself at any time. The sensors are the means whereby the system senses its environment. In principle, any suitable physical variable could be the basis of a sensor. The main sensors currently in use are those of vision, touch and proximity, and sound.

The job of the sensor itself is to convert a physical variable into some form of measure, usually electrical, suitable for further processing. The simplest kind of touch sensor, a switch, converts a mechanical force into a binary electrical signal. In contrast, a television camera converts a complex image having a continuous variation in several parameters, e.g. colour, contrast, brightness, into an electrical signal which, in all probability, for economic reasons will be a discretely sampled signal of the continuously varying input parameter.

Industrial thermionic television cameras have been available for some years. There is now considerable commercial pressure from the entertainment sector of the electronics business to develop a replacement all-solid-state camera. Indeed, it is now possible to buy solid-state cameras having a resolution of 256×320 points. Current thermionic television camera technology can achieve a resolution of more than 800 lines (equivalent to about 800×1000 points), and it is unlikely that solid-state cameras will exceed this spatial resolution for some years. If greater resolution than this is required, multiple cameras or flying spot techniques have to be used.

The use of solid-state television cameras will greatly improve the robustness and reliability of the camera as well as making it easier to use as a measuring sensor. The thermionic camera is not good for this purpose, as the spatial position of each picture element (pixel) is determined by a combination of electrical and mechanical factors. The electrical factors will probably vary with time.

Scanning range finders have been proposed as a fruitful source of information about industrial scenes by Stanford Research Institute.[1] Indeed, in some situations it may be impossible to resolve visual ambiguities without detailed range, textural or colour information. There are two methods for determining range. In the first, one relies on analysis of the observable parallax between two images perceived from different camera positions. A large amount of correlation processing is necessary between the two images to obtain the information on range of all parts of the picture. An alternative is a 'range prober' of the radar, sonar, or lidar type. The biggest difficulty with these methods is that of obtaining a scanning system capable of sampling the field at high enough resolution to be useful, without being impossibly expensive or slow.

Simple proximity detectors and strain gauges have been in use for some years. Automatic assembly, including insertions, makes demands for force detectors which give multiaxis information. On each of the three orthogonal axes one can experience a force, a torque and a bending moment. Tactile sensing is multidimensional in the same sense that mechanical manipulation must be considered multidimensional. It is mechanically difficult to construct a rigid and robust structure in which tactile sensors or strain gauges can be incorporated to give unambiguous measurement of each of these possible nine touch sense signals. The geometry of the touch sensor itself will determine the complexity of the primary signals and the consequent complexity of the 'disambiguation' processing which will be necessary in order to obtain discrete separated signals. Ideally, one would like little coupling between the various outputs, but in practice this is virtually impossible. Such devices are not commonly available.

3.2 Sensor Data Reduction

Modern sensors give much data. 'Intelligent' data reduction before analysis is essential. Development of picture processors, using dedicated microprocessors to control special-purpose high-speed picture 'computers' to reduce the quantity of data present in normal television video, is underway at several centres. At present such conditioning and reduction of data is done on a serial basis primarily because most television cameras produce their data on a single serial line.

In principle it is possible to envisage a television-pickup device in which the signal is in large part in parallel. In the future it may be possible to do parallel processing on the direct output from such cameras in a similar way to that which is understood to be done in the human eye.[2]

The outputs from multiaxis strain gauge systems probably require processing to separate the components of forces along each axis. Once again the use of a dedicated microprocessor may be a cost effective solution.

3.3 Strategy and Planning

A fundamental principle involved in flexible automation is that the structuring of the processing is on a hierarchical basis. This is probably going to be true both at the machine level and at the individual function level. At some stages of the operation, knowledge of the presence or absence of a part in the field of view is all that is needed. At a later stage, detailed orientation information could be required. Still later, information about the location of a hole in a specific face of the part may be necessary. The 'filtering' of the sensory data to provide only sufficient data to resolve the questions that are pertinent at a given instant can be done in equipment associated with the sensors, and not in the main control processor.

Thus the main overall control may be based in a moderate sized computer, whereas each functional unit will be built up from a number of individual modules, each with their own 'intelligent' microprocessors. Even within each production unit, each of the functions will be carried out using separate processors, each reporting to a level above. The production units themselves, of which there will be several, will be in direct communication with the main programming and control unit, of which there will be only one and that will be primarily concerned with planning strategy and modelling. Thus effective operations depend on an efficient method of inter-processor communications, an area which is not yet adequately developed.

This area of strategy and planning seems to be the least well understood area.

3.4 Control

Control of effectors, and the design of the effectors themselves are known art, although current manipulators tend to be massive and over-strong, slow and imprecise (at least so far as the needs of the electronics industry are concerned). An operating volume of, say, $30 \times 30 \times 30$ cm and a precision within that volume of about $\pm 0{\cdot}1$ mm, together with a transit time of 100 ms would be useful. A capability to handle a mass of 2–5 kg would probably be adequate. Detailed control of the axes of the manipulator, co-ordinate transformations between 'world' co-ordinates and machine actuator co-ordinates—including the possibility of a time varying frame—and interpolation, should all be done separately from the overall control processor.

Safety is another factor which must be mentioned. A machine which is programmed in detail, in principle remains within known confines. A machine, of the type being considered, modifies its own behaviour according to circumstances as it observes them. Its actions are not predetermined even when repeating apparently identical tasks. Humans in the vicinity of the machine should remember this! This property may also make the servicing of the system more difficult. Techniques developed for computer servicing, in which specific test programs for individual parts are used may have to be applied.

4 Visually-controlled Automatic PCB Drilling System

As an example of a system having some of these attributes, an automatic printed circuit board drilling system (ref. 3 and Fig. 1) has been built, which finds its drilling positions by 'looking' at the etched copper pattern on the board through a television camera and recognizing potential drilling positions. The definition of the visual appearance of a potential drilling position is given in general terms as a disk of copper with a suitably sized dot within it. No other information, apart from this definition of what constitutes a drilling point is needed by the system. It is not necessary to specify the positions or number of the drilling points on the board, and consequently the machine can drill different board patterns equally well, without any adjustments, provided only

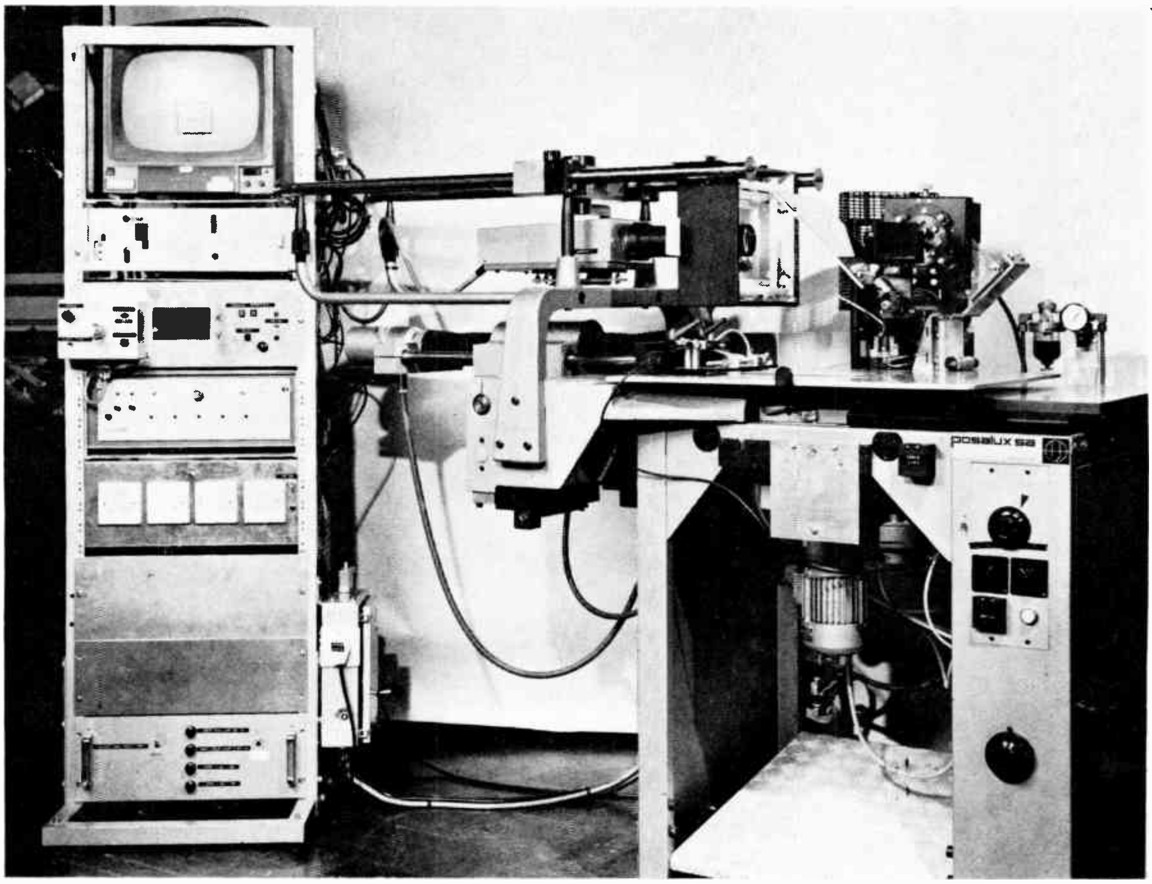


Fig. 1. Automatic visually controlled printed circuit board drilling machine.

that the appearance of the points to be 'drilled' on the various boards are defined in the general specification known by the system.

When a human operator drills a printed circuit board, using a single spindle drilling machine, he observes the board through some sort of magnifying optical system, and moves each point he identifies as a drilling point to a reference point—the crosswires—where the drill is located. He then actuates the drill. In this seemingly simple operation, the operator, almost subconsciously, has established a scale factor between the movement of the board in his hands, and the observed movement of the image in the viewing system. He also will make allowance for any offset of the drill's actual position with respect to the crosswires, and, if he is a good operator, monitor his own performance as he works, making corrections when necessary.

Finally, he must establish a search procedure that ensures that the whole of the board is systematically scanned so that no holes to be drilled are missed.

The automatic system does each of these functions, including comprehensive self-calibration, by drilling an initial test hole in a scrap region on the border of the board in order to observe the actual drill position. After this first hole, the system observes the position of each hole it has just drilled and makes corrections as necessary to the calibration 'constants', scale and offset. This application of 'sampled visual feedback' ensures, like any feedback system, that the effects of drifts in the system—in this case especially the television camera—are minimized.

The performance of the automatic drilling system as built was not adequate for production drilling use without much more development work. However, it has been suggested that the system could form the basis for an automatic digitizer, and to this end the experimental system had an optional ability to punch an $X-Y$ position tape, which subsequently could be read back into the system and used to control the drilling table in normal (i.e. non-visual) numerically controlled manner.

The control software, which ran in a Honeywell DDP 516 mini-computer consisted of a few thousand statements in Fortran, (together with some Assembler inserts for direct hardware control), and was in consequence very slow. On average the system drilled holes, in completely unspecified positions, at a rate of about six to seven seconds per hole. This included inputting video, processing it, moving the machine carriage, checking, drilling the hole and rechecking the drilled hole. The video input unit used was particularly slow, taking in only one point per television line per frame. More recent developments have provided more than a two hundred-fold increase in speed for this function.

By further development of the system, using a more modern television acquisition unit, optimizing the software, and conducting some operations in parallel, rather than waiting for each to be completed before moving on to start the next, it was thought that a rate of one drilled hole per second could have been reliably achieved. In any case, the principal intention of the work was to gain experience in the construction of a visually controlled machine, and to demonstrate the feasibility and practicality of such a system. Having achieved these objectives, the project has now been terminated.

The printed circuit 'world' was a convenient two-dimensional world in which to start. A proprietary machine was available which could be used as a mechanical test-bed (Posalux Copyfor) which meant that expensive and time consuming mechanical developments were avoided.

5 Visually-controlled Piecepart Orientation and Assembly

The real world is three-dimensional and to develop systems for assembly, which is a three-dimensional activity, one must work in the real world with all its difficulties.

In the Electronics Industry one can find many examples where three-dimensional parts are made, possibly in quite large numbers, and are put into store pending assembly into more complex entities. In many cases, either for technological, or economic reasons the orientation of these parts cannot be preserved, in spite of the fact that at the time of manufacture the orientation was very precisely known. For example, small punched and formed sheet metal parts may be deburred and plated in drums. This process completely destroys any known orientation, and one is faced with a box of jumbled components to be assembled, probably to other components in a similar pile.

Sometimes these parts can be difficult to feed by traditional means, such as bowl feeders, when the feeder is used both to separate and select parts in the correct orientation. Automatic assembly machines require a steady stream of parts, all of which are in the correct orientation, and so to provide the assembly machines with 'difficult' parts usually involves a human operator, 'off-line', orientating and loading the parts into magazines which can then, in turn, be fitted onto the assembly machine.

5.1 Experimental Equipment

The use of vision, as an important sensory means, together with a computer controlled handling system could solve this problem in a general way, and one current research objective at Philips Research Laboratories is to devise a system capable of locating and correctly orientating such parts when presented to the system entirely at random.

As with the p.c.b. drilling system, a main design aim was to build a system that was robust and self-calibrating, so that differences in the exact mechanical situation from time to time, would be irrelevant. The self-calibration facility must cater for differences in scale, position and lighting.

The system is capable of being 'taught' the desired orientation of a part. To do this the system is shown a number of parts in the correct orientation, a number in incorrect orientations (but telling the system what their orientations are), and some parts in the wrong state (for example, upside down). The last category have to be rejected by the system. The system applies a number of modelling techniques in turn to each of the object views and determines the optimum combination of models to use for the object concerned. It selects the optimum by trying each method in turn, in order of increasing 'complexity' until it finds a set which correctly determines the identity and orientation of all the 'correct' parts, whilst rejecting all the 'incorrect' parts.

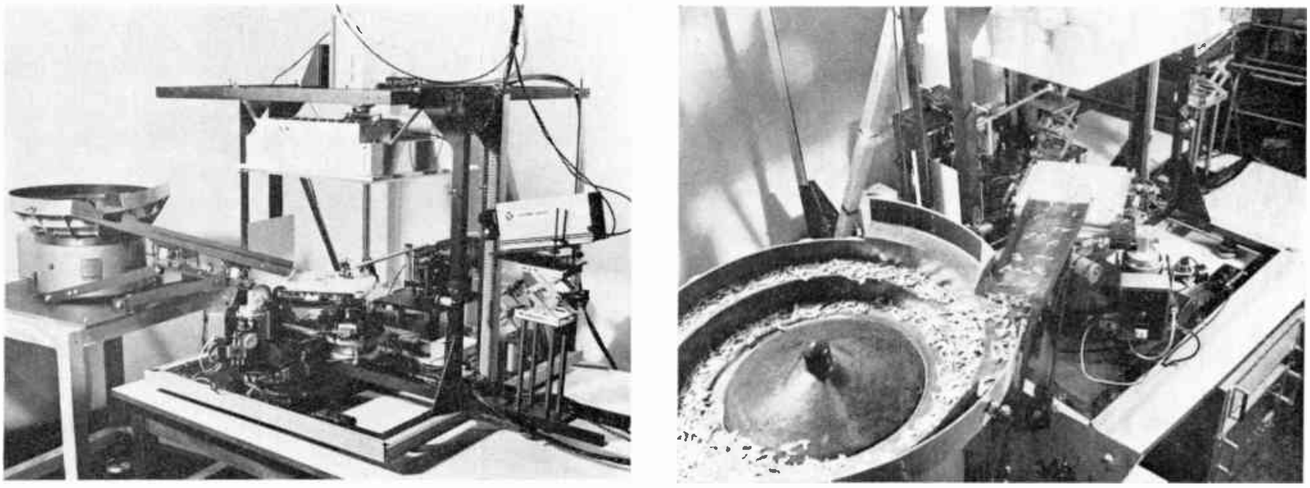
In the experiment an 'untooled' vibratory bowl feeder is used, in conjunction with a computer-controlled moving belt to spread a number of components in the field of view of a television camera (see Fig. 2(a) and (b)). The function of the bowl and belt combination is solely to distribute components so that as high a percentage as possible do not overlap. No orientating or selecting is attempted, and consequently the bowl/belt combination should be able to feed a wide range of very different components without mechanical adjustment or tooling.

The moving belt is in fact mounted on the top of a computer-controlled table which can be rotated about a fixed vertical axis, as well as translated in two horizontal directions at right angles. All the motions of the table can be controlled by the computer.

Two television cameras view the top of the belt, one mounted with its axis vertical, and approximately co-linear with the axis of rotation of the table and belt assembly, and the other viewing across the top surface of the belt on the table.

To use vision, it is important to have adequate illumination. The lighting requirements for good computer vision are difficult but critical. At the present state of the art, the image interpretation algorithms in the computer are far less tolerant of variations in perceived grey scale than the human eye-brain combination.

In some situations back lighting, producing very high contrast silhouettes, can be helpful. The endless belt, mentioned above, is translucent, and encloses a number of discharge lamps which provide a uniform back lighting through the belt, which throws any objects on the belt into strong silhouette (Fig. 3(a)). If front lighting is needed, so-called 'shadowless' diffuse lighting from an extended source (Fig. 3(b)) avoids the very severe



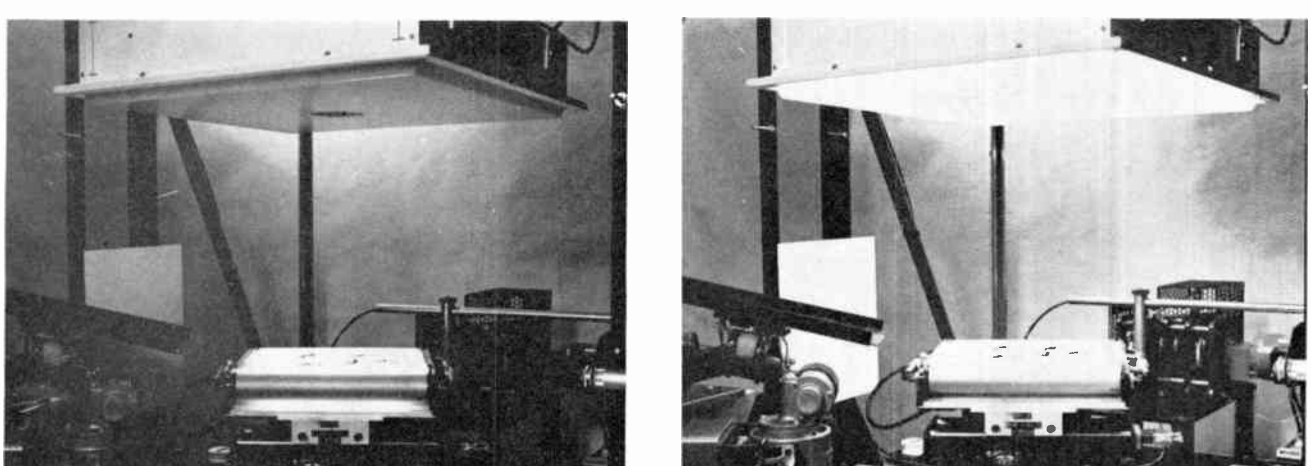
(a) General view of visually-controlled pick-and-place machine. (b) Part feeding by untooled bowl feeder.

Fig. 2.

picture-processing problems associated with sharp shadows. Many of the parts to be processed are very reflective, and their apparent image changes enormously according to their orientation with respect to lighting and camera angles. The use of diffuse lighting minimizes this effect.

A simple 'goal post action' manipulator, driven via a non-linear drive and cam mechanism, is provided. This has a pneumatically-operated parallel jaw gripper, which can pick up a part from one specified place in space (on the table), and transfer it to another defined point (off the table). The action of this 'manipulator' can be started by the computer, and once started, it will complete its action under the control of cam-driven micro-switches. The mechanism has two 'rest' positions—over the table pick-up point and over the set down point. In Fig. 2 (a) the gripper can be seen at the table pick-up position. Although such a mechanical handling system is very limiting, it can, in principle, be used to cope with parts that are the 'wrong' way up by mounting an inverting jig on the table. Upside-down parts would be identified as such and positioned for pick-up. The gripper would then remove the part from the table, but retain hold of it. The table would then be positioned so that the inverting jig is at the pick-up point. The part held in the gripper would next be returned to the inverting jig, which is then activated, and the part, now the correct way up, removed normally.

When the field of view of the television camera has a number of parts within it, the computer vision system locates individual non-overlapping parts in turn and identifies them as acceptable (i.e. the correct way up).



(a) Internally lit belt (back lighting). (b) Diffuse front lighting.

Fig. 3.

It does this by taking measurements of the object and applying them to the modelling procedures determined as optimum during the training phase. The output from this is the position and rotational angle of the object, as well as an indication of the 'goodness of fit' of the object with the models. The program can use these values to position the table in X, Y and angle, so that the handling system can pick up the part and transfer it in known orientation to the output point, which represents a magazine, or the input to an assembly machine.

For more detailed description of the modelling procedures used in the software see ref. 4.

5.2 Present Performance

The pick-and-place machine is controlled by a minicomputer. At the time of writing the system is being rewritten in RTL2 for Philips P857 minicomputers. The experiments briefly described above were run using a Honeywell DDP516 as the controlling minicomputer and the system programs were written mostly in Fortran IV. The computer had 16 k of 16-bit words of core store, and one disk. The programs are highly modular, and during the operation modules are extensively 'chained' into core from the disk. Typically, for the simple objects so far tried, the training phase takes between 5 and 10 minutes, with machine initialization taking another 5 minutes. The program, during the operating phase, processes each object in 15–20 seconds.

6 Conclusions

A machine of the type described in Section 5 is clearly not usable in industry in its present form, but it does demonstrate that the exciting concept of a production system that can deal effectively with locally varying conditions and also be used for a number of different tasks without complete redesign, is a real practical possibility.

There are several areas of difficulty in which current knowledge is barely adequate for the task. We do not yet know enough about how to program multiple processor systems, nor yet how to connect them together effectively. A new kind of software is needed that is natural and easy to use at shop floor level, but yet effective in this multiprocessor environment. Methods for the real-time processing of sensory data will have to be worked out, as well as cost effective path control algorithms for robot handling devices, that can be implemented in cheap microprocessors. The Electronics Industry also needs an effective programmable robot handling device suited to its requirements.

This paper has only touched on some specific areas in which we are trying to demonstrate how intelligent automation can help our Electronics Industry. It has concentrated on the handling of small mechanical parts—a labour intensive area—but, in spite of present shortcomings of available technology, the techniques of computer science, artificial intelligence and pattern recognition will surely make a significant impact within the next few years, in production methods applied to a wide range of electronic products from integrated circuits to washing machines.

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Social implications of intelligent machines*

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SUMMARY

The much-discussed issues of privacy, unemployment, leisure, centralization of political power, and military misuse of technology are raised by work in artificial intelligence no less than by applications exploiting the 'brute force' of computers. But this paper focuses specifically on matters associated with the social use of *intelligent* machines in particular.

Some current and predicted developments in machine intelligence are described and possible ill and good effects these may have on society outlined.

Precautionary measures that might be taken in the writing and presentation of programs to forestall the social dangers implicit in this area of research are examined.

* *This paper is based on Chapter 15 of the writer's book 'Artificial Intelligence and Natural Man,' to be published summer 1977 (Harvester Press, Hassocks, Sussex).*

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1 Current Achievements and Future Developments

Computer hardware gets steadily cheaper: it is predicted that by the year 2000, a 65 k bit silicon chip capable of 20 million instructions a second will sell for one US dollar. But the social application of intelligent machines also demands advances in software, such as more powerful programming languages and improved organization and use of knowledge. Work in artificial intelligence has shown that the problems of organizing and accessing large data bases will not be quickly solved. The early optimism in the field has waned accordingly: already by 1962, the mediocrity of chess programs was being stressed by someone who in 1957 had predicted that a computer would be world chess champion within 10 years. And much current research aims to develop organizational principles whereby a knowledge-domain can be economically represented and appropriately addressed without triggering a combinatorial explosion.[1]

Nevertheless, professionals participating in a multistage 'Delphi' forecasting exercise have predicted that within the next 30 years (in many cases, within only 10 or 15 years), social applications of artificial intelligence will be widely, i.e. commercially, available.[2] In general, the prototype is expected 5 ± 2 years ahead of the commercial version. The dates I shall mention are taken from this Delphi study (although my own view is that these predictions tend to underestimate the difficulties involved).

The applications forecast run from robot housecleaners, chauffeurs, and industrial workers, through programmed gameplayers and storytellers, to automatic teachers, physicians, legal justices, marriage counsellors, and literary critics. In all these cases, the emphasis is on reasoned and flexible judgment on the program's part, as opposed to the storage and regurgitation of isolated facts, or the repetitive performance of a fixed sequence of discriminations and movements.

For example, the computer diagnosticians of the 1980s will not simply store lists of symptom–diagnosis pairs, or prescribe treatment in a blindly dogmatic (and apparently 'objective') fashion. One current prototype is the MYCIN system, an interactive program that simulates a medical consultant specializing in infectious diseases.[3] It engages in question-and-answer conversations (lasting 20 minutes on average) with doctors needing specialist help, and in 75% of cases gives the same counsel as a human expert. The physician asks MYCIN for advice on the identification of micro-organisms and the prescription of antibiotics, and also for explanations of its advice expressed at the appropriate level of detail.

MYCIN's explanatory capacity enables physicians who disagree with specific aspects of the program's clinical rationale rationally to *reject* MYCIN's advice. It also helps non-specialist doctors to learn more about the complexities of diagnosis and therapy in this class of diseases. And it allows human consultants to make general improvements in the program, by telling it about relevant knowledge that they realize in specific cases to be missing or inadequately stated.

A program like MYCIN involves artificial intelligence techniques. Quite apart from its (rather restricted) natural language understanding, its ability to explain itself on many different levels of detail implies a self-knowledge of its reasoning and goal-structure that are crucial to intelligent thinking. And its ability to learn by being told implies some mastery of the problem of making spontaneous inferences on the basis of input information, though admittedly only for a very limited area of discourse.

Many features of MYCIN would be embodied also in programmed legal arbiters (prototype predicted by 1988). These would not only search for relevant legal precedents in the judicial literature—a far from trivial task—but would also offer legal advice. Like MYCIN, legal arbiters will preferably be used to *augment* human judgment, rather than *replace* it. Accordingly, like MYCIN, they should when appropriate offer several (reasoned) alternative judgments, not just the one of which they are most confident. MYCIN's assessment of degrees of confidence is not a mere statistical probability measure. It takes into account psychological factors about the evidential relations of beliefs, factors that philosophers of science have considered in regard to 'confirmation theory'. Legal programs, too, would have to incorporate more subtle concepts of *confidence* and *evidence* than Bayesian probability, in order to avoid judicial absurdities of various types.[4]

Flexible planning, and an intelligently structured representation of knowledge, is used by the Computer-Based Consultant, a system designed to give on-the-job advice about how to assemble a machine to novice mechanics having varied levels of expertise.[5] The program uses the specific queries posed by the human novice as cues directing it to answer at one level or another. Thus it tells one mechanic simply to 'Replace the pump', but advises a less experienced person first to 'Remove the 4 mounting bolts at the base of the pump using a $\frac{3}{8}$-inch open-end wrench'. When a human failure occurs because of an unexpected happening (including but not restricted to previous mistakes on the novice's part), the Consultant can question the mechanic in an intelligent fashion so as to locate the difficulty. In most cases, this will not be a simple matter of asking 'What's the trouble?' since the novice usually does not know just what has gone wrong, and may claim to have followed the program's advice to the letter. Because the program's representation of the semantics of this domain includes detailed and intelligently structured knowledge, in the majority of cases it is able to spot the trouble and work out a way of putting the human worker back on the right track.

Future automatic tutors will be more sophisticated than today's computer-aided instruction systems, even those that allow differential branching of the 'syllabus' according to the student's mistakes and queries. Like MYCIN and the Computer-Based-Consultant, they will be able to initiate and answer questions at various levels of detail, according to the pupil's range of expertise. They will concentrate on asking probing questions enabling them to model the student's understanding of the topic, and will devise an individually tailored tutorial strategy designed to build on this understanding in fruitful ways. Such programs presuppose an intelligently structured representation of the knowledge concerned, in its various aspects and degrees. Commercial availability is forecast for 1988, and exploratory programs already exist.[6]

Public access to a powerful computer would be required for many of the predicted social applications of artificial intelligence. John McCarthy accordingly has forecast the widespread use of video-teletype *home information terminals*, linked to a national network of time-sharing computers.[7]

A speech-understanding program would allow the user to speak requests instead of typing them.[8] At present, this can be reliably done (for instance, by the HEARSAY system[9] for playing voice-chess) only by using a very small and deliberately distinct vocabulary, with unnatural pauses between the words. This is because (as in the interpretation of visual scenes) the continuous stream of normal speech has to be sensibly segmented into individual words before it can be understood—but, as artificial intelligence research has shown, it has first to be understood in order to be segmented. Even the individual sounds cannot be distinguished on purely auditory grounds, but only by reference to the wider linguistic context. However, commercial uses are forecast for 1983.

According to some forecasts, the stationary home terminal will in 1995 be supplemented by a domestic robot. It should not be necessary to clear the floor so that the robot can vacuum it: the robot itself will supposedly be able to recognize the objects littering the room and put them in their proper place—or, by default, in one corner. Current achievements suggest that a robot might fairly soon be able to recognize a waste-paper bin wrongly placed by the window, or even high up on the table, so as to reposition it by the desk.[10] But *only* if the room is otherwise unnaturally tidy, and *only* if the bin, window, table, and desk are of uniform type.

Industrial and agricultural robots (forecast by 1980) are less fanciful. These would not have a fixed sensorimotor capability, like the automated machines of today. Instead, they would be flexible in operation, and could learn *new* tasks. They would learn not by being laboriously reprogrammed, but by being shown examples of (for instance) new machine parts and machine tools, and by being given an outline sketch of the desired procedure which they would then elaborate in detail. The sort of planning facilities used by the Computer-Based-Consultant, or programs like BUILD, would be crucial here. BUILD plans how to assemble brick-structures which may require 'creative' steps such as using a temporary scaffold, counterweight, or support.[11] Features like potential stability and steadiness of movement are continually taken into account in deciding what to do, and if a safer method can be found of constructing the desired building then that method will be used. If it turns out that the 'safer' method is not safe after all, BUILD can alter course accordingly, meanwhile losing none of the information gained during the aborted attempt. Slight local difficulties can be recognized and overcome without affecting the general strategy, but graver obstacles prompt radical replanning.

There are already some mobile carrier-robots, and programmed hand–eye systems that can assemble simple machines from components they learn to recognize by being shown examples or that (like MIT's COPY-DEMO[12]) can build visually demonstrated structures out of a 'warehouse' of familiar parts. Moreover, a robot linked to the Computer-Based-Consultant would be able to assemble a pump even if someone else had left the job half-finished, or had wrongly positioned some of the parts. This flexible behaviour is very different from that of current industry's computer-controlled devices, such as the Unimate, which require everything to be in the right place at the right time.

2 Possible Effects on Concepts of Self and Society

The potential social influence of artificial intelligence is ambiguous, for two reasons. First, specific applications (as of any science) may be used for good or evil ends, and may have unsuspected side-effects. Second, much depends on the background human context, including the general public's implicit philosophical assumptions or 'image of man'. I shall first discuss some possible bad effects, and then sketch potential good effects of intelligent machines.

There is a widespread suspicion of artificial intelligence among the general public, based on the common philosophical assumption that regarding man as a computational mechanism entails denying human subjectivity, individuality, and moral freedom. This suspicion has been voiced by critics of urban industrialism such as Theodore Roszak and Herbert Marcuse,[13] and by psychologists in touch with laymen seeking practical help. For example, this complaint is from Rollo May, a therapeutic and counselling psychologist:[14]

> 'I take very seriously . . . the dehumanizing dangers in our tendency in modern science to make man over into the image of the machine, into the image of the techniques by which we study him . . . A central core of modern man's "neurosis" is the undermining of his experience of himself as responsible, the sapping of his willing and decision.'

May's point is that choices made without confidence in their possible relevance to eventual action are unlikely to be effective—or perhaps even to be made at all. For if a man's self-image represents himself to himself as an autonomous purposive creature capable of pursuing certain ends, then it can be used to generate choices and guide his action accordingly. Even in machines, as is evident in planning programs such as BUILD, the internal representation of the possible modes of action that are available to the system can be crucial in directing performance. But if a 'depersonalization' of the self-image occurs so that the self is no longer seen as a truly purposive system, then relatively *in*human, 'pathological' behaviour can be expected in consequence.

This type of degenerate self-model is encouraged by artificial intelligence in general, given the popular (though mistaken) philosophical assumption of total incompatibility between mechanism and humanism. What May calls 'the undermining of one's experience of oneself as responsible' may therefore be exacerbated by the development of clever programs.

As well as having immediate consequences in one's personal life, this sapping of willpower can have widespread social implications. For example, the political institution of participatory democracy assumes an ascription of responsibility to individuals which fits ill with the dehumanized image remarked by May. Consequently, providing citizens with home terminals, with the partial aim of enabling them to vote and express their political views without leaving their fireside,[15] might subtly undermine their sense of civic responsibility. This is the reverse of the intended effect, which is to encourage individual citizens to engage more fully in democratic government, thereby lessening the common feeling of alienated helplessness with respect to the governmental process. (Of course, to *feel* less a cog is not necessarily to *be* any less a cog: the home terminal might function as a subtle form of social control, damping down dissent by contenting people with an illusory sense of political participation.)

While any intelligent program may have a dehumanizing effect on people who see an unbridgeable metaphysical gulf between themselves and machines, as many people do, some would be especially open to this criticism. For instance, the prediction that by the year 2000 automatic interviewers will be used to aid the diagnosis and treatment of psychiatric patients is a suggestion that many would spurn. Thus Joseph Weizenbaum, the creator of the early conversational program ELIZA,[16] has bitterly denounced the 'obscene' idea of employing programs in clinical situations.[17]

In medical contexts dealing with basically physical illness, artificial intelligence may be more welcome. The MYCIN system has not yet been tried out in a clinical situation, though the authors report some resistance on the part of clinicians to the idea of using the program. When MYCIN has achieved a 90% match with human experts, it will be introduced experimentally into a hospital; only then will its authors be able to see who uses it, how often, and what effect it has on the prescribing practices of doctors and the clinical status of their patients. But a much simpler program for the diagnosis of peptic ulcers has been used on patients, who often claim to prefer this diagnostic method.[18] Ironically, they describe the machine (with which they communicate by teletype) as more friendly, polite, relaxing, and comprehensible than the average physician.

These chastening observations about the superiority of the personal habits of programs over those of human doctors can doubtless be expected also with regard to automatic lawyers, bureaucrats, and teachers. While perhaps appreciated in isolated interactions of a tedious, technical, or embarrassing nature, this imperturbable mode might come to be consciously spurned in human relations in general, with a consequent increased emphasis on emotional spontaneity. Alternatively, the opposite effect might result: the blandness of one's guest-computer might come to be emulated in one's own mode of expression—or that of one's children. (The possible ill effect on children was cited in the Delphi survey as a disadvantage of the domestic robot.)

In general, one has to consider the dehumanizing effects of people's becoming decreasingly dependent upon human contact for satisfaction of their needs. Many who today can do their jobs only by going to a particular place of work, might tomorrow be able to stay at home and communicate with their clients and co-workers via the home terminal. The socially isolating influence of television is as nothing to the alienation and loneliness that might result from over-enthusiastic reliance on the home terminal and associated gadgetry.

Let us now ask whether social applications of artificial intelligence might have any *welcome* effects on the way people view themselves and other people.

Computational models of intelligence are in fact markedly more human than the behaviourist models of mankind that have been widely accepted for years, because the computational approach can endorse the humanist's stress on the idiosyncracy of people's subjective world-views and on the directive role of the self-image. A program constructs its interpretation of the input by way of its particular epistemological scheme, or set of inner models of the world, and the same input may thus be 'experienced' very differently by different programs. If this commonly unsuspected 'humanizing' feature of artificial intelligence can be brought home to the general public, then many of the ill effects I have hypothesized will be allayed.

Educational methods based on the pedagogical philosophy of LOGO-turtles[19] might change ways of thinking about 'failure'. Instead of the passively defeatist 'I'm not good at this', the child would say 'How can I make myself better at it?' This attitude is encouraged by the computational way of thinking about thinking, with its emphasis on the creative interrelation of many different procedures, and on the unintended effects of specifiable bugs in basically well-conceived attempts to achieve one's goal. By contrast, constructive self-criticism is not encouraged by a conception of intelligence that views it as the product of a number of mysterious monolithic 'talents' or abilities, which one either has or lacks, willy-nilly. (An increase in the use of programming in schools may also help to avert the growth of a socially divisive 'computer elite', a small group of people whose members are the only ones to understand computation and so the only ones not to feel alienated in the computerized society of the future.)

Publicly available programs are unlikely to be rendered 'emotional', even assuming this to be in principle possible, since there would be little point in doing so. If people still felt a need to draw a line between themselves and 'machines', their valuation of the emotional life would probably increase, with corresponding effects on cultural mores. Incorporated in the self-image of most Westerners is the Protestant Ethic that only hard work is a really serious activity. And 'work' is implicitly defined as paid, as done in one's employer's time rather than in one's own 'leisure' time, and at the employer's behest rather than for one's own purposes. Consequently, massive unemployment could be more soul-destroying than the most repetitive of factory jobs, causing men destructively to see themselves as social parasites. This is less likely to happen to women, who enjoy an internalized acceptance of emotional values that enables then to derive greater fulfilment from personal relations and the expression of emotions outside the immediate family circle. If automation increases men's opportunities for human interaction, with friends as well as family, we may expect radical changes in the social definitions of sexual roles (for emotionality at present is seen as secondary to the masculine role). These changes would be due primarily to economic shifts in working-hours and the sexual division of labour, but they could be reinforced by a general increase in evaluation of the emotional life deriving from the 'emotionless' nature of programs.

3 Precautionary Measures in Writing and Presenting Programs

Sometimes things will go wrong, so that a program needs to be adjusted. Programmers who wish to know what is going on, and what needs to be stopped should anything go amiss, must take steps beforehand to allow for this. Their programs should be intelligible and explicit, so that 'what is going on' is not buried in the code or implicitly embodied in procedures whose aim and effect is obscure.

Programs should be generously commented, so that what a procedure is *supposed* to be doing (and *why*) is readily visible. The importance of this for aiding debugging (whether by a human or an automatic programmer) is evident from the program-writing program, HACKER.[20] HACKER writes programs to perform tasks such as stacking bricks in specified ways, and is able to correct its own mistakes—and to avoid similar mistakes in future tasks of a generally similar nature—by way of its understanding of the purposive structure of task and program alike. HACKER uses the intention-coding comments it attaches to each line of its 'first draft' programs in amending these programs later. Only because it has such a good idea of what it is trying to do, and how it is trying to do it, is it able self-critically to modify its own procedures.

Intelligibility and explicitness are to some extent opposed, and programs get less readable as they approach the machine code level. What counts as 'machine code' is likely to become rather more intelligible to human beings, since instructions that now have to be programmed may be 'hardwired' into the electronics of the machine.

To economize on computation time, the next best thing to hardwiring is compiling. It would in general be advantageous to have the possibility of switching from compiled to interpreted mode if necessary, so as intelligently to guide the giving of detailed instructions to the machine in light of current circumstances, and the programmer should specify the sorts of contexts in which this switch might be advisable. The learning program HACKER, when in doubt (and when running a new program for the first time), can switch into a slower 'careful' mode in which every step is carefully examined before it is taken.

It is easier to see what is going on if subroutines are written so that they can easily be 'got out' from the program as a whole. This principle of modular programming is exemplified in programs like BUILD. The understanding and improvement of BUILD are facilitated by the clear distinction between the intercommunicating 'expert' subroutines. Modular programming will be required also in writing programs that cannot possibly be spied on or maliciously altered. For unless it is small, a program cannot be proved to perform *exactly* the functions required by the designer *and no other functions whatever*. The only way to make unauthorized access absolutely unfeasible would be to build the system around individually proved modules, or 'security kernels'. Modular programming also helps to counter the conservatism inherent in widespread applications of very complex systems, for if faults can be adjusted without necessitating widespread tinkering with the system then programmers will be better able to face the task of improving a large-scale system.

If programmers are to be able to see what is going on, they should not use programming techniques which—while making for readable programs—render the control structure obscure. For example, use of the programming language PLANNER tends to produce readable programs in which one cannot tell what is going on by examining the code.[21] PLANNER programs are legible because it is a 'goal-directed' language in which routines can be indirectly invoked by way of general 'goal-patterns' matching the index of the routines in question. Specific advice to try one routine before another can be included by the programmer. But the language embodies an automatic backtrack facility which tags on to the end of the specific advice (if any) the instruction to USE ANYTHING that might work: that is, any routine whose index-pattern matches the goal currently being sought. This strategy might lead to some nasty situations: a distraught parent in squalid surroundings may try anything to stop the baby screaming—and succeed appallingly well. A human has to be distraught to disregard the side-effects of 'effective' measures, but a program may not even know about them.

Moreover, in the PLANNER automatic backtrack situation, the program simply tries out the first method that seems apt, since it has no way of comparing all possibilities beforehand. The knowledge that hitting may hurt the baby could be buried inside the relevant procedure, to be found only when this way of making the baby quiet was run. Only if the programmer had specifically included the advice never to hit the baby, would a PLANNER program refuse even to consider it. The programming language CONNIVER, (which was developed largely in response to the difficulties involved in PLANNER backtracking), by contrast does allow for the potential choices to be listed for higher-level criticism.[22] (BUILD uses this facility in deciding on the safest way to build a brick-house.) If a CONNIVER program knew that hitting hurts, and was able to access this knowledge when needed, it would be able to control itself long enough to find an alternative way of quieting the baby, or to decide to abandon this goal as not legally achievable.

This example makes it clear that a flexibly intelligent control structure is only useful if the program embodies sensible criteria of what effects are 'undesirable'. Some 'sensible' criteria are culture-specific, and one may expect much moral-political disagreement about what precautions regarding artificial intelligence are worthwhile. Isaac Asimov's well-known 'Three Laws of Robotics' each assume that we know (and have communicated to the robot's program) what is to be counted as 'harm'.

Should we, for instance, regard it as harmful to lie? (We commonly say it is immoral, and utilitarians argue that it is socially harmful.) But if so, we may be landed with a teletyping program that is forbidden to tell tactful white lies. One of the reasons people often have for lying is precisely to *avoid* harming others. The more 'personal' the program, the more likely that lying (or a tell-tale silence?) might be in order. Some people would even claim that for social-political reasons—such as preventing dissent, disorder, or panic—certain 'impersonal facts' should be kept from the general public. On this view, should all home terminal programs (particularly those notionally contributing to participatory government) be kept ignorant of them also, or should they be able intelligently to take account of them while 'protectively' keeping them to themselves, if necessary lying in order to do so?

The ethical ambiguity of lying is only one of many difficult cases. One may therefore experience some reserve about recommendations of a new profession of value-impact forecasters: ethical experts armed with scientific tools for making cost-benefit judgments.[23] Roszak has sourly commented:[24] 'What these ethical engineers will know of "value" (Old Style: the meaning of life) may of course be only a computer simulation of a statistical illusion gleaned from questionnaires whose unreality crudely approximates a moral imbecile's conception of an ethical decision.'

Roszak regards the use of psychological terms in psychological contexts, and artificial intelligence research in general, as inescapably dehumanizing for the culture that admits them. He would urge programmers not merely to refuse to write obviously exploitative programs, but to re-examine the philosophical assumptions of their whole enterprise. In view of the discussion in Section 2, this surely is not too much to ask. Psychological theories in general are not purely *descriptive*, but are largely *constitutive* of social reality, and computational theories are no exception. If the public believes—rightly or wrongly—that science regards people as 'nothing but clockwork', then clockwork-people we may tend to become. This is why computer scientists should stress the basic philosophical compatibility of 'humanist' and computational views.

In this connection, perhaps programs for public use should include explicit reminders of some of the differences between computers and people. This is done (for utilitarian reasons) in the peptic ulcer program[18] previously described: it continually reminds patients that they are on-line to a machine. The reminder helps to avoid mystification of the patients, stressing that they are merely 'filling in a form' by teletype rather than engaging in flexible communication, still less participating in a human relationship. 'Plausibility-tricks' are sometimes included in language-using programs. For instance, the CAI programs currently used in schools take care to address the children from time to time by their first names, so as to put them at their ease. In view of the dehumanizing potential of computer applications (quite apart from the possible results of an overgenerous misunderstanding by the person), it may be that the limits of individual programs should be made as clear as possible, to users, and plausibility tricks used sparingly—if at all.

On one point, however, even Roszak presumably would agree that the *similarity* between people and programs should be deliberately stressed. One of his objections to the social use of computers in an advisory capacity is that the machine may be seen by the public (including the politicians) as purely *objective*, and therefore not to be argued with. Accordingly, the inescapable subjectivity of a program's judgments should be made clear to its users. We saw that this is done implicitly in the MYCIN medical consultant: MYCIN not only offers alternative judgments when it perceives several possibilities of diagnosis or treatment, but gives its reasons for each so that physicians can rationally reject its advice if they see fit. In general, it would be worthwhile somehow to remind the user that programs function within their own subjective cognitive worlds, just as we do. Any differences between the two are matter for epistemological debate, not for servile capitulation on the part of the person.

4 Conclusions

Increasingly intelligent machines are likely to become socially available, whether for use by the general public or by political and administrative institutions.

Many of the potential ill-effects depend on the common (though mistaken) view that mechanism is incompatible with 'human' qualities. If the public assume that science offers an image of man that is irreconcilable with humanism, they must either deny their humanity—with socially destructive results—or else forfeit a scientific understanding of mankind.

So in addition to writing programs in a sensible fashion (so that the control structure is perspicuous and alteration is facilitated), professionals involved in artificial intelligence should take pains to see that this choice is not regarded by the public as unavoidable. For example, they should avoid 'plausibility tricks' in programs that might lead to unnecessary mystification of the users, and they should point out that a program's data and inference-procedures may always be questioned in principle, just as a person's can be.

Recognition of these issues by the profession considered as a social institution (as opposed to isolated individuals within it) will be necessary if they are to be adequately faced. Insofar as the profession succeeds in reassuring the public that mechanism (of sufficient complexity) is in principle capable of generating the distinctively human characteristics of subjectivity, purpose, and choice, the increasing social use of intelligent machines will present less of a threat to humane conceptions of self and society.

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Medicine is more than just medicines

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Based on a presentation at the Institution's Golden Jubilee Convention held in Cambridge on 28th June to 1st July 1976.

The part which electrotechnology can play in medicine is discussed under the broad headings of diagnosis, prevention and replacement parts. Among the problems to be solved, which are reviewed, are the really effective use of computers in diagnosis and the interfacing of prosthetics with the nervous system and the muscles.

First a diagnosis and then the cure: the traditional course of medical events in the treatment of the demonstrably sick. But there are other matters of concern which are becoming increasingly important; early diagnosis before harm has been done, the prevention of disease rather than its control, and the provision of parts to replace those lost or made defective through accident and age, or by disease yet to be prevented. It is becoming increasingly clear that medical progress has come to rely, and will continue increasingly to rely, on disciplines which are totally alien to a medical education. Indeed it is beyond question that medical education itself must undergo radical changes in order that society may benefit from rapid technological advances in subjects which could well appear to have no association whatever with medical practice. However the process is not a one way system; technologists will be excused neither their brashness nor their ignorance of the constraints and problems presented by either biology or society. Early progress in preventive medicine owed more to civil engineers and chemists than to medicine itself, but medicine had to point out the problem; the solution, as it should be, was left to engineers—those whose duty it is to provide society with the practical things it wants. However, preventing disease is more than the provision of sewers and hygienically packed foods, or the destruction of mosquitoes on stagnant water; it includes the detection of potentially hazardous substances, the isolation of environmental dangers and the elimination of injurious stress—all unavoidably involve increasingly advanced equipment and techniques from which electronic instruments cannot be divorced. But to build an instrument or make a measurement does not solve a problem; those concerned with its solution, each one of them, cannot escape an appreciation of the basis of society's burden, even if it is only the realization that many of the diseases which shorten life, particularly in the so-called advanced civilizations, are introduced by civilization itself and are not the responsibility of natural events.

Much of the improvement in medical care during recent years has been ascribed to advances in detection and diagnosis; these successes must be maintained, but to do so, as in every other branch of science, now demands research and development of a continuously increasing complexity—only rarely today do worthwhile discoveries result from observation and simple apparatus. The detection of disease in an advanced stage presents us with no really serious problems, but the chances of success in its treatment are immeasurably improved if an early diagnosis is made. This of course, in engineering terms, means that in the early stages the symptoms—disease—are less prominent in relation to the patient's normal state—health; a situation commonly referred to in the physical sciences as the signal/noise ratio. Many of the physical problems of poor signal-to-noise ratio have already been solved by a variety of methods contributed by many disciplines; medicine has still to foster the development of its own arsenal of up-to-date techniques for attacking analogous but dissimilar situations. The most difficult of subjects, and the most rewarding if successful, is the detection of incipient disease in an apparently healthy patient—success in this problem would lead to the introduction of mass preventive screening. The symptoms of disease as they now present themselves may not be those which technology can best attack; it may be that complex combinations of other factors should be taken into statistical account, a clear case for computer assistance and mathematical ingenuity.

Replacement parts—prostheses—for the human anatomy, are perhaps one of the more obvious applications of technology to medicine. In some, pins and joints, electricity plays no direct part; others, pacemakers and hearing aids for instance, are almost exclusively electronic. The scope for research and inventiveness is almost limitless in a field which eventually, with age, affects all of us. But looking a very long way into the future, society will need to decide the point at which the replacement of ageing or diseased parts must stop—even longevity must have some limits.

Diagnosis

Early diagnosis is one field in which electrotechnology could make a substantial contribution, but at what cost to national exchequers of those nations that can afford it, and what of those who cannot? Let it be done by computer! say the proponents from that industry, but in spite of the efforts of enthusiastic pioneers, diagnostic algorithms have still to be agreed. The successful introduction of computers here is in part an exercise for educating the producers and users, and in part the development of satisfactory communications between user and machine. Engineers have long been accustomed to interpreting details in the moving pattern of an oscilloscope display, making use of velocity, intensity, position, displacement, addition, subtraction and so on: no such everyday device is at the service of medicine. It is difficult to think of any less efficient communicator than the mass of figures on some computer printouts, or the cluttered surface of a Visual Display Unit. Perhaps an oscilloscope display as we know it is not the

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right way for medicine; that device was after all developed by engineers for engineers, and by them it continues to improve. Biological variables are many, very many, but what use do our displays make of colour, shape (Fig. 1), intensity or velocity—the electronic techniques all exist, but we need someone to say what is wanted, and a Mr. Henry Ford to produce it. We might well profit from an examinaation of some altogether different fields: compared for instance with its predecessors, the instrumentation already developed for the next generation of aircraft conveys much more information in much less space with much greater efficiency: the important is automatically given arresting priority, reminders are issued, and inadvertently improper actions rendered impossible. The problem may well be more difficult in medicine, but that is no reason why we should ignore it.

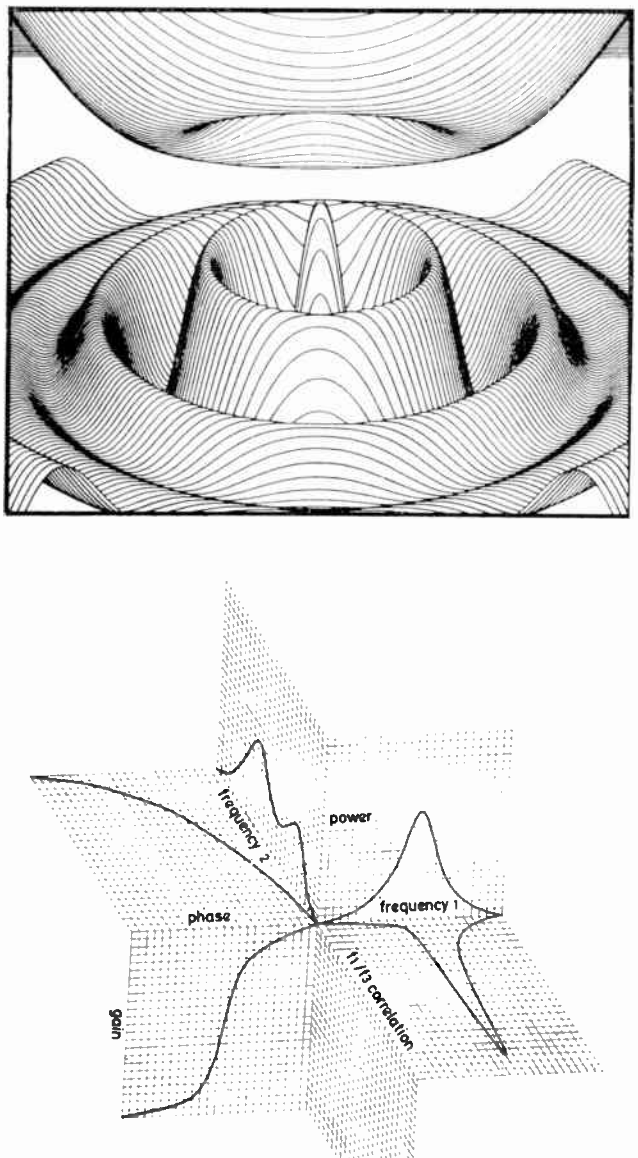

Fig. 1. Medical data are frequently multidimensional. Two possible ways in which such data might be displayed are shown in this Figure. (The curves and labels are for illustration only and do not refer to any particular situation.)

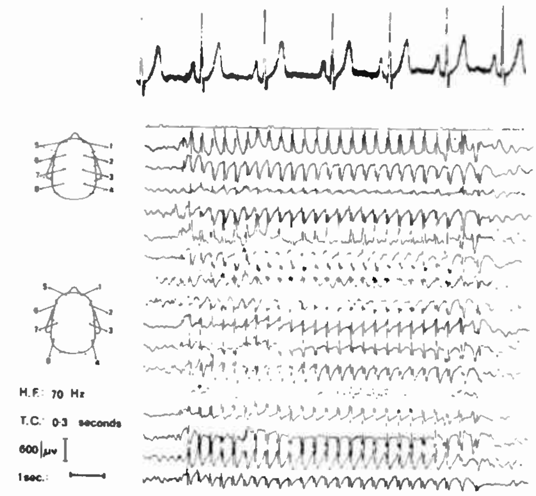

Fig. 2. The upper trace, one from a multichannel recording, is from the electrical activity of the heart (e.c.g.); the mechanics of its production and its automatic interpretation have both been extensively studied. The lower traces are from the electrical activity of the brain (e.e.g.); the mechanism in this case is not well understood and attempts at automatic analysis have not met with universal acceptance.

Current diagnostic procedures unavoidably contain a large measure of opinion, based on previous experience: machines are notoriously bad for dealing with opinions. What is needed is additional objective evidence for the machine to digest; it could then at least do the tedious non-intellectual chores, ensure that significant factors are not overlooked and maybe suggest the next helpful step. Computers are not introduced in order to displace medical staff, but to relieve them of trivia and allow more time for the practice of intelligent medicine; nevertheless we must accept the fact that some well qualified and experienced practitioners spend their time providing a valuable, and lucrative, service which with extra effort could largely be transferred to a machine—it would be unrealistic of us to expect these individuals not to protest. The many computer programs which analyse electrocardiograms are testimony enough to illustrate the difficulties and expense involved in dealing with a relatively simple electrophysiological signal whose origin and underlying anatomy and physiology are well understood (Fig. 2), but the day cannot be far away when an e.c.g. will be analysed automatically with no more difficulty than is at present experienced with automated clinical chemistry.

Now that the actual calculating part of computers, the central processor, is of negligible cost for small intallations, we must see in the not very distant future a considerable increase in their use in diagnostic medicine; once again it must be emphasized that whatever comes out of any kind of computer can be of no better quality than that which goes into it, be it data or programs. We have in the past always been limited by what men can do in a reasonable time; in some ways that limitation has now been removed, and given that we can arrive by leisurely argument at a sequence of logical steps, no matter how involved they may be, the computer will execute them repetitively and without error in negligible time. Help is needed from mathematicians and statisticians for the development of techniques which will increase the useful information that can be extracted from a mass of apparently random or uncorrelated data (Fig. 3), but only engineering technology can translate these abstractions into acceptable user-proof hardware.

There are just a few private organizations that provide for their clients a screening service to detect, at an early stage, signs of incipient ailments which might appear in strength later on. These examinations use conventional clinical equipment and base their recommendations on the usual recordings and an experienced but expensive opinion. It is clearly desirable that services of this kind should be available to whole populations, but it is equally clear that in the absence of some new automation, the mass provision of such a service is economically impossible. It is particularly noteworthy that increasing attention is being paid to non-invasive methods for recording both the electrophysiological and the physical signals upon which early diagnosis might be made. This not only relieves the patient of the pain and inconvenience inseparable from hypodermic needles and the like, but also contributes to the speed with which an examination could be carried out: doctors and ancillary staff may use their time more profitably elsewhere. On frequent medical occasions we record so much data but from it extract so little information: developments in predictive statistics may help to raise the information extraction rate and also suggest where we might usefully limit the acquisition of primary data. The essence of this early diagnosis exercise is to predict a likely individual outcome from a minimum of data collected from a maximum of individuals in the population.

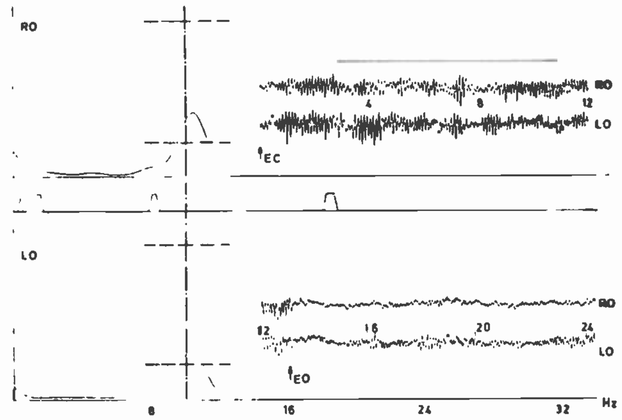

Fig. 3. One possible approach to the analysis of data of a quasi-random nature. This example is from two e.e.g. channels—right and left sides of the scalp. Two power spectral densities are displayed, together with—centre trace—an indication of the frequencies at which statistically significant differences exist between the two p.s.d.s.

Although experimental work is progressing, there is little real automation at present used in clinical medicine, whether by general practitioners or by large hospital departments (with the possible exception of clinical chemistry). We might suggest automation as one way of making more profitable the time of skilled clinical personnel, of reducing the time which patients spend away from their employment, and of ensuring more efficient use of expensive diagnostic machinery, some of which might continue to work for twenty-four hours a day rather than be confined either to occasional use or to the general hours of clinical medicine. Such a process cannot lie wholly within the province of those who may call themselves control and automation engineers, nor of those who are included under the general title of doctors; one understands the problem and the other the tools available—a fruitful outcome is not to be expected until they join in an understanding manner and thereby fertilize concepts which otherwise will remain unfulfilled. With all the automation which might possibly be introduced for improving the quality of medical diagnosis, it should not be forgotten that a part of that diagnosis will always remain a matter of human relations between a sick person and a perceptive, sympathetic doctor.

Prevention

From time to time we are invited, in the interests of preventing disease, to reduce for example our consumption of dairy produce by 20%, or fat meat by 15%, and to substitute 20% more fruit or green vegetables and even 10% more bread. Such advice is no doubt given in good faith and is well-founded, but it has no point if the practical housewife cannot put it into effect, and there are several reasons why she may not be able to do so. If cholesterol for instance is the offending substance, there is no way, short of a well equipped laboratory and its staff, of measuring it; the 20% is a whole population statistic, but the housewife has no interest in populations, only in the individuals of her immediate family—how much of that toxic material is each permitted, and when purchasing the family food, how does she know how much of this poison she has bought. We label food with the price, sale date, and other 'useful' information—why not indicate also the content of its potential poisons, and teach people how to use that information. But that presumably will have to await the new inexpensive 'cholesterolometers' and the like, which no doubt electrotechnology is about to invent.

Left to itself, biological evolution has ensured that our nutritional needs are met from sources conveniently available; a desert Bedouin suffers not at all from the lack of fish, and an Eskimo is in no fear of his life in the absence of dates. But western civilization has learnt how not to feed itself from its own natural resources and western civilization will not for much longer be confined to the west. Although much is known about the desirable calorific requirements and a suitable complement of vitamins, there are many nutritional questions to which we have as yet no answer. Obesity is not necessarily a consequence of over-eating—why? or, what makes us eat?—there is no agreed answer. What has electrotechnology to offer as a means of measuring the nutritional value of potential sources of food, could it help to provide practical advice to those who produce food, food which is not only adequate for survival but which does not abet the development of disease? It is not enough that the solution should satisfy the technological mind, it should not remove one of the basic pleasures of life and thereby predictably introduce psychological difficulties which we may be in no position to treat.

Telemedicine is seen by many as one answer to the provision of an improved medical service, particularly in remote areas. It assumes that a high quality expertise, housed in some central location and supported by advanced apparatus and services, could be developed and linked to remote stations staffed by medical auxiliaries; emergency services would be located at, and controlled by, the central authority. The economics of such schemes depend on a comparison between the cost of doctors and their support and the cost of buying and maintaining an elaborate special-purpose communication network and all that goes with it. In favour of the scheme is that expensive capital facilities might be more fully utilized, distance is of negligible importance, and there would be freer access to the best medical advice: against is the risk that a single technical fault could completely disrupt the service, patient transport would be more expensive and a new brand of medical auxiliary would be required for its operation, and no doubt also for its administration. Keeping in mind the extra staff, the fault liability, and the difficulty of operating in locations where technical competence and a respect for property are not well established, the financial balance sheet is not easy to strike; although whatever faults such a system might have, there are places where any medical aid would be an improvement over the existing reliance on natural survival. A network of this kind could clearly be used as an aid to preventive as well as curative medicine. The spread of disease could be monitored more rapidly, drought famine and pestilence detected before they assume epidemic proportions, and expert advice would be available on questions relating to methods for the detection and prevention of disease: in less developed areas disease remains undetected until it is far too late, and all too often few attempts are made to prevent the occurrence or spread of illness. But this Utopia could not even be approached unless we first produce a greatly improved communication system suited to local requirements, and with it an administrative bureaucracy capable of immediate decisions and a positive desire to help the sick rather than to preserve the sanctity of its rule book.

Replacement Parts

Providing replacement parts for the human anatomy must surely present one of the most exciting opportunities for biomedical engineers. A start has already been made, but the problems are by no means all of an engineering nature; once more, ambitions will not be satisfied unless several disciplines co-operate to arrive at a common understanding of what is wanted. False teeth and glasses are commonplace and socially acceptable, whether the need is occasioned by accident, disease or age; hearing aids are somewhat less acceptable, and artificial limbs acceptable only if they mimic the real ones in form and colour. All these aids contribute to the well-being of their users but they are viewed too often as embarrassing external signs of some personal deficiency. The coming generations of prostheses will defeat society's prejudices only if they are both unobtrusive and effective.

Limb prostheses pose some difficult engineering questions, in particular the provision of adequate power supplies: electric, pneumatic and human energies have all been tried but with no more than limited success. Nickel–cadmium batteries (re-charged during the night) have operating lifetimes of about a year and may be concealed within the limb itself, but there is evidence (Johns Hopkins University Hospital, Baltimore, USA) that amputees will readily accept a power source external to the limb, attached for instance to a belt. This solves several engineering problems immediately—the weight of the limb is reduced and therefore energy is not wasted in the useless movement of the energy source; more space is made available for the mechanics of complex functions, such as are met in elbow disarticulations; and in general an external power supply would provide more energy than is available from a source integral with the limb. The body itself consists of a series of electrolytes and semi-permeable membranes, which have from time to time been used to provide, even after death, continuous supplies of electricity, but only in very small amounts. Nevertheless, a few modest advances beyond current c.m.o.s. technology could permit quite complex control functions, but not actual movements, to be powered entirely from biological batteries. Small nuclear sources are now in use; when large amounts of energy are demanded they of course present quite different problems, since the user must be protected from the undesirable effects of radiation. The ultimate limb prosthesis would be one whose functions were controlled by nerves remaining in the stump; those functions would be accompanied by the production, from the prosthesis, of signals which could be returned to the brain and so complete the original biological feedback loop to the intact limb. Unfortunately, nerves are not organized into carefully arranged cables, and a successful bidirectional interface between largely electrochemical neural signals and wholly electronic wiring of the prosthesis control system has yet to be discovered: nevertheless, some myoelectrically controlled limb prostheses have been constructed.

Whilst much is understood about action and purpose of single nerve fibres, a bundle of fibres, viewed as a signal conducting pathway, appears to contain both a substantial random element and substantial redundancy. Perhaps when a really satisfactory neuro-electronic interface has been developed, a microprocessor, which by that time will be more micro than it now is, could decode the neural demands and then in the reverse direction re-encode signals which the brain could accept as replacements for the original proprioceptive information; electronics may provide the eventual machinery, but much electrophysiology will be necessary before success is ours. Not only will it be necessary to break both input and output neural codes with mathematical precision, but a physical interface will need to take into account the dimensions and form of neural 'wiring', each conductor of which is only some 10 μm in diameter—nearly one-hundredth of the smallest electrical wire now available. A measure of what still has to be done is perhaps that the archaic split hook artificial hand and the peg leg are almost as functionally effective as the latest neuro-electronic prosthesis, but their social acceptability is minimal.

Internal replacements—cardiac pacemakers, joints, bones and the like—are concealed and therefore merit complete social acceptance. These internal prostheses fall into two main categories—replacements for major organs, heart, kidneys, liver and so on; and artificial sensory communication prostheses—the eyes, ears and vocal cords. In a sense, the principles of the major organ group are already well established: heart–lung machines are common in open heart surgery, and renal dialysis devices are freely available for patient use; both are extra-corporeal and embarrassingly large, and very substantial physical and engineering problems have to be solved before these established principles can be converted into surgically implantable permanent replacements. Even when the hardware has been successfully completed there are the problems of rejection, absorption and erosion by powerfully invasive body fluids; problems which have already been met in cardiac pacemakers, pins and joints. To these must be added the purely engineering problems such as lead flexibility (30 million flexions per year in a pacemaker), and no internal organ is naturally fixed in relation to the skeleton, which itself is a mobile structure. There are, too, the competing techniques of transplant surgery, which for the moment show greater promise—but the more successful we are with physical replacements and the prevention of accident, disease and pestilence, the fewer organ donors will be available.

Experiments are already under way to probe the possibilities for an 'intelligent' interface between bodily demands and artificial organs. Physiology has well-established procedures for regulating the functions of body organs to meet the demands of the environment, and the activities or the psychology of the user. Engineers' replacement parts should ideally act in a similar way and take account of continually changing needs, rather than be controlled by some electrical element entirely dependent on 'unintelligent' physical properties of a man-made controller.

Experiments have already started, with some promise of success, in an attempt to formulate ways in which prostheses for the special senses may be produced. We may take as an example a sensory aid for the blind, in which the visual cortex

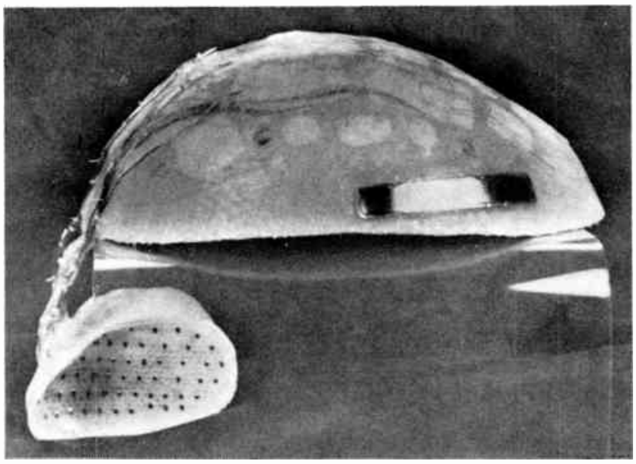

Fig. 4. An intra-cranial electrode system, shown on the left of the photograph, and its extra-cranial attachment: an experimental sensory aid for the blind.[15]

of the brain is stimulated by a series of computer derived pulses that produce a pattern of phosphenes 'visible' to the subject. By means of an intracranial implant, a matrix of 80 stimulating electrodes attached to a silicone rubber shell is implanted over the cortex on each side of the brain (Fig. 4). An extracranial part of the system, containing micro-electronics to organize and drive these electrodes, is inserted between the scalp and the skull: there is a radio frequency link between the electronics and a computer responsible for producing patterns of excitatory pulses among the 160 possible electrodes. With this equipment simple patterns of phosphenes, perceived by the subject as point and diffuse sources in three dimensional space, can be used to convey elementary messages. Ignorance of the anatomy and physiology of the visual cortex of the brain forbids a prediction of the phosphene pattern which would be seen as a consequence of the activation of a particular set of electrodes; it is therefore necessary to plot by painstaking experiment the results of trial stimulations and afterwards enter this information into the controlling computer program. Practical results have indicated that Braille-like messages can be transmitted with encouraging success. This work is only in its exploratory stages but the conceptual complexity of both the problem and its potential solution, the intricate engineering and its interface, the improved understanding of detailed physiology, and the surgical techniques yet to be perfected before the aid could be successfully implanted, must surely amount to one of the most challenging acts of co-operative research. Similar work is going on with the aim of providing artificial ears and vocal cords, and some elementary brain implants are already in experimental clinical use. These are examples of those rare studies, the successful outcome of which will benefit all mankind—only the most exceptional will depart this life without the need at some time for assistance to combat a diminishing effectiveness of sight or hearing.

In Conclusion

That electrotechnology has a major part to play in any successful health service is beyond doubt; but how best to apply it? There are increasing signs that society is beginning to question the conduct of medical research and practice, to question the relative priorities which medicine itself ascribes to its own activities, and whether its very large sums of money are well directed. Even in some of the most advanced countries, it is claimed, infant mortality rises, life expectancy decreases and the rejection on medical grounds of a third of those applying to join the armed services, suggest that the quality of life has failed to keep pace with the self-imposed stresses of a modern society. It is now abundantly clear that neither medicine alone, nor by itself any other discipline, can solve our most pressing medical dilemmas: it is equally evident that technology cannot avoid its share of responsibility simply by claiming that awkward decisions must be made by someone else, and that understanding the whole problem is not its business. Collaboration is of course in everyone's interest, but in a practical manner; the promotion of good health will in no way be assisted by empty extravagant language more suited to political promises than scientific progress.

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Technical Notes

Progress in Applying Optical Fibre Communication Techniques

Telecommunications

Until recently, most trials of optical fibre communication have been laboratory experiments. But by the end of last year, work on optical fibre systems at the Post Office's Research Centre at Martlesham Heath was sufficiently well advanced for the Post Office to be confident that a demonstration trial could be satisfactorily connected to the public telephone system. The new link runs for 13 km (8 miles) between the Research Centre and Ipswich telephone exchange.

The new system operates over one pair of fibres in optical fibre cable installed in telephone ducts already housing conventional cables. Although capable of carrying up to 120 phone calls simultaneously, the new link at present connects four telephones at the Research Centre to the Ipswich exchange, and calls can be directly dialled into the national telephone network. The link has only one intermediate repeater—in Kesgrave telephone exchange.

Eventually the optical fibre system will be used to link an experimental electronic telephone exchange at Martlesham to Britain's trunk telephone network. It will also be used for detailed studies which will help the Post Office determine the most economic ways of using optical fibres in Britain's future telephone network, and the Research Department will be using it for experiments to check optical system reliability and to see whether much higher performances can be achieved.

Throughout the development of optical fibre systems over the past ten years, the Post Office has maintained close relations with British industry. Facilities have been provided for trying out private developments on Post Office premises—for example, Standard Telephones and Cables' experimental high-capacity optical fibre system between Hitchin and Stevenage—and research and development contracts have been placed for the development of lasers and optical fibres. The objective in this collaboration, as in the Post Office's own research effort, is the development of reliable, high-quality systems, fully engineered for commercial production, and providing the Post Office with the maximum economic benefit optical fibres are capable of offering.

Cable Television

A field trial was set up in Hastings in March 1976 by Rediffusion as part of a programme designed to determine the applicability of fibre optics to the distribution of television programmes and to obtain familiarity with the many new techniques which it employs. The system was believed to be the first optical fibre link to be installed in a working system to be used by the paying public, anywhere in the world.

Although the transmission of vision signals has been demonstrated in several laboratories, these have generally operated at base band. The signal transmitted, in Hastings however, is on an amplitude modulated h.f. carrier of 8·9 MHz with lower side band. This is exactly the same signal as is distributed on the local cable network.

A two-core fibre optic cable has been drawn into the ducts on a 1,427 metre section of the vision trunk route from the Blackman Avenue kiosk into the Rediffusion Offices on the Ponswood Estate. This cable carries the BBC 1 and Southern ITV programmes, which are currently distributed to more than 30,000 homes in the towns of Hastings, St. Leonards and Bexhill. The installation has been made in such a way that the signals from the optical fibres can replace those brought in on conventional coaxial cables, the conventional system being retained but no longer connected for the period of the trial.

The fibre optic link starts in the kiosk, where two optical transmitters feed the fibres of a two-core fibre optic cable. This cable was supplied by BICC in two sections, joined at a kiosk 791 metres from the Blackman kiosk. The optical signals are converted back into electrical form in the Ponswood kiosk, and the low level signals fed into convenient points on h.f. cable-television repeaters for the subsequent networks.

The optical transmitter is an input voltage to output optical power device, the conversion from electron current to photon current taking place in a gallium arsenide light emitting diode (Plessey HR954). At the receiving end, the photon current is converted back to electron current, to recover the original drive which is, of course, the full vision signal on an 8·9 MHz carrier. (The sound component is carried separately in accordance with Rediffusion practice in the UK.)

The specified radiance of the l.e.d. is 35 watts of infra-red output (at 900 nanometres wavelength) per steradian per square centimetre at 300 mA, but typical devices achieve 50 $Wsr^{-1}cm^{-2}$ over a 50 μm diameter circle. The light gathered by the fibre, which has a core diameter 85 μm and numerical aperture 0·16 is about an eighth of a milliwatt. The fibre is coupled to the Burrus-type light emitting diode by index matching fluid.

The cable uses Corning silica step index fibres. It has a flat polyethylene sheath 7 mm × 4 mm with two 1 mm steel strength members. Two fibres are carried loosely in a rectangular cavity on the neutral axis. The attenuations over the section have been matched at 19 dB approximately.

A cable joint incorporates a copper block in which a fine groove has been impressed by a length of optical fibre, and in which the ends of the fibres to be joined are carefully butted together and clamped. To avoid loss due to imperfections and surface reflections, a small amount of index matching liquid is applied at the joint before clamping. All fibre ends used in these couplings are cleaved squarely using a bend, pull and score technique.

The optical receiver uses index matching fluid to couple the fibre end to the photodiode in a similar way to the transmitter. The detector uses a low-capacitance p-i-n photodiode feeding a low-noise preamplifier to regenerate the vision signal.

Radar Video

Details have been announced of another kind of application of these techniques. A prototype optical communications cable, manufactured by Pilkington PE Limited of St. Asaph and installed in HMS *Tiger* a year ago, has now completed more than 3,500 operational hours with no degradation in performance. The information carried by the link includes radar video and sync, aerial bearing and ship's head marker.

Consisting of three optical fibre bundles fabricated into a reinforced cable structure of overall diameter 8 mm and 110 m long, the cable replaces two coaxial cables and one five-core cable. Fibres used have a numerical aperture of 0·48 and a loss of <100 dB/km. The bandwidth is 13 MHz with video transmitted at baseband up to 5 MHz, the bearing and marker information being transmitted digitally. A combination of frequency division and time division multiplexing is used.

The cable was manufactured for the Admiralty Surface Weapons establishment, Portsdown, who designed and developed the total system, and it was installed using normal dockyard techniques in cable trays using the latest plastics clipping techniques. After installation, trials were carried out to simulate optical connector repairs. A prototype connector kit developed by ASWE was used and the cable was successfully re-terminated on board. The complete elimination of ground loop problems has made multiplexing a relatively straightforward procedure.

Data Transmission

What was claimed to be the world's first fibre optic communications link for a non-military application was installed over a year ago by the ITT Components Group Optic Equipment Division, at the Bournemouth Headquarters of the Dorset Police. The link connects the central computer with video display units which are situated some distance away.

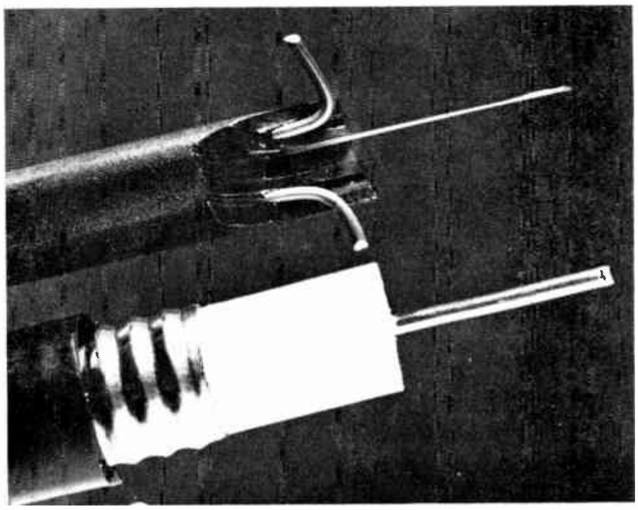
Although the system provides for the transmission of analogue or digital information over a single, one-way channel, it is currently being used in an analogue mode for the transmission of a video signal containing character information for display on the v.d.u. equipment.

The equipment comprises two terminals—transmitter and receiver—together with a 25 m length of 3-core fibre-optic cable. Light pulses are transmitted through the cable by means of pulse position modulation over a 50 Hz to 5·5 MHz bandwidth which enables 10 megabits of information per second to be carried by the system. The light source is a gallium arsenide laser diode.

Fibre optic links have a number of advantages over normal electrical communication systems. For example, because they have total electrical isolation between input and output, they eliminate earth loop problems, electrical fault propagation, and sparking in hazardous environments. Photon transmission, by its very nature, provides a very high information bandwidth and very 'secure' information in that it is almost impossible to 'tap' a fibre optic cable. Other features include the elimination of cross-talk and electromagnetic or radio interference, and the fact that the link cannot be damaged by electromagnetic pulses.

Configuration of Optical Fibre Cable

The optical fibre used by BICC for many current systems is made by the doped deposited silica process patented by Corning Glass Works of the USA, and is shown in the photograph. The fibres are contained within two cavities arranged



The two hair-like fibres in the top cable each carry the same amount of programme information as the standard copper cable below.

in the cable to lie on the neutral axis between two flanking steel wires. These wires provide the longitudinal strength to permit the cable to be installed by conventional techniques in standard cable ducts. The sheath of the cable is black polyethylene. The small size of the cable makes very efficient use of duct space. In a particular trial link in the City of London (used in the Confravision network) a 1·8 km length of fibre has an attenuation (including losses at joints) of only 8 dB.

Television Noise Reduction System

The BBC has developed, and is currently testing, a digital signal-processing system designed to reduce the amount of noise transmitted with television pictures. Random video noise is usually seen on viewers' screens as a moving 'grainy' background and most of it is usually generated within the receiver, but some noise is inevitably transmitted with the picture, varying in level from source to source. The new equipment is designed to alleviate the effects of this *transmitted* video noise.

The BBC noise reduction equipment is the first to be successfully used with the PAL colour television system, and some formidable problems had to be overcome in achieving a satisfactory design. During recent trials, which have proved very successful, the equipment has been used on a wide variety of programme material transmitted on both BBC-1 and BBC-2. Over a period of ten days about fourteen hours of live and recorded programmes were processed; these included a Silver Jubilee concert transmitted from the Royal Albert Hall where the difficult lighting conditions led to rather noisy pictures which were greatly improved by noise reduction processing.

No serious problems have been encountered in the use of the prototype equipment and work has now started aimed at an automatic noise reduction system for full operational use.

Background to the development

The subject of video (picture) noise reduction has recently excited considerable interest, particularly in the USA, for its potential application to pictures originating from video equipment used for electronic journalism. In this operation television cameras and portable video tape recorders are used instead of film, sometimes under very poor lighting conditions, with the possible result of poor quality pictures with an objectionable amount of added noise.

Electronic journalism is therefore an obvious candidate for noise reduction techniques, but the BBC's system is not restricted to this type of application. It can be used not only on pictures of poor overall quality, but also on pictures which are of excellent quality in all respects except for the presence of visible added noise. Such noise may arise from many causes in normal studio operations: for example, multi-generation video tape, long transmission links, standards conversion, pre-amplifier noise from cameras, and grain structure on cine film.

Due to these noisy sources a compromise must often be struck between resolution and the visibility of noise and grain. An effective system of noise reduction of the composite colour signal can, by removing the need for this compromise, provide a very significant improvement to the final quality of transmitted pictures, whether derived from studio, outside broadcast, or film.

Principle of operation

The new system, developed by the BBC Research Department at Kingswood Warren, uses a television picture store in a recirculating mode, so that many successive television pictures are added together. The effect of this operation is to reduce noise by integration. The wanted picture detail, being present on every picture, is reinforced relative to the noise, which is random. Unfortunately, this technique cannot be applied to areas of the picture containing rapid movement, because integration of successive pictures would result in smeared images of moving objects. An additional problem is that the colour subcarrier would be reduced along with the noise because it is transmitted in a sequence of eight television fields.

Both of these problems have been successfully overcome and are the subject of patent applications. The prototype equipment at present requires manual adjustment to suit the noise level of the pictures to be processed, but work is in hand on a modification which will allow this adjustment to be made automatically. The system can easily be adapted to work with the 525-line NTSC colour television system, and it is likely that a version of the equipment will be designed that can be used with both PAL and NTSC.

Electronic Traffic Aids on Major Roads

The European Economic Community has initiated an important research project, concerned with devising a standardized system of electronic traffic aids on major roads. The project, known as COST 30, is being undertaken under the auspices of the Committee on European Co-operation in the field of Scientific and Technical Research (COST), and the new agreement has been signed by the 19 countries participating in COST plus the Community itself.

The agreement provides for close co-operation between signatories in carrying out research and development in their own laboratories and, it is hoped, could result in the setting up of a European system which, suitably standardized, would guarantee that a driver enjoys the same services, whatever his route, in those countries which have adopted the system.

The need for greater standardization becomes clearer when the explosion of cross-frontier traffic since 1950 is taken into account. In the Community countries, traffic on inter-city roads was six times heavier in 1970 compared with 1950, while in a decade 7·5 times as many vehicles have crossed frontiers. Inevitably this has meant a large number of accidents, repeated traffic jams, environmental degeneration and increasing complexity in driving. The object of COST 30 is to develop techniques for the common control and real-time management of traffic on major roads throughout the participating countries in the hope that this will result in smoother, more accident-free driving.

Nine working parties, under the direction of a Management Committee, will co-ordinate activities in the following specific fields:

A study of road information requirements, based on surveys, statistical analyses, situation analysis or any other suitable methods.

A study of the need to detect traffic incidents and abnormal occurrences and the development and operation of manual or automatic detection systems.

The development to prototype stage of a system for predicting and detecting weather conditions which have an unfavourable effect on visibility and road-holding; a study of the influence of short-term weather-forecasting on road management.

The study of techniques of aural communication with drivers. Two different aspects will be examined in this area:

(a) 'topical' communication, used to relay solely to drivers concerned information on local occurrences, such as slowing down of traffic or a temporary obstacle;

(b) regional information, designed to reach a wider public both at home and in-vehicle.

Appraisal of the usefulness of the techniques of in-vehicle visual communication. Visual display could prove extremely useful for route guidance purposes: when approaching crossroads, drivers could be told which direction to take in order to reach a specific destination under optimum conditions.

Development of variable roadside signalling techniques. These techniques are already being tested in a number of countries. Pooling of technical know-how on the subject should enable joint basic requirements to be formulated or certain types of equipment to be recommended.

Determination of the structure and semantic content of messages in the various languages used. It should be ensured that, whatever the country in which they are travelling, road users correctly interpret messages addressed to them and that the terminology used corresponds to one to which they are accustomed.

Analysis of road traffic management problems and determination of what may be necessary to implement a coherent system based on the techniques developed above. This Working Party will also examine the question of the cost of new equipment and compare it with the overall benefits expected from introducing it.

The Agreement will cover a period of three years, and after two years the Management Committee will consider whether to embark on trials or a public experiment.

Aluminium Foil Provides Radar Protection

When the Scottish Air Traffic Control Centre (ScATCC) at Prestwick, Ayrshire, required to protect its electronic workshops and equipment room from a nearby radar, the National Air Traffic Service of the Civil Aviation Authority called in the Radio Frequency Interference/Electro-Magnetic Compatibility Division of Belling-Lee which solved the problem with aluminium foil and steel mesh.

ScATCC's workshop and equipment room stands just 750 m from one of the airfield radar scanners and measurements inside the room showed that interference levels were at times as high as 50 V/m. ScATCC's requirement was not to produce a high-performance shielded enclosure but simply to reduce the radar interference to an acceptable level and at minimum cost.

By lining one wall and a small area of the floor and ceiling adjacent to the wall with aluminium foil 0·13 mm thick, Belling-Lee effectively built a large reflecting surface which provided protection to the immediate area of the building.

INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS

Notice of Annual General Meeting

NOTICE IS HEREBY GIVEN that the SIXTEENTH ANNUAL GENERAL MEETING of the Institution since Incorporation by Royal Charter will be held on THURSDAY, 13th OCTOBER, 1977, at 6.00 p.m. in the Large Theatre at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London W.C.1.

AGENDA

1. To receive the Minutes of the Fifteenth Annual General Meeting of the Institution since Incorporation by Royal Charter held on 6th October 1976. (Reported on pages 561–565 of the November 1976 issue of *The Radio and Electronic Engineer*.)
2. To receive the Annual Report of the Council for the year ended 31st March 1977. (Published in the August/September 1977 issue of *The Radio and Electronic Engineer*.)
3. To receive the Auditor's Report, Accounts and Balance Sheet for the year ended 31st March 1977. (Published in the August/September 1977 issue of *The Radio and Electronic Engineer*.)
4. To confirm election of the Council for 1977–78.
   In accordance with Bye-Law 49 the Council's nominations were sent to Corporate members by a Notice dated 9th June 1977 in the June 1977 issue of *The Radio and Electronic Engineer*. As no other nominations have been received under Bye-Law 50 for the following offices, a ballot will not be necessary and the following members will be elected:

The President

Professor W. A. Gambling, D.SC., PH.D.

The Vice-President

Under Bye-Law 46, all Vice-Presidents retire each year but may be re-elected provided they do not thereby serve for more than three years in succession.

For Re-election: Professor D. E. N. Davies, D.SC., PH.D.; Professor W. Gosling, A.R.C.S., B.SC.; D. W. Heightman; R. C. Hills, B.SC.; Professor J. R. James, B.SC., PH.D.; J. Powell, B.SC., M.SC.

The Honorary Treasurer

For Re-election: S. R. Wilkins

Ordinary Members of Council

Under Bye-Law 48, ordinary Members of Council are elected for three years and may not hold that office for more than three years in succession.

Members

For Election: A. F. Dyson, DIP. EL.

The remaining members of Council will continue to serve in accordance with periods of office laid down in Bye-Law 48.

5. To appoint Auditors and to determine their remuneration. (Council recommends the re-appointment of Gladstone, Jenkins & Co., 50 Bloomsbury Street, London W.C.1.)
6. To appoint Solicitors. (Council recommends the re-appointment of Braund and Hill, 6 Gray's Inn Square, London W.C.1.)
7. Awards to Premium Winners.
8. Any other business. (*Notice of any other business must have reached the Secretary not less than forty-two days prior to the meeting.*)

By Order of the Council,

23rd August 1977 S. M. DAVIDSON, *Secretary.*

The 51st Annual Report of the Council of the Institution

For the year ending 31st March, 1977

The Council is pleased to present the 51st Annual Report of the Institution—the 16th since Incorporation by Royal Charter. The Annual General Meeting will be held on Thursday, 13th October 1977, at the London School of Hygiene and Tropical Medicine, commencing at 6 p.m.

INTRODUCTION

THE annual review of the work and achievements of the Institution over the past year is presented in detail in the separate sections on committee activity which make up the main body of this report in the customary IERE manner. From the wealth of material covered in these committee reports several items of special significance to the Institution warrant emphasis here.

First, the pause in growth in membership: a problem that was forecast in the last Annual Report. It is now apparent that there are many pervasive reasons for this, including increasing pressure of inflation on personal budgets in general and on salary differentials in particular, the current high level of unemployment and the general atmosphere of uncertainty that such difficulties generate. But it is now clear that a major factor bearing on the problem is the increasing difficulty encountered by many candidates and non-corporate members in their struggle to achieve the narrow and inflexible academic standards demanded of them under current CEI regulations for achievement of corporate membership. This problem—which is not exclusive to IERE—is addressed at some length in the report of the Education and Training Committee. It is a matter of great concern to Council: quite apart from its impact on the health of the Institution, it is a pointer to the wider national problem of inadequate generation of the quantity and quality of technologically qualified manpower which the nation must have if it is to compete successfully in the world market place. This is clearly a problem which the Institution must strive to resolve in the year ahead.

Next, the achievement of accord within the profession on the revised Charter and Bye-laws for CEI. This major advance after so much long and difficult negotiation has the full support of Council; and it is most fervently to be hoped that the way is now clear for CEI to take more positive and authoritative action to advance the cause, the image and the utilization of the engineering profession in the national interest.

Third, the continuing worry of inflation and its debilitating effect on the economic health of the Institution. This year's accounts show a much healthier position than heretofore, due mainly to the receipt of the increased subscription income approved by Council on 8th October 1975. But costs continue to rise and there is still a long way to go to clear the accumulated deficit shown on the Balance Sheet. Expenditure will have to be cut still further and income from other sources increased if services are to be maintained at their present level. In this context the set-back to Council's long-term housing plan mentioned in the Executive Committee section of this report was a major reverse making early resolution of the Institution's immediate housing problem a high priority matter for the year ahead.

Finally, the retirement of Mr G. D. Clifford after 40 year's dedicated service to the Institution as Secretary is deserving of very special emphasis. His truly outstanding contribution to the life and work of the Institution was the subject of a special editorial in the March 1977 Journal; and Council welcomes the opportunity afforded by this Annual Report on his final year of service to formally record its gratitude for all that Graham Clifford has done to further the advancement of radio and electronic engineering whilst bringing the Institution from infancy to its present maturity and high professional standing.

EXECUTIVE COMMITTEE

Whilst the general pattern of Institution activity has now reverted to that of our recent pre-Golden Jubilee years, the Executive Committee has had to devote much time to the special problems posed by the changing role and structure of the Council of Engineering Institutions and the unremitting pressures of inflation on all economic aspects of the work of the Institution. Prominent in this latter context has been planning for the future housing of the Institution: this is one of the key factors in the search for economies that might be effected to combat the ever rising cost of all requirements and services, without increasing the rates of membership subscriptions.

How to ensure that properly qualified radio and electronic engineers were aware of, and appreciated, the need to belong to their own professional body was a constant theme of the Committee's discussions, as was the necessity for the Institution to continue to consolidate and improve its services.

The work of the Executive Committee, in addition to those matters commented upon here, has been concerned with the activities of all the Standing Committees, Organizing Committees and Working Parties, which play such a vital part in the life of the Institution.

Council of Engineering Institutions. The draft of a Supplemental Charter and new Bye-laws for CEI was circulated to constituent Institutions in February 1976 and copies were distributed to its members by the IERE in March 1976. After further consideration in the light of the many comments forthcoming, amendments were made and in due course a petition was submitted to the Privy Council.* This followed long and sometimes contentious discussion of important issues, such as the status of the individual member and his registration with CEI, the composition of the governing body, the method of election, and the procedure for setting up committees. Progress of discussions was closely monitored by the Executive Committee whose guiding principles throughout have been that CEI should remain a federal structure, and that individual institutions should retain control of their own learned society activities, their own registration of members and their own finances. The eventual CEI submission to the Privy Council was in accord with these principles.

Institution Housing. The setting-up of a House Committee, reported last year, indicated Council's concern that the Institution did not have a permanent home, even though it had occupied premises in Bedford Square for over thirty years. In any event, steep increases in rent and rates for these premises made it imperative to seek alternative accommodation.

The House Committee was instructed to look into the possibility of obtaining the freehold of a suitable property in a reasonably accessible country location, maintaining only a small office in London. In due course, the Committee recommended the purchase of a property south of London which would have met the Institution's need. However, with the rapid advance of interest rates, the very high cost of financing such a project caused Council to reconsider the problem in late 1976 when it was reluctantly decided that it would be impractical to proceed until a much larger capital sum was available specifically for the purpose.

To this end the first steps to set up a new Housing Fund were taken and there was a most encouraging initial response from industry and from senior members.

It is intended to invite the membership as a whole to subscribe to the new Fund when it is more firmly established.

Meanwhile measures have been taken to reduce expenditure at 8 and 9 Bedford Square by vacating surplus accommodation in favour of the lessors.

Future Administration. The Executive Committee meeting on 3rd March 1977 and the Council meeting on 31st March 1977 were the last to be attended by Mr. G. D. Clifford as Secretary of the Institution. As announced in the Annual Report for the year ended 31st March 1976†, Air Vice-Marshal S. M. Davidson was appointed Secretary from 1st April 1977, while Mr. Clifford will remain until February 1978 as a Director for special projects. Deep appreciation was expressed in the Executive Committee and in Council for Mr. Clifford's services to the Institution over the past forty years—a record of service probably unequalled in any other professional body.

Queen Elizabeth II Silver Jubilee Prize. Appropriate ways in which the Institution might commemorate the Silver Jubilee of its Patron, Her Majesty Queen Elizabeth II, were considered and it was eventually agreed that an award should be instituted for outstanding innovation or development in radio and electronics which has provided economic or social benefit. It is intended that the prize should be in the form of a silver plaque or other object of appropriate design bearing an engraved citation. The prize was announced in March 1977 when members were invited to submit nominations‡.

Acknowledgments. Many members willingly and voluntarily help the Institution by serving on its committees at headquarters and in the Sections and Divisions at home and overseas. Others represent the Institution at BSI and in other similar organizations. On behalf of Council, the Executive Committee wishes to express the Institution's gratitude to all these members, whose dedicated service and professional expertise is crucial to the continued success of the Institution.

Despite the high national level of unemployment the recruitment of staff suited to the work of the Institution in the London area remains a problem. Shortage—and too frequent change—of assistants has placed a severe burden on senior staff throughout the year. The Executive Committee accordingly acknowledges, on behalf of Council, the valuable work of all members of the staff whose loyal service and willing co-operation in these difficult circumstances has contributed so much to the fulfilment of the Institution's task during the period of this report.

OVERSEAS RELATIONS

The overseas work of the Institution within our own local Divisions and Sections, and in concert with CEI and the international organizations with which IERE has long-established links§, has continued without major change throughout the period of this report.

Early in the year, however, the Executive Committee, noting

* *The Radio and Electronic Engineer*, **46**, No. 8/9, p. 456, August/September 1976; No. 11, p. 565, November 1976; **47**, No. 12, p. 75, January/February 1977.

† *The Radio and Electronic Engineer*, **46**, No. 8/9, p. 432, August/September 1976.

‡ *The Radio and Electronic Engineer*, **47**, No. 3, p. 133, March 1977; No. 4, p. 184, April 1977.

§ Commonwealth Engineering Conference (CEC), World Federation of Engineering Organizations (WFEO), International Federation of Automatic Control (IFAC), etc.

recent significant changes in the pattern of the Institution's overseas membership, considered that a review of our overseas organization and activities should be put in hand, and Council subsequently approved the Committee's recommendation that the Overseas Relations Committee be re-convened for this purpose. One very important factor to be considered as part of this review is the Institution's relationship with kindred bodies overseas. Council at present takes the view that whilst overseas applicants should still be encouraged to seek membership of IERE, it is clearly undesirable that the Institution should actively compete locally with national learned and qualifying bodies appropriate to our discipline where these are now well-established overseas. And it was interested to note that whilst IERE membership was not improving materially in some of the larger well-developed countries overseas, it was growing fast in some other overseas areas which are not yet so well served locally in learned society terms. The establishment of a new Section in Hong Kong during the period of this report, news of which was published in the April 1977 issue of the Journal, demonstrates the Institution's continuing resolve to respond locally to the developing needs of overseas members as widely and constructively as possible as and when the need arises.

In the context of the Institution's representative work overseas the 1976 EUREL meeting is worthy of special mention. This General Assembly of the Convention of National Societies of Electrical Engineers of Western Europe took place in Munich and the Institution was represented by Professor William Gosling (Vice-President). The General Assembly concerned itself, *inter alia*, with the problems of extending international co-operation, and with the EUROCON conference scheduled for May 1977. At Professor Gosling's suggestion it was agreed to look into the problems of radio-frequency congestion in Western Europe. A report of the General Assembly was published in the January/February 1977 issue of the Journal.

PROFESSIONAL ACTIVITIES COMMITTEE

The Professional Activities Committee is charged with the responsibility of co-ordinating the Institution's meetings activities and ensuring that the annual programme is kept reasonably balanced. Overall the Committee can take a broader view of the electronics scene than can the individual. Group Committees are responsible for the organization of major specialized colloquia and meetings: any omission of important current topics can thus be noted and rectified.

All six of the Institution's long-established specialized groups have been active during the period of this report; and the two new groups which were formed some two years ago, namely the Measurements and Instruments Group and the Electronics Production Technology Group have now firmly established themselves and have held successful meetings this year.

Local Section Activity in Great Britain. The sixteen local sections which operate in Great Britain outside London have again been very active and have organized between them a total of 123 meetings. Over 30 of these were held jointly with other Institutions or with branches of CEI.

Noteworthy was the Scottish Section's half-day Symposium on 'Teletext' held in February 1977 at Napier College, Edinburgh. This event attracted an audience of some 200. The choice of a topical subject coupled with first-class lecturers and an easily accessible venue contributed to the success of this meeting.

London Meetings. In London there has been a continuation of the trend, which has been noted in previous years, for low attendances at evening meetings, the average for the year being thirty. The emphasis in programme planning has therefore moved to whole-day or half-day colloquia.

During the year from April 1976 to March 1977 fourteen colloquia and eleven evening lecture meetings were held in London. At six of these events attendances exceeded one hundred, a response amply justifying the efforts of the Specialized Group Committee concerned.

Most of the colloquia are now held at the Royal Institution in Albemarle Street, London W1, where the well-equipped and conveniently situated lecture theatres provide a highly cost-effective substitute for the lecture room at 9 Bedford Square, now given up as an economy measure.

A novel venture this year was the staging of the first Easter Vacation School. This was held on the campus of Reading University, the subject chosen being 'The Practical Use of Control Theory'.

Conferences Organized by the Institution. During the year the Institution organized three major conferences:

'Applications of Electronics in Medicine' was held in April 1976 at the University of Southampton. 42 papers were read and 296 delegates attended.

'Video and Data Recording' was held in July 1976 at the University of Birmingham. 34 papers were read and 237 delegates attended.

'Computer Systems and Technology' was held in March 1977 at the University of Sussex. 30 papers were read and 346 delegates attended.

The full texts of the papers presented at these three conferences are published in IERE Conference Proceedings Nos. 34, 35 and 36. These are currently on sale from the Institution's Publications Department.

Golden Jubilee Convention. The learned society activities associated with the 50th Anniversary of the Institution's foundation concluded with the Golden Jubilee Convention, 'Electronics in Society', which was held at Cambridge from 28th June to 1st July, 1976.

In essence the Convention reviewed the contribution electronics technology has made to society in general over the past fifty years and, more importantly, surmised some of its future effects. Perhaps one of the most striking realizations was the extent to which electronics has changed society over the last five decades—a change which until fairly recently has been gradual and, therefore, not always fully appreciated.

Several of the Institution's Conventions have included in their programmes the presentation of a Clerk Maxwell Memorial Lecture—indeed the Inaugural Lecture was given in the Cavendish Laboratory by Professor G. W. O. Howe during the 1951 Convention and three of the subsequent lectures were also given in this historically appropriate building. This year the Ninth Lecture was given by the eminent Dutch physicist, Dr. H. B. G. Casimir.

During the week official functions were held in other parts of the University and at the Guildhall, Cambridge, and the convention concluded with a memorable banquet in the Hall of King's College.

Joint Conferences. In addition to the Conferences organized by the IERE the Institution co-sponsored a number of events organized by other bodies. In the course of the year many invitations to support conferences, vacation schools and exhibitions were received by the Institution. The Professional Activities Committee considered each of these and recommended to Council whether any particular invitation should be accepted or declined. Council policy is to decline invitations not directly associated with the 'advancement of the science and practice of radio and electronic engineering'.

CEI Branches. The Institution is represented on the Committees of the Branches of CEI, of which there are now fifteen throughout the United Kingdom, and is also represented on five joint committees of graduates and students. The local Branches arrange meetings with as wide an appeal to the different engineering disciplines as possible. Symposia on careers and participation in student recruitment together with other similar ventures are some of the important activities of these Branches.

Representation on BSI Committees and Other Organizations. The Institution has supported the work of standardization for many years and a number of Institution members serve on Technical Committees of the British Standards Institution. IERE is also represented on a number of other outside technical committees and organizations; details of all these appointments are given in Appendices 6 and 7.

Programme Booklet. It was reported last year that discussions had taken place with the Institution of Electrical Engineers on improving the format of the joint booklet to make it more attractive to the members of both Institutions. Members will already have noticed some change to the format and further plans for improvement are in hand.

Inter-Learned Society Liaison Working Party. The Components and Circuits Group have been using a computer program devised to assist in the co-ordination of meetings organized by Professional Groups of the Institution of Electrical Engineers and the Institute of Physics. So far the meetings of the organizations subscribing to this facility have been concerned only with thin film devices and applications. The possibility of extending the data base to cover a wider field of electronics meetings activities is now being examined.

Acknowledgment. The Committee, on behalf of Council, wishes to thank the Royal Institution, Universities, Technical Colleges and other organizations for providing accommodation for meetings; and editors of technical periodicals and the producers of national and local radio programmes for publicizing details of Institution meetings and other activities in Great Britain and overseas.

EDUCATION AND TRAINING COMMITTEE

Since the Committee is the body responsible for advising the Institution's Council on matters relating to the education and training of Chartered Electronic and Radio Engineers, it is particularly interested in qualifications of degree standard —including the CEI examinations. However, formal education begins at school, and changes in course structure at fundamental or intermediate level can influence the whole education and training structure. Consequently the Committee has, during the year, given further thought to the teaching of Mathematics for would-be engineers, and has taken an active interest in the work of the Technician Education Council in formulating new courses for Technicians and Technician Engineers. Because the Committee believes that it is important not only that the new TEC courses should be right in themselves, but also that they should provide smooth progression to degree courses for students with the necessary ability, two Colloquia were organized by the Education and Training Group to discuss developments in education and training up to present Higher National Diploma level.

At degree level, there is no shortage of suitable courses in electronic engineering at Universities and Polytechnics for anyone who has the necessary ability and is able to undertake full-time study. There is, nevertheless, a 'content' problem which is not merely the obvious one of need for continual up-dating of the syllabus. Because of the rapid expansion of our technology, it is necessary to consider such questions as whether some 'traditional' material could be omitted to 'lighten the load' or whether complete re-structuring is needed. The Committee has therefore, with the approval of Council, set up a Working Group to study the problem, and thought is being given to the arrangement of a conference on the subject.

However, whereas there is no lack of courses for the full-time student, concern is felt about the problems facing those seeking to improve their qualifications by part-time study. The Committee has already submitted a paper to CEI Standing Committee A, drawing attention to the fact that good part-time courses of preparation for Part 2 of the CEI examination for those who are exempt from Part 1 are increasingly difficult to find. The recommendations made in the paper, which also includes proposals for separating the compulsory subject 'The Engineer in Society' from the rest of the Part 2 examination, have been referred to the Board of Moderators for study.

The problems of the part-time student would clearly be eased considerably if exemption from the CEI examination could be achieved by means of suitable Open University degrees. Until the recommendations made by the Working Group appointed by the CEI to study the problem have been confirmed, the Committee will not be able to give firm guidance to those interested in this possibility, although as a result of preliminary studies which it undertook in December 1976 it should quickly be able to interpret the CEI requirement, once it is known, in terms of electronic engineering studies. There may be some temporary difficulties, however, in meeting the anticipated requirement for the equivalent of not less than two full credits in engineering subjects at level 3 or higher, without including some which are not 'mainstream' electronic engineering.

As a consequence of its absorption of the former Academic Standards Committee (mentioned in the previous Annual Report) the Education and Training Committee has become the body responsible for overseeing the day-to-day implementation of the Council's education policy, as well as its formulation. The Bye-laws relating to applications for corporate membership require that applicants should 'have passed an examination or other academic test in accordance with the Council's requirements and those of the Council of Engineering Institutions'. The requirements of the latter body are that the applicant should hold a qualification of no less a standard than that of a first degree in engineering awarded by a United Kingdom university. It is therefore necessary, in the case of applicants who hold degrees awarded overseas, or who hold qualifications of mixed origin, none of which is in itself of the required standard, for the Committee, acting as Council's agent, to judge whether the Bye-law requirements have been met and to submit its verdict for confirmation by the appropriate CEI Committees.

Inevitably there are from time to time differences of opinion: the Committee therefore participated wholeheartedly in the drafting of CEI Statement No. 12, which was published this year, which states the assessment criteria which will be used by the CEI Committees. Since the Statement was intended to give a little more freedom for the assessors to judge the applicants 'in the round', the Committee was disturbed to learn of attempts which are being made to use it as licence for the adoption of more rigid academic attitudes. It has drawn the attention of the IERE Council to the danger, and, with the Council's full approval, will continue to oppose any attempts to move towards a less balanced approach to these applications.

Where the qualifications of Technicians and Technician Engineers are concerned, the Committee's anxieties have been of the opposite kind: like many other bodies, it has feared that the new awards being established by the Technician Education Council will be of lower standard than those which they are intended to replace. If, as the TEC claims, they will nevertheless meet the needs of industry, the change will not adversely affect those for whom they represent the academic 'ceiling', but difficulties could arise for those who find that they have the ability and desire to proceed further. The two Colloquia organized by the Committee for discussion of this problem have already been reported in *The Radio and Electronic Engineer*:* the Committee was pleased to learn that the two awards for which TEC courses appear unlikely to provide an adequate replacement—the OND in Technology and the HND in Electrical/Electronic Engineering—are to be allowed to continue *sine die*. It is to be hoped that in the next Annual Report the Committee will be able to record that the danger against which it finds it necessary to be permanently alert—that the Utopians may destroy systems which, though imperfect, have served us well, before their 'ideal' replacements are ready and proved—has been averted in this area of prime professional interest.

Chartered Electronic and Radio Engineers are seldom, if ever, under-employed: there can therefore scarcely be anything more indicative of the importance attached by the profession to the work of the Committee than the fact that although it currently has five more than its 'target' membership of fifteen, there is a waiting list of highly-placed people, in both the educational and industrial fields, who are eager to join in that work.

* 'Technicians and Technician Engineers in the Electronics Industry' *The Radio and Electronic Engineer*, **47**, No. 1/2, p. 81, January/February 1977. 'The Future of Higher Diplomas', *The Radio and Electronic Engineer*, **47**, No. 5, pp. 238–40, May 1977.

MEMBERSHIP COMMITTEE

During the year the Committee considered 688 membership proposals: 470 for direct election, 182 for transfer and 36 for reinstatement. The Committee also continued the regrettable but necessary task of processing lapsed-member cases under Bye-law 32. These cases accounted for 771 of the 1,121 removals from the Register for all reasons. The final result for the year is summarized in Table 1 from which it will be seen that whilst the total membership fell by 4·4% the corporate membership strength did not change materially. Indeed the main elements of loss of membership were concentrated in the Graduate and Student sections as was foreseen in the previous year's report. This reflects yet again the problems associated with CEI examination exemption rules mentioned at some length in the Education and Training section of this report. These problems, especially when aggravated by current inflationary pressures, are clearly a severe deterrent to continued membership for those not yet qualified for corporate status and are a matter of great concern to the Institution.

In view of this and the general need to increase membership to further the aims and objectives of the Institution, the Committee has devoted much time in the latter part of the year to the preparation of a wide-ranging study on recruitment for submission to Council later in 1977.

Other matters which received the attention of the Committee included codifying a procedure for the reinstatement of former members and considering amendments to the Bye-law relating to remission of subscription in view of the fact that there is now a general trend to earlier retirement.

Table 1. Institution Membership April 1976 to March 1977

		Additions				Deductions				
	Membership at 31.3.76	Direct Election	Reinstatement	Transfers	Total Additions	Deaths Resignations Removals	Transfers	Total Deductions	Nett Gain (+) or Loss (−)	Membership at 31.3.77
Honorary Fellows	11	—	—	—	—	—	—	—	—	—
Fellows	713	4	—	15	19	27	—	27	−8	705
Members	7362	60	14	76	150	199	15	214	−64	7298
Total Corporate Membership	**8086**	**64**	**14**	**91**	**169**	**226**	**15**	**241**	**−72**	**8014**
Graduates	3649	42	14	39	95	434	66	500	−405	3244
Companions	19	1	—	—	1	—	—	—	+1	20
Associates	391	15	6	6	27	43	3	46	−19	372
Associate Members	690	101	2	27	130	24	2	26	+104	794
Students	1413	240	—	—	240	394	77	471	−231	1182
Total Non-Corporate Membership	**6162**	**399**	**22**	**72**	**493**	**895**	**148**	**1043**	**−550**	**5612**
Grand Total	**14248**	**463**	**36**	**163**	**662**	**1121**	**163**	**1284**	**−622**	**13626**

PAPERS COMMITTEE

During the past year the Committee's preoccupation, influencing its prime task of obtaining and assessing papers, has been to meet the continually changing requirements which members have of their Journal. Broadly speaking, members of this Institution are engaged in research, development, production, operation or teaching, and endeavouring to meet the strict professional interests of one group might seem to be irrelevant to most of the other groups. Because the Journal has a role in presenting original work in electronic engineering, a role enshrined in its aims and objects which are printed on the first page of every issue, the task of publishing material with more than an appeal to specialist interests is rendered even more difficult within the practical bounds set by today's costs.

A compromise has clearly to be reached between the various alternatives. Whatever their immediate professional interests, most members find the opportunity of at least scanning specialist papers to be a relatively easy way of maintaining 'current awareness' of what is going on in other areas. Keeping the Journal in its present form which combines both original specialized papers and general interest material is considered to fulfil the aims of promoting the advancement of radio and electronics, provided that the general interest section is stengthened and made more broadly useful.

This then has been the Committee's work during 1976-77: to encourage the writing of papers which have the widest possible appeal but without lowering the intellectual standard from that which the traditional content of *The Radio and Electronic Engineer* has endeavoured to uphold.

Assesment of Papers. The importance of maintaining professional standards in the papers published in the Journal has been referred to in previous Annual Reports and it is essentially the striking of a balance between erudition and popularity. The number of papers considered by the Committee during the past year was below that for 1975 when the Golden Jubilee issue of 19 papers increased the volume appreciably. Comparison of the numbers of papers accepted and rejected reveal that the balance of papers suitable for publication has swung significantly in an unfavourable direction. The details are as follows, the 1975/76 figures being shown in parentheses:—

Number of papers considered	128 (151)
Accepted for publication	44 (62)
Returned for revision	17 (21)
Rejected	67 (68)

The need to encourage authors whose papers fall short of the desired standard is considered very carefully by the Committee and that the number of papers found acceptable after revision along lines suggested by referees has increased.

Papers read at the Golden Jubilee Convention have been considered in subsequent written form for publication, as well as a selection of papers given at the Conference on Video and Data Recording.

General interest papers of the required standard are not easily specified or written: here the Committee is deliberately moving with caution but already a number of such papers have been published, drawn from various sources. There is a place in the Journal for surveys, intended for those not specialized in particular fields, but aiming to interpret the latest 'state of the art' in an engineering context; there is also a place for papers which deal with a theme which is applicable 'across the board' and may not be basically technical. Local Section meetings have proved to be fruitful sources of papers in the first category; and papers or lectures given outside this Institution have been included in the second category.

Premiums. Details of the Premiums to be awarded to the authors of outstanding papers published in the Journal during 1976 are given in Appendix 8; twelve of the twenty available Premiums are being awarded.

INSTITUTION PUBLICATIONS

The Radio and Electronic Engineer The universal impact of rising costs has militated against any increase in size of the Institution's Journal, and yet again increased charges have been recorded for printing, paper and distribution. The year's volume was 17% smaller than that for 1975 as the following figures show:

Papers etc.	469 (604) pages
General	167 (164) ,,
Advertisements etc.	116 (138) ,,
Total	752 (906) ,,

In order to achieve economies in production and especially in distribution, the August and September issues were combined and the Council has decided that during 1977 there will be ten separate Journals, two being double—and normally feature—issues.

Some 66 papers, addresses and articles were published during the year. This was 14 fewer than in 1975 when the Golden Jubilee issue was produced. The proportion of general matter, which includes articles of a semi-technical or non-technical nature as well as Institution announcements has been increased from about a quarter to a third of the total pages.

Increasing costs can be offset in two ways—by increasing advertisement revenue and by increasing subscriptions by non-members. Little if any progress has been made in the former but steady progress has been achieved in the latter. The circulation overall has fallen slightly compared with 1975, however, due to removal of members from the registers. The figure certified by the Audit Bureau of Circulation was 14,693.

Association of Learned and Professional Society Publishers. The Institution has continued in membership of ALPSP and the information on matters of mutual interest which is obtained has proved of considerable value. ALPSP also publicizes the Institution's Journal and other publications through a combined catalogue distributed widely to libraries throughout the world and at exhibitions.

Conference Proceedings. During the year the Golden Jubilee Convention and three major Conferences were held: 'The Applications of Electronics in Medicine', 'Video and Data Recording' and 'Computer Systems and Technology'. Proceedings were produced for the three Conferences and comprised a total of 113 papers, amounting to 978 pages. Conference Proceedings attract considerable interest and there is a lively worldwide demand for copies after each Conference.

National Electronics Review. The Institution has continued to edit and publish the National Electronics Council's bi-monthly journal, *National Electronics Review*. The established series of reports on electronics research in British and Commonwealth Universities and Polytechnics and the Company Profiles continue to be valuable features of this journal. A wide range of articles on other subjects of topical electronics interest have been published during the year, among which 'Electronic Technology at the Royal Aircraft Establishment' and 'Electronics Research at the Department of Engineering Science, Oxford University' were particularly noteworthy.

The *National Electronics Review* may be obtained on subscription by members of the IERE and other Institutions at a reduced rate, details of which may be obtained from the Institution. Back numbers in bound volume form may be obtained on application to the Secretary of NEC, Mr. D. Dibsdall, O.B.E., C.Eng., M.I.E.R.E., Abell House, John Islip Street, London SW1P 4LN.

Indian Proceedings. This was the fifteenth year of publication of *IEE-IERE Proceedings—India*, distributed bimonthly to members of the two Institutions in India. The usual broad range of papers—23 in all—was published and the six issues comprised 270 pages, the highest number to date. The Indian Proceedings is edited and published by the IERE Administrative Office in Bangalore.

LIBRARY AND INFORMATION SERVICES

In providing services to members the Institution's library has had, of necessity, to tread a difficult path in coping with rising prices of periodicals and books. Considerable care has to be taken in assessing which journals and books can be purchased, the normal criteria of excellence and topicality having to be accompanied by a judgement as to the likely use which will be made of a particular title. If only minority appeal seems likely then the book will not be bought but will be borrowed either from the library of another Institution or from the British Lending Library. Inter-library loans enable individual libraries to conserve their resources and provide opportunities for mutual co-operation.

Increasing use is made of photocopies in meeting requests for the loan of journals containing articles of interest. More often than not the enquirer needs a permanent record and, as an authorized library, the Institution can supply this using its own files and facilities; where an article is not held, a photocopy can usually be obtained from BLL or elsewhere.

The information services of the library have been well used during the past year and enquiries made have ranged from the simple request for the address of a manufacturer to the compilation of lists of references on a wide variety of specialized subjects. In order to facilitate rapid and efficient use of the library's resources, both by the staff and by members making enquiries in person, there has been extensive reorganization and rationalization of the lending and reference sections, the holdings of serial journals and the catalogue card index.

FINANCE COMMITTEE

Despite the continuing spiral of inflation which has had its adverse effect on the charges incurred in every department of the Institution's activities, the cost of running the Institution for the year ended 31st March 1977 was less than 6% higher than for the previous year. This result has been achieved without any lessening of the services and benefits to members.

As will be seen from the Income and Expenditure Account, income from all sources has shown a desirable increase: the first full year's impact of the membership subscription increase has produced an additional £51,000 and there has been an improvement of upwards of 13% on the income from publications and symposia.

The net result of all this is that at the end of a most difficult year the excess of expenditure over income stands at just over £6,000 which compares more than favourably with nearly £55,000 deficit for last year. This comparatively encouraging result must not give rise to any complacency. There is no indication that cost inflation will ease during the coming year and the tightest control will still have to be exercised if these increases are to be contained.

The accommodation problem continues to be one of the major contributory factors to the Institution's increasing expenditure. A saving has been made by giving up some of the space in 8/9 Bedford Square with consequent reduction in rent and rates, albeit at some cost in operating convenience. It must be remembered, however, that at the end of the coming financial year the existing compromise rental agreement for 8/9 Bedford Square expires, at which time the Institution may well be faced with a rent charge of nearly twice our present commitment.

The Council's ultimate housing objective continues to be the purchase of freehold premises and the Institution is indebted to Mr. Clifford for his efforts in promoting a special fund to meet this need, and to the many friends inside and outside the Institution who have already responded most generously. The current very high price of suitable premises, however, is such that this freehold purchase plan must of necessity remain a long-term objective. In the meantime, it would appear to be absolutely essential to obtain, before the next financial year is out, smaller, more cost-effective rented premises in the London area, in order to stabilize the Institution's overall housing costs at a level well below that likely to be charged in the future at 8/9 Bedford Square.

This report would not be complete without mentioning Mr. F. N. G. Leevers, who retires as Chairman of the Finance Committee this year. Mr. Leevers has served on the Finance Committee for thirteen years, for the last nine years in the capacity of Chairman; and the Institution's grateful thanks are due to him for his unstinting personal contribution to the work of this important committee for so many years. His successor as Chairman is Mr. D. W. Heightman, a Vice-President of the Institution, who has been a member of the Finance Committee for the past eight years.

ANNUAL ACCOUNTS OF THE INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MARCH 1977

	1977 £	1977 £	1976 £	1976 £
INCOME				
Subscriptions Received including arrears		227,070		175,548
Entrance, Transfer and Exemption Fees		2,477		2,344
Sales:				
Institution Journal ..	32,900		28,543	
Other Publications (net) ..	11,773		10,185	
		44,673		38,728
Fees Received—Symposia and Colloquia		41,096		37,436
Dividends and Interest Received		1,517		1,936
Total Income		316,833		255,992
Deduct:				
EXPENDITURE				
Cost of Publishing Journal				
Printing Costs	57,632		54,174	
Less: Advertising Receipts ..	4,844		8,731	
	52,788		45,443	
Postage	18,247		24,656	
Envelopes and Wrappers ..	539		462	
	71,574		70,561	
Direct Expenses relating to Symposia and Colloquia ..				
Printing of Papers	4,796		8,801	
Accommodation and Travel	18,765		16,526	
	23,561	95,135	25,327	95,888
		221,698		160,104
Deduct:				
Administration Expenses				
Salaries and National Insurance	92,016		86,553	
Superannuation Scheme ..	8,536		4,852	
Postage and Telephone ..	17,192		14,669	
Printing and Stationery ..	4,560		6,156	
Computer Service	5,882		6,076	
Travelling and Entertaining Expenses	5,345		5,430	
Council and Committee Expenses	4,084		4,460	
Delegates' Expenses ..	1,755		1,284	
Bank Charges and Differences on Exchange ..	5,171		3,623	
Audit Fees	850		850	
Miscellaneous Expenses ..	2,591		1,903	
	147,982		135,856	
Establishment				
Rent, Rates and Insurance ..	35,208		36,513	
Lighting and Heating ..	2,451		1,763	
Office Expenses and Cleaning	7,551		5,606	
Repairs and Maintenance ..	819		5,280	
	46,029		49,162	
Divisions and Sections Operating Expenses				
Salaries, Printing, Stationery, Postage and Office Expenses	11,467		7,383	
Hire of Accommodation, Lectures and Meeting Expenses	5,074		2,914	
Travelling Expenses	464		1,578	
Indian Proceedings	2,205		1,435	
	19,210		13,310	
Carried forward	213,221	221,698	198,328	160,104

Income and Expenditure Account (continued)

	1977 £	1977 £	1976 £	1976 £
Brought forward	213,221	221,698	198,328	160,104
Subscriptions to the Council of Engineering Institutions ..	6,854		5,832	
Cambridge Convention ..	1,886		—	
Meetings and Golden Jubilee Celebrations	—		5,693	
Awards and Contributions to Other Institutions	1,091		754	
Depreciation				
Amortization of Leasehold Premises	2,267		2,267	
Furniture, Fittings and Equipment	1,631		1,218	
Library	951		765	
	4,849	227,901	4,250	214,857
Excess of Expenditure over Income for the year		6,203		54,753
Add:				
Adverse Balance 1st April 1976		72,345		7,717
		78,548		62,470
Add:				
Exceptional Items:—				
Additional Amortization in respect of part of Leasehold premises surrendered during the year	10,000		—	
Provision for deferred repairs	5,000		—	
Prior year adjustments ..	—	15,000	9,875	9,875
Adverse Balance 31st March 1977		£93,548		£72,345

STATEMENT OF SOURCE AND APPLICATION OF FUNDS IN THE YEAR ENDED 31st MARCH 1977

	£	£
Source of Funds		
Donations to Premises Fund	14,137	
Increase in Subscriptions received in advance	7,281	
Short Term Borrowings—Bank overdraft ..	16,474	
		37,892
Less:		
Deficit for Year, after adjusting for depreciation provided of £14,849		(6,354)
		£31,538
Application of Funds		
Purchase of Investments*—on account of Premises Fund	17,221	
Purchase of Investments—other	376	
Purchase of Fixed Assets	2,629	
		20,226
Working Capital (Net)		
Decrease in Stocks	(1,035)	
Decrease in Debtors	(3,425)	
Decrease in Income Tax repayable	(463)	
Decrease in Creditors	13,835	
Increase in Bank and Cash Balance	2,400	
		11,312
		£31,538

*Including cash held for investment.

BALANCE SHEET AS AT 31st MARCH 1977

	1977 £	1977 £	1976 £	1976 £
Fixed Assets (Note 1)		24,146		36,366
Quoted Investments at Cost (Note 2) . .	27,916		27,540	
Less: Surplus on Sale	4,182		4,182	
(Market Value £24,219 1976 £22,375)		23,734		23,358
Premises Fund Investment				
11% South Staffordshire Loan repayable March 1978	16,000		—	
Balance at Bank	1,221		—	
		17,221		—
Current Assets				
Stock of Institution's Publications (Note 3)	17,111		18,146	
Income Tax repayment claim	186		649	
Sundry Debtors and Pre-payments	18,294		21,719	
Balances at Bank and in Hand	15,586	51,177	13,186	53,700
		116,278		113,424
Less:				
Current Liabilities				
Sundry Creditors and Provisions		64,884		78,719
		51,394		34,705
Add:				
General Fund Account				
Adverse Balance		93,548		72,345
		£144,942		£107,050
Represented by:				
Premises Fund Account (Note 4)		17,221		3,084
Deferred Revenue Subscriptions and Receipts in Advance		40,857		33,576
Short Term Borrowings Bank Overdraft		86,864		70,390
		£144,942		£107,050

Signed

P. A. ALLAWAY (*President*)
D. W. HEIGHTMAN (*Chairman, Finance Committee*)
S. R. WILKINS (*Hon. Treasurer*)
S. M. DAVIDSON (*Secretary*)

Notes forming part of the Accounts for the year ended 31st March 1977

1. Fixed Assets

	Leasehold Improvements 8/9 Bedford Square, London £	*Furniture and Equipment* £	*Library* £	*Total* £
Cost				
At 31st March 1976. .	24,940	27,046	14,479	66,465
Additions	—	—	2,629	2,629
At 31st March 1977. .	24,940	27,046	17,108	69,094
Aggregate Depreciation				
At 31st March 1976. .	4,535	17,964	7,600	30,099
Provided during year	2,267	1,631	951	4,849
Additional Provision	10,000	—	—	10,000
At 31st March 1977. .	16,802	19,595	8,551	44,948
Net Book Values				
At 31st March 1976. .	20,405	9,082	6,879	36,366
At 31st March 1977. .	8,138	7,451	8,557	24,146

2. Quoted Investments

Nominal		*Cost* £
500	Allied Textile Co. Ltd. 25p Ordinary Shares	511
£1,000	7¼% Barnet Corporation Loan 1982/4	982
2,000	B.B.A. Group Ltd. 25p Ordinary Shares	1,115
700	Boots Pure Drug Co. Ltd. 25p Ordinary Shares . .	988
1,250	British Oxygen Co. Ltd. 25p Ordinary Shares	768
£500	British Petroleum Co. Ltd. 8% Cumulative First Preference Stock	685
500	Decca Ltd. 25p Ordinary Shares	1,422
125	Decca Ltd. 25p 'A' Ordinary Shares	424
200	Distillers Co. Ltd. 50p Ordinary Shares	342
1,000	Dunlop Co. Ltd. 50p Ordinary Shares	1,180
1,000	E.M.I. Ltd. 50p Ordinary Shares	2,654
699	English China Clays Ltd. 25p Ordinary Shares . .	840
374	Grattan Warehouses Ltd. 25p Ordinary Shares . .	802
500	Hartle Machinery International Ltd. 25p Ordinary Shares	205
562	I.C.I. Ltd. £1 Ordinary Shares	2,247
£270	Inchcape & Co. Ltd. 12½% Unsecured Loan Stock 1993/98	99
£1,000	Islington Corporation 10% Redeemable Stock 1982/83	995
823	Lonrho Ltd. 25p Ordinary Shares	1,124
1,600	Marks & Spencer Ltd. 25p Ordinary Shares	2,187
£1,000	Middlesex County Council 6¼% Redeemable Stock 1975/77	973
500	Muirhead Ltd. 25p Ordinary Shares	557
£2,000	New Zealand 7½% Stock 1977	1,987
625	Plessey Co. Ltd. 50p Ordinary Shares	1,149
281	Racal Electronics 25p Ordinary Shares	755
£1,000	Slough Corporation 8¾% Redeemable Stock 1979/80. .	990
£521	Southern Rhodesia 6% Stock 1978/81	515
£500	Stock Exchange 7¼% Mortgage Debenture Stock 1990/95	485
£500	Thorn Electrical Industries Ltd. 5% Convertible Unsecured Loan Stock 1990/94	522
£1,220	5½% Treasury Stock 2008/12 (donated)	—
500	United Gas Industries Ltd. 25p Ordinary Shares . .	413
		£27,916

3. Stock of the Institution's publications is stated at the lower of cost and net realizable value.

4. Premises Fund Account

	1977 £	1976 £
Balance 1st April 1976 (transferred from Premises Improvement Account)	3,084	2,838
Add:		
Receipts during year—		
Donations	11,697	246
Covenanted Subscriptions	2,440	—
Balance 31st March 1977	£17,221	£3,084

5. Rates of Exchange

Overseas remittances and receipts during the year have been converted into sterling at the current rates then ruling, and the bank and cash balances held overseas at 31st March 1977 at the rate of exchange ruling at that date. Any resulting exchange differences have been included with Bank charges in the Income and Expenditure Account.

AUDITORS' REPORT TO THE MEMBERS OF THE INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS

We have examined the annexed accounts which have been prepared under the Historical Cost Convention and in our opinion, based on our examination, these accounts give, under the accounting convention stated above, a true and fair view of the state of the Institution's affairs at 31st March 1977 and of the deficit and source and application of funds of the Institution for the year ended on that date and comply with the Royal Charter and Bye-Laws of the Institution.

0 Bloomsbury Street, London WC1B 3QY
9th July 1977

GLADSTONE, JENKINS & CO.
Chartered Accountants

Appendix 1

Membership of the Council and its Committees as at 31st March 1977

The Council of the Institution

President:

P. A. ALLAWAY, C.B.E., D.Tech. (*Fellow*)

Past Presidents:

A. A. Dyson, O.B.E. (*Fellow*)
Sir Ieuan Maddock, C.B., O.B.E., D.Sc., F.R.S. (*Fellow*)
H.R.H. The Duke of Kent, G.C.M.G., G.C.V.O. (*Fellow*)

Vice Presidents:

Professor D. E. N. Davies, D.Sc., Ph.D (*Fellow*)
Professor W. A. Gambling, Ph.D., D.Sc. (*Fellow*)
Professor W. Gosling, B.Sc. (*Fellow*)
D. W. Heightman (*Fellow*)
R. C. Hills, B.Sc. (Eng.) (*Fellow*)
Professor J. R. James, Ph.D. (*Fellow*)
J. Powell, M.Sc. (*Fellow*)

Ordinary and ex-officio Members:

N. G. V. Anslow (*Member*)
J. B. Bennett (*Member*)*
M. S. Birkin (*Member*)
L. A. Bonvini (*Fellow*)
C. S. den Brinker, M.Sc. (*Fellow*)*
Sir Raymond Brown, O.B.E. (*Fellow*)
M. A. Burchall (*Member*)*
Professor D. S. Campbell, B.Sc., D.Sc., D.I.C. (*Fellow*)
W. H. Clark (*Member*)*
K. Copeland (*Member*)
P. L. Dalgliesh (*Member*)*
Lieutenant-Commander J. Domican, RN (*Associate Member*)
N. G. Donnithorne (*Member*)*
L. B. Dowding (*Member*)*
F. Goodall, Ph.D., M.Sc. (*Member*)*
A. P. Griffiths (*Member*)*
T. D. Ibbotson (*Associate*)
C. T. Lamping (*Member*)*
G. Lauder, B.Sc. (*Member*)*
Brigadier R. W. A. Lonsdale, B.Sc. (*Fellow*)
L. F. Mathews, O.B.E. (*Fellow*)
A. D. Patterson, B.A. (*Member*)*
V. J. Phillips, Ph.D., B.Sc. (*Member*)
W. L. Price, O.B.E., Ph.D. (*Fellow*)*
Sir John Read (*Companion*)
T. G. Sanders (*Member*)*
S. J. H. Stevens, B.Sc. (Eng.) (*Fellow*)
L. A. Trinogga, M.Sc., Ph.D. (*Member*)*
Group Captain J. M. Walker, RAF (*Member*)
C. L. Wilkinson (*Member*)*

Honorary Treasurer:

S. R. Wilkins (*Fellow*)

Director and Secretary:

Graham D. Clifford, C.M.G. (*Fellow*)

**Chairman of a Local Section in the UK*

Standing Committees of the Council

Executive Committee

Chairman:
The President

Air Vice-Marshal S. M. Davidson, C.B.E. (*Fellow*)
A. A. Dyson, O.B.E. (*Fellow*)
Professor W. A. Gambling, Ph.D., D.Sc. (*Fellow*)
Professor W. Gosling, B.Sc. (*Fellow*)
D. W. Heightman (*Fellow*)
Professor J. R. James, Ph.D. (*Fellow*)
Sir Ieuan Maddock, C.B., O.B.E., D.Sc., F.R.S. (*Fellow*)
J. Powell, M.Sc. (*Fellow*)

Finance Committee

Chairman:
F. N. G. Leevers, B.Sc.(Eng.) *Fellow*)

D. W. Heightman (*Fellow*)
G. Phillips (*Associate*)
S. R. Wilkins (*Fellow*)

Education and Training Committee

Chairman:
D. L. A. Smith, B.Sc. (Eng.) (*Fellow*)

Air Vice-Marshal S. M. Davidson, C.B.E. (*Fellow*)
D. Dick (*Fellow*)
K. E. Everett, Ph.D., M.Sc. (Eng.) (*Fellow*)
Cdr. A. H. Fraser, B.Sc. (Eng.), RN (*Member*)
B. F. Gray, B.Sc. (Eng.) (*Fellow*)
P. J. Gallagher, Ph.D. (*Member*)
G. P. Heywood, B.Sc. (*Graduate*)
C. H. G. Jones (*Member*)
A. J. Kenward, B.Sc. (*Member*)
Group Capt. R. W. Leppard (*Member*)
P. J. Morley (*Member*)
Professor K. G. Nichols, B.Sc., M.Sc. (*Fellow*)
W. L. Price, O.B.E., Ph.D., M.Sc. (*Fellow*)
A. C. Shotton, B.Sc. (*Fellow*)
Col. F. R. Spragg, B.Sc. (*Fellow*)
A. Tranter, B.Sc. (Eng.) (*Member*)
Col. J. Vevers, O.B.E. (*Fellow*)

Membership Committee

Chairman:
Brigadier R. W. A. Lonsdale, B.Sc. (*Fellow*)

C. W. Brown, M.A. (*Member*)
R. M. Clark (*Member*)
D. N. J. Cudlip (*Member*)
Wing Cdr. P. J. Dunlop, RAF (Ret.) (*Fellow*)
N. L. Garlick, M.Sc. (Eng.) (*Fellow*)
R. C. Hills, B.Sc. (Eng.) (*Fellow*)
H. Hudson (*Member*)
G. H. Pegler (*Fellow*)
S. H. Perry (*Fellow*)
R. S. Roberts (*Fellow*)
Group Capt. J. M. Walker, RAF (*Member*)
M. M. Zepler, M.A., Dip. El. (*Member*)

Professional Activities Committee

Chairman:
Professor D. S. Campbell, B.Sc., D.Sc., D.I.C. (*Fellow*)

Col. W. Barker (*Member*)
Lt. Col. F. G. Barnes, M.A., R Sigs (Ret.) (*Member*)
K. Copeland (*Member*)
A. F. Dyson, Dip.El. (*Member*)
M. H. W. Gall, M.A. (*Fellow*)
J. R. Halsall, Dip.El. (*Member*)
A. Hann, B.Sc. (*Fellow*)
Brigadier R. Knowles, C.B.E. (*Fellow*)
R. Larry (*Fellow*)
D. L. A. Smith, B.Sc. (Eng.) (*Fellow*)
W. E. Willison (*Fellow*)

Papers Committee

Chairman:
Professor J. R. James, Ph.D., (*Fellow*) (*to* 12.1.77)
L. A. Bonvini (*Fellow*) (*from* 13.1.77)

Deputy Chairman
L. W. Barclay, B.Sc. (*Fellow*)

J. Bilbrough (*Fellow*)
W. G. Burrows, Ph.D. (*Member*)
R. J. Cox, B.Sc. (*Member*)
Professor E. A. Faulkner, Ph.D. (*Fellow*)
K. G. Freeman, B.Sc. (*Member*)
Professor D. W. Lewin, M.Sc. (*Fellow*)
T. B. McCrirrick (*Fellow*)
J. R. Parks, Ph.D. (*Member*)
E. Robinson, Ph.D. (*Fellow*)
L. A. Smulian, B.Sc. (*Fellow*)
A. G. Wray, M.A. (*Fellow*)

Trustees of the Institution Benevolent Fund

The President (*ex-officio*)
S. R. Wilkins (*Fellow*) *Hon. Treasurer*
Graham D. Clifford, C.M.G. (*Fellow*) *Hon. Secretary*

Specialized Group Committees

Aerospace, Maritime and Military Systems

Chairman:
T. W. Welch (*Fellow*)

N. G. V. Anslow (*Member*)
Col. W. Barker (*Member*)
Wing Cdr. F. S. Cocker, D.F.C., RAF (*Member*)
Professor J. W. R. Griffiths, Ph.D. (*Fellow*)
A. Hann, B.Sc. (*Fellow*)
A. Harrison, B.Sc. (*Fellow*)
J. A. C. Kinnear (*Fellow*)
R. B. Mitson (*Member*)
R. N. Lord, M.A. (*Member*)
C. H. Nicholson (*Fellow*)

D. M. O'Hanlon (*Fellow*)
C. Powell (*Fellow*)
R. M. Trim, O.B.E. (*Fellow*)

Automation and Control Systems

Chairman:
M. S. Birkin (*Member*)

P. Atkinson, B.Sc.(Eng.) (*Member*)
M. T. Challenger (*Member*)
A. E. Crawford (*Fellow*)
J. R. Halsall, Dip.El. (*Member*)
W. F. Hilton, D.Sc. (*Fellow*)
Inst. Cdr. D. J. Kenner, B.Sc., M.Sc., RN (Ret.) (*Member*)
Brigadier R. Knowles, C.B.E. (*Fellow*)
J. L. Paterson (*Member*)
Professor D. R. Towill, D.Sc. (*Fellow*)
D. E. O'N. Waddington (*Fellow*)

Communications

Chairman:
Professor J. W. R. Griffiths, Ph.D. (*Fellow*)

A. R. Bailey, M.Sc., Ph.D. (*Fellow*)
L. W. Barclay, B.Sc. (*Fellow*)
Professor D. E. N. Davies, D.Sc., Ph.D. (*Fellow*)
L. W. Germany (*Fellow*)
A. N. Heightman (*Fellow*)
R. C. Hills, B.Sc. (Eng.) (*Fellow*)
J. J. Jarrett (*Member*)
G. R. Jessop (*Member*)
A. A. Kay (*Fellow*)
R. Larry (*Fellow*)
P. L. Mothersole (*Fellow*)
R. S. Roberts (*Fellow*)
R. E. C. B. Smith (*Member*)
K. R. Thrower (*Member*)
K. E. Ward (*Member*)
M. M. Zepler, M.A., Dip.El. (*Member*)

Components and Circuits

Chairman:
A. Pugh, B.Sc., Ph.D. (*Fellow*)

C. S. den Brinker, M.Sc. (*Fellow*)
P. W. Boyce (*Member*)
J. S. Brothers (*Member*)
Professor D. S. Campbell, B.Sc., D.Sc., D.I.C. (*Fellow*)
J. B. Lock (*Member*)
B. V. Northall, C.G.I.A. (*Member*)
D. R. Ollington (*Fellow*)

Computer

Chairman:
Professor D. W. Lewin, M.Sc. (*Fellow*)

Col. W. Barker (*Member*)
P. L. Hawkes, B.Sc. (*Member*)
D. T. Law (*Member*)
Wing Cdr. D. G. L. Packer, B.Sc., D.U.S., RAF (*Member*)
T. J. Stakemire (*Member*)
E. R. Tomlinson (*Member*)
S. E. Williamson, B.Sc., Ph.D. (*Member*)

Electronics Production Technology

Chairman:
A. F. Dyson, Dip.El. (*Member*)

J. W. Anstead (*Member*)
J. F. Burns (*Member*)
D. S. Girling (*Fellow*)
L. Hale (*Member*)
R. W. Hill (*Member*)
D. G. Horan (*Member*)
R. P. Marie (*Member*)
B. Pike (*Member*)

Measurements and Instruments

Chairman:
Professor P. B. Fellgett, M.A., Ph.D. (*Fellow*)

M. H. W. Gall, M.A. (*Fellow*)
P. A. Payne, Ph.D. (*Graduate*)
R. W. A. Siddle (*Member*)
G. W. Taylor (*Member*)
D. E. O'N. Waddington (*Fellow*)

Medical and Biological Electronics

Chairman:
R. Brennand (*Member*) (*to* 31.12.76)
K. Copeland (*Member*) (*from* 1.1.77)
A. J. Huelin (*Member*)
P. A. Payne, Ph.D. (*Graduate*)
L. W. Price, M.A. (*Member*)
J. R. Roberts, B.Sc., Ph.D. (*Graduate*)
H. J. Terry, B.A., Ph.D. (*Member*)

Appendix 2

Representatives of the Institution on the Board and Committees of the Council of Engineering Institutions

Board

Professor W. A. Gambling, Ph.D., D.Sc. (*Fellow*)
Professor W. Gosling, B.Sc. (*Fellow*) (ALTERNATE)

Executive Committee

P. A. Allaway, C.B.E., D.Tech. (*Fellow*)

Standing Committee A

D. L. A. Smith, B.Sc. (Eng.) (*Fellow*)

Standing Committee B

J. Powell, M.Sc. (*Fellow*)

Standing Committee C

Air Vice-Marshal S. M. Davidson, C.B.E. (*Fellow*)

CEI-CSTI Joint Affairs Committee

To be appointed

Council for Environmental Science and Engineering

Professor H. M. Barlow, Ph.D., F.R.S. (*Honorary Fellow*)

British National Committee on Ocean Engineering

P. W. Warden (*Member*)
M. J. Tucker, B.Sc. (*Member*) (ALTERNATE)

Committee on Health and Safety

Colonel F. R. Spragg, B.Sc. (*Fellow*)

Engineers Registration Board

Technician Engineer Section Board, Supervisory Committee and Joint Membership Committee
K. J. Coppin, B.Sc. (*Member*)

Joint Qualifications Committee
Brigadier R. W. A. Lonsdale, B.Sc. (*Fellow*): *Chairman*

Appendix 3

Institution Representation at Universities, Polytechnics and Colleges

University of Aston in Birmingham

Convocation
Professor D. G. Tucker, D.Sc., Ph.D. (*Fellow*)

Barnsley College of Technology

Engineering Advisory Committee
D. Shaw, B.Sc. (*Fellow*)

University of Bradford

Court
P. J. Gallagher, M.Sc., Ph.D. (*Member*)

Darlington College of Technology

Electrical Engineering and Science Advisory Committee
R. W. Blouet (*Member*)

East Ham Technical College

Electrical Engineering Advisory Committee
D. W. Bradfield, B.Sc. (*Member*)

Glasgow College of Technology

Advisory Board
R. D. Pittilo, B.Sc. (*Member*)

City of Gloucester College of Technology

Electrical Engineering Advisory Committee
H. V. Sims (*Fellow*)

Huddersfield Technical College

Engineering Advisory Committee
R. Barnes (*Member*)

Merton Technical College

Board of Governors
A. A. Kay (*Fellow*)

City of Nottingham Education Committee

Electrical Engineering Advisory Committee
F. W. Hopwood (*Member*)

University of Nottingham

Court
Air Vice-Marshal S. M. Davidson, C.B.E. (*Fellow*)

Reading College of Technology

Board of Governors
Major-General Sir Leonard Atkinson, K.B.E., B.Sc. (*Past President*)

Southall College of Technology

Governing Body
B. S. Pover (*Member*)
Administrative Committee
A. G. Wray, M.A. (*Fellow*)

South East London College

Engineering Consultative Committee
J. I. Collings (*Fellow*)

Stannington College of Further Education, Sheffield

Electrical and Telecommunications Consultative Committee
P. A. Bennett (*Fellow*)

University of Surrey

Court
Sir Ieuan Maddock, C.B., O.B.E., D.Sc., F.R.S. (*Past President*)

Wakefield College of Art and Technology

Engineering Advisory Committee
G. F. Lane-Fox (*Member*)

University of Wales Institute of Science and Technology

Court
Professor W. Gosling, B.Sc. (*Fellow*)

Watford College of Technology

Engineering Advisory Committee
F. P. Thomson, O.B.E. (*Member*)

Widnes Technical College

Electrical and Instrument Engineering Advisory Committee
D. Chalmers (*Fellow*)

Appendix 4

Representatives on Joint Committees for the Awards of National Certificates and Diplomas in Engineering

England and Wales

Higher National Certificates and Diplomas in Electrical and Electronic Engineering

B. F. Gray, B.Sc. (Eng.) (*Fellow*): *Chairman*
D. L. A. Smith, B.Sc. (Eng.) (*Fellow*)
A. Tranter, B.Sc. (Eng.) (*Member*)

Ordinary National Certificates and Diplomas in Engineering

B. F. Gray, B.Sc. (Eng.) (*Fellow*)

Scotland

National Certificates in Electrical and Electronic Engineering

D. S. Gordon, Ph.D., B.Sc. (*Member*)
D. Dick, D.I.C. (*Fellow*)

Northern Ireland

Higher National Certificates in Electrical and Electronic Engineering

Captain A. W. Allen, RN (Ret.) (*Member*)
J. A. C. Craig, B.Sc. (*Member*)

Ordinary National Certificates and Diplomas in Engineering

J. A. C. Craig, B.Sc. (*Member*)

Appendix 5

Institution Representation on Other Educational Bodies

City and Guilds of London Institute

Telecommunications Advisory Committee
B. F. Gray, B.Sc. (Eng.) (*Fellow*)

Joint Advisory Committee for Radio, Television and Electronics
W. B. K. Ellis, B.Sc. (*Member*)

Radio Amateurs' Examination Advisory Committee
R. G. D. Holmes (*Fellow*)

Advisory Committee on Communication of Technical Information
F. P. Thomson, O.B.E. (*Member*)

Council for National Academic Awards

Electrical and Electronic Engineering Board
B. F. Gray, B.Sc. (Eng.) (*Fellow*) (*to* 13.8.75)
A. G. Wray, M.A. (*Fellow*)

Technical Education Council (TEC)

Programme Committee A2
K. R. Thrower (*Member*)

London and Home Counties Regional Advisory Council for Technological Education

Advisory Committee on Electrical and Electronic Engineering
K. J. Coppin, B.Sc. (*Member*)

North Western Advisory Council for Further Education

Specialist Advisory Committee for National Education
A. G. Brown (*Member*)

Radio Television and Electronics Examination Board

F. O. M. Bennewitz (*Member*)
W. B. K. Ellis, B.Sc. (*Member*)
N. G. Green (*Member*)

Scottish Technical Education Council (ScoTEC)

Course Committee A2
P. G. Wilks, B.Sc. (*Member*)

Yorkshire Council for Further Education

Engineering County Advisory Committee
F. O. M. Bennewitz, M.Sc. (*Member*)

Welsh Joint Education Committee

Advisory Panel for Electrical Engineering
I. D. Dodd, B.Sc. (*Member*)

Appendix 6

Members Appointed to Represent the Institution on External Bodies

Royal Society

Committee on Scientific Information
Admiral of the Fleet the Earl Mountbatten of Burma, K.G., F.R.S. (*Honorary Fellow*)
Panel on Mechanized Information Retrieval
Graham D. Clifford, C.M.G. (*Fellow*)

EUREL (Convention of National Societies of Electrical Engineers of Western Europe)

Professor W. Gosling, B.Sc. (*Fellow*)
F. W. Sharp (*Fellow*)

British National Council for Non-Destructive Testing

A. Nemet, Dr. Ing. (*Fellow*)

British Nuclear Energy Society

R. J. Cox, B.Sc. (*Member*)

International Broadcasting Convention

Management Committee and Programme Committee
P. L. Mothersole (*Fellow*)
R. S. Roberts (*Fellow*)

National Council for Quality and Reliability

Brigadier R. Knowles, C.B.E. (*Fellow*)

National Electronics Council

Sir Ieuan Maddock, C.B., O.B.E., D.Sc., F.R.S. (*Past President*)
Graham D. Clifford, C.M.G. (*Fellow*)

Watt Committee on Energy

M. S. Birkin (*Member*)
J. M. Keble (*Member*)

Parliamentary and Scientific Committee

Executive Committee
J. Langham Thompson (*Fellow*)
Graham D. Clifford, C.M.G. (*Fellow*)

British Electrotechnical Approvals Board

R. S. Roberts (*Fellow*)

Economic Development Committee for the Electronics Industry

Working Group on Scientific and Technological Manpower
Graham D. Clifford, C.M.G. (*Fellow*)

Association of Learned and Professional Society Publishers

General Assembly and Council
F. W. Sharp (*Fellow*)

UK Automatic Control Council

Professor D. W. Lewin, M.Sc. (*Fellow*)
M. S. Birkin (*Member*)
Professor D. R. Towill, D.Sc. (*Fellow*)
ALTERNATE

UK Liaison Committee for Sciences Allied to Medicine and Biology

J. R. Roberts, B.Sc., Ph.D.

Standing Committee of Kindred Societies

Major-General Sir Leonard Atkinson, K.B.E., B.Sc. (*Past President*)
Graham D. Clifford, C.M.G. (*Fellow*)

Appendix 7

Members representing the IERE on Technical Committees of the British Standards Institution

EEL/–	**Electronic Equipment**	Brigadier R. Knowles, C.B.E. (*Fellow*)
ECL/–	**Electronic Components**	Brigadier R. Knowles, C.B.E. (*Fellow*)
E/–/12	**Maintenance/Terotechnology**	L. A. Bonvini (*Fellow*); Brigadier R. W. A. Lonsdale, B.Sc. (*Fellow*)
EPC/1	**Acoustics**	W. V. Richings (*Fellow*)
LEL/103	**Medical Electrical and Radiological Equipment**	R. Brennand (*Member*)
LEL/103/2	**Electro-Medical Equipment**	A. J. Huelin (*Member*)
LEL/103/–/4	**Safety—Medical Electrical and Radiological Equipment**	A. J. Huelin (*Member*)
LEL/103/–/5	**Installations—Medical Electrical and Radiological Equipment**	A. J. Huelin (*Member*)
GEL/TLE/1	**Terminology Common to Power and Telecommunications**	E. H. Jones, B.Sc. (Eng.) (*Fellow*)
GEL/TLE/1/1	**Fundamental Terminology**	E. H. Jones, B.Sc. (Eng.) (*Fellow*)
GEL/TLE/1/10	**General Heavy Electrical Terminology**	E. H. Jones, B.Sc. (Eng.) (*Fellow*)
GEL/TLE/1/20	**Magnetism Terminology**	E. H. Jones, B.Sc. (Eng.) (*Fellow*)
NSS/5/6	**Audio Aids (School Music)**	M. H. Evans (*Member*)
ECL/5	**Electronic Tubes and Valves**	G. R. Jessop (*Member*)
ECL/5/8	**Tube and Valve Performance—Light Conversion**	(*vacant*)
EEl/8/8	**Oscilloscopes**	D. Styles (*Member*)
ECL/12/5	**Microwave Semiconductor Devices**	R. R. Harman (*Member*)
GEL/6	**Electronic Reliability**	Brigadier R. Knowles, C.B.E. (*Fellow*)

ECL/17	**Integrated Electronic Circuits** (*vacant*)	
ECL/17/1	**Performance of Integrated Electronic Circuits** (*vacant*)	
EEI/23	**Radiation-induced Ignition and Detonation** Col. F. R. Spragg, B.Sc. (*Fellow*)	
EEL/23/–/1	**Research and Development Co-ordination** Col. F. R. Spragg, B.Sc. (*Fellow*)	
EEL/24	**Electro-Acoustics** S. Kelly (*Fellow*)	
EEL/24/1	**Audio Engineering** S. Kelly (*Fellow*)	
EEL/25	**Radio Communication** R. Larry (*Fellow*)	
EEC/25/4	**Aerials** C. Hale (*Member*)	
EEL/26	**Performance of Household High Fidelity Audio Equipment** R. S. Roberts (*Fellow*)	
MEE/41	**Code of Practice on the Safe Use of Cranes** W. P. Rowley, M.B.E. (*Fellow*)	

Appendix 8

Award of Institution Premiums for 1976

Main Premiums

CLERK MAXWELL PREMIUM *Value £75*
'An automatic clarifier for s.s.b. speech communication'
Professor W. Gosling (University of Bath), Dr S. R. Al-Araji (University of Iraq) and J. R. Olivera (University of Havana)
(Published in the February 1976 issue of the Journal)

HEINRICH HERTZ PREMIUM *Value £50*
(Physical or mathematical aspects of electronics or radio)
'Performance of an M-ary p.s.k. system in the presence of additive noise, inter-symbol interference and fading'
Dr J. Nowakowski and I. Protasewicz (Technical University of Gdansk)
(February)

MARCONI PREMIUM *Value £50*
(Engineering)
'An h.f. channel simulator using a new Rayleigh fading method'
J. D. Ralphs (Communications Engineering Department, Foreign and Commonwealth Office) and F. M. E. Sladen (University of Southampton)
(December)

Specialized Technical Premiums

CHARLES BABBAGE PREMIUM *Value £25*
(Computers)
'Integrator design for a differential analyser'
W. Forsythe (University of Technology, Loughborough) and S. L. Houseman (IBM Laboratories, Hursley Park)
(December)

LORD BRABAZON PREMIUM *Value £25*
(Aerospace, maritime and military systems)
'Identification of complex geometrical shapes by means of low-frequency radar returns'
Dr Y.-T. Lin (Sandia Laboratories, Albuquerque, New Mexico and Professor A. A. Ksienski (Ohio State University ElectroScience Laboratory)
(October)

REDIFFUSION TELEVISION PREMIUM *Value £50*
(Communications)
'Surface acoustic wave matched filters for communications systems'
K. V. Lever, Dr E. Patterson, P. C. Stevens and I. M. Wilson (GEC Hirst Research Centre)
(May)

A. F. BULGIN PREMIUM *Value £25*
(Components and circuits)
'Signal processing applications of charge-coupled devices'
Dr J. Mavor (University of Edinburgh)
(August/September)

SIR CHARLES WHEATSTONE PREMIUM *Value £25*
(Instrumentation and measurement)
'The use of a high sensitivity ultrasonic current meter in an oceanographic data acquisition system'
T. Gytre (Institution of Marine Research, Bergen)
(December)

General Premiums

ARTHUR GAY PREMIUM *Value £25*
(Production techniques)
'The development of an automatic wiring analyser system for testing telephone switching rack backplanes'
B. Coolbear (Standard Telephones & Cables Ltd.) and G. Lovitt (Standard Telecommunication Laboratories Ltd.)
(July)

LESLIE MCMICHAEL PREMIUM *Value £25*
(Management techniques)
'The comparative cost of associative memory'
R. M. Lea (Brunel University)
(October)

SIR J. C. BOSE PREMIUM *Value £25*
(Outstanding paper by an Indian scientist or engineer)
'The synthesis of ladder networks with resistances at both ends by the recurrent-continuant method'
Dr D. K. Jha and Dr S. C. Prasad (University of Bihar, India)
(August/September)

LOCAL SECTIONS PREMIUM *Value £25*
(Outstanding paper first read before any of the Local Sections in Great Britain outside London)
'Submillimetre waves—a survey of the "state of the art" and some recent developments in research'
Dr R. J. Batt (Portsmouth Polytechnic) and Professor D. J. Harris (UWIST)
(August/September)

Papers of sufficiently high standard were not published within the terms of the following Premiums and they are withheld:

J. Langham Thompson Premium (Control engineering)

Dr V. K. Zworykin Premium (Medical and biological electronics)

P. Perring Thoms Premium (Radio or television reception)

Dr Norman Partridge Premium (Audio frequency engineering)

Lord Rutherford Premium (Atomic or nuclear physics)

Eric Zepler Premium (Education of electronic and radio engineers)

Admiral Sir Henry Jackson Premium (History of radio or electronics)

Hugh Brennan Premium (North Eastern Section paper)

NOMINATIONS FOR ELECTION TO COUNCIL

Brief Biographical Notes

In accordance with Bye-Law 43 the Council's nominations for election to the 1977–78 Council were notified to Corporate Members in the June issue of the Institution's Journal.

FOR ELECTION AS PRESIDENT OF THE INSTITUTION

Professor William Alexander Gambling, D.Sc., Ph.D., B.Sc., F.I.E.E., Fellow 1964, Member 1958, age 50, has held a Chair in Electronics at the University of Southampton since 1964, and has been Head of the Department since 1974; he has also served as Dean of the Faculty of Engineering and Applied Science for two years. Professor Gambling graduated in Electrical Engineering from the University of Bristol; his Ph..D. was awarded by the University of Liverpool and his D.Sc. by the University of Bristol. Before going to Southampton, Professor Gambling was a lecturer at the University of Liverpool and he also spent two years as a postdoctoral research fellow at the University of British Columbia. He has held appointments as visiting professor at the Bhabha Atomic Research Centre, Bombay, and at the University of Colorado. He is a member of the Optics and Infra-Red Committee of the Electronics Research Council and of the Technology Sub-Committee of the UGC.

Actively involved in Institution affairs for many years, Professor Gambling has served as Chairman of the Southern Section Committee and of conference organizing committees, on the Education Committee, and as an Ordinary Member of the Council; he was a Vice-President from 1970–1973 and from 1974 to 1977. He is the IERE member on the Board of CEI.

FOR RE-ELECTION AS VICE-PRESIDENTS

Professor David Evan Naunton Davies, D.Sc., Ph.D., B,Sc., F.I.E.E., Fellow 1974, Member 1962, age 41, has held a Chair in Electrical Engineering at University College London since 1971.*

D. E. N. Davies

W. Gosling

Denis William Heightman. Fellow 1968, Member 1942, age 65, is a director/consultant to Thorn Television Rentals Ltd.*

Professor William Gosling, B.Sc., F.I.E.E., M.Inst.P., Fellow 1968, age 45, is Head of the Electronics Group at the School of Engineering at the University of Bath.†

Raymond Clement Hills, B.Sc.(Eng.), F.I.E.E., Fellow 1972, Member 1961, age 44, is Chief Engineer, Transmitters, of the Independent Broadcasting Authority.†

Professor James Roderick James, Ph.D., B.Sc., F.I.E.E., Fellow 1975, Member 1960, Graduate 1956, age 44, holds the Chair of Electronics at the Royal Military College of Science, Shrivenham.*

John Powell, T.D., B.Sc., M.Sc., Fellow 1965, Member 1957, Graduate 1953, age 53, is Chief Engineer (Submarine Systems) with Cable and Wireless Ltd.*

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*See also August 1975 Journal †See also August 1976 Journal

D. W. Heightman

R. C. Hills

J. R. James

J. Powell

FOR RE-ELECTION AS HONORARY TREASURER

Sydney Rutherford Wilkins, Fellow 1942, Member 1935, Associate 1934, age 66, is Managing Director of Fleming Instruments Ltd. He was first elected Honorary Treasurer in 1973. (A fuller note on his professional career was published in the Journal for September 1972.)

S. R. Wilkins

A. F. Dyson

FOR ELECTION AS ORDINARY MEMBER OF COUNCIL

From the Class of Members

Arthur Frank Dyson (Member 1968, Graduate 1962) age 44 years, gained his Diploma in Electrical Engineering from Rugby College of Technology in conjunction with a 'sandwich' course at the British Thomson Houston Co. Ltd. He then moved to the BT-H Semiconductor Division at Lincoln and worked on the development of power semi-conductors. In 1961 Mr. Dyson went to the USA and joined Erie Technological Products Inc. He returned to the UK in 1963 and joined Erie Electronics Ltd., as assistant general manager, becoming engineering director of Erie's UK Group in 1967. Following the company's assimilation into ITT Components Group Europe, he is now Director of the Resistor Division at Great Yarmouth.

Colloquium Report: Printed Circuit Wiring

A Components and Circuits Group Colloquium held at the Royal Institution, Albemarle Street, London on 24th May 1977

This very relevant and practical topic provided the setting for a lively half-day colloquium in which four speakers gave widely differing presentations. The first contribution, by Mr. G. D. Pound of Marconi Space and Defence Systems, on 'The Philosophy Behind Modern P.C.B. Plants' was delivered with profound personal knowledge. He gave a first-hand, authoritative account of the various aspects of setting up a plant, such as for the one which he had set up in Scotland. These ranged from the standardization of laminate size to the pollution problems associated with the disposal of processing chemicals. This proved to be a most appropriate talk with which to set the scene in current printed-circuit board technology.

A paper 'Quality Assurance Solderability Testing' written by Mr. G. C. Wilson and delivered by Mr. D. S. Kingsley (Ferranti), looked at the problems associated with the storage of printed-circuit boards, an aspect which is often conveniently overlooked. On the one hand it makes good sense to manufacture a large batch of printed-circuit boards, but unless these are stored properly, consequences may arise, of which Mr. Kingsley gave graphic descriptions. Experiments with accelerated ageing of circuit boards in the presence of steam and oxygen were described in his presentation, and the impression was gained that rate of deterioration is well understood and Ferranti has contributed a great deal to this understanding.

Mr. T. Hogan (Welwyn Electric) gave a theatrical presentation under the title 'An Illustrated Guide to Flexible Circuits'. This was made possible by the singularly impressive nature of flexible circuits and their application to systems wiring. Some case-histories he presented provided unique illustrations, in particular, the dramatic cost reduction which is possible when cable harnesses are replaced by flexible circuits. There is no doubt that this technology will be exploited enthusiastically in the immediate future.

A competitive method to flexible circuits formed the topic of the final contribution by Mr. C. C. M. Wright of Intel Connectors (not associated with the US computer company). Mr. Wright addressed the audience on 'Flat Cable/Connector Systems', and while this was on the periphery of the theme of the colloquium it provided one of the most lively discussions of the afternoon. This method of interconnection is applicable to situations of low-quantity production and dramatically reduces the cost of back-plane wiring within electronic cubicles. Mr. Wright was able to demonstrate the engineering methods of the system with a comprehensive range of connectors and cables.

The discussion period highlighted various aspects of the four talks and the audience subsequently enthusiastically gathered details at close range from the exhibits displayed by the speakers. For the last half hour, the lecture room resembled a street market while those attending gleaned information from the speakers and there is no doubt that the occasion proved valuable for all concerned.

ALAN PUGH

IERE News and Commentary

Move to New IERE Headquarters

The Institution will vacate 8/9 Bedford Square and will move into smaller, modern and more efficient rented premises at 99 Gower Street, London, WC1E 6AZ during August/September 1977. The object of this operation, which is highlighted elsewhere in this issue of the Journal, is to avoid commitment to the further swingeing increase in rent due in April 1978 under the terms of the Lease on 8/9 Bedford Square and to reduce all other elements of the Institution's housing costs as much, and as quickly, as possible.

The phased plan for the move has been devised to minimize disruption to services to members during August/September and to ensure as far as possible that all facilities are re-established in the new building in time for the start of the new session of professional activities. Mail should be addressed to the Institution at 99 Gower Street, London, WC1E 6AZ, with effect from 16th September. The Bedford Square telephone exchange (01-637 2771) will, however, continue to provide a telephone service for the headquarters until 30th September, when the Institution's new exchange at 99 Gower Street will take over the task, using the new telephone number 01-388 3071.

More detailed information on the new headquarters building and its place in the Institution's long-term housing plan will be included in the October issue of the Journal.

Vice Chairman Designate for CEI

The Board of the Council of Engineering Institutions at its meeting of 28th July 1977 gave unanimous approval to the appointment of Dr George S. Hislop as Vice-Chairman Designate of the Council for 1978–9. Dr Hislop will take up the appointment after the Council's Annual Meeting which will be held towards the end of January 1978. It is customary for the Vice-Chairman to succeed to the Chairmanship of the CEI after one year in office.

The present Chairman of the Council, whose term of office will be completed in January 1978, is Sir Charles Pringle, and the Vice-Chairman is Sir John Atwell.

Dr Hislop is an aeronautical engineer of international repute and was President of the Royal Aeronautical Society in 1973–4. He has served on the Board and the Executive Committee of the Council of Engineering Institutions for a number of years.

New Members Elected to CEI

At its meeting on 28th July 1977 the Board of the Council of Engineering Institutions resolved to elect the Institution of Metallurgists to Constituent Membership. This brings the number of Constituent Members of CEI to sixteen.

Elected to Affiliate Membership were the Institution of Nuclear Engineers and the Institution of Highway Engineers. There are no other Affiliates.

The Council's Chairman, Sir Charles Pringle, comments that these elections represent 'a significant development for CEI, which is anxious to ensure that the professional interests of qualified engineers of all disciplines are even better represented to the nation'.

ICI Diagnostic Techniques Prize

Following the successful symposium 'Diagnostic Techniques' held by the Northern Branch of IChemE last September, ICI Limited has established a prize of £1,000 to be awarded annually for five years and to be administered by the Institution of Chemical Engineers.

The prize is being awarded in the belief that engineering equipment integrity is of the first importance in safe plant operation. Since the traditional technique of inspection has been found wanting in so many situations, ICI believes that on-line methods of testing must become increasingly important. Consequently the prize will be awarded for the best innovative technique, or new application of existing technology, preferably capable of use in more than one industry and certainly capable of application to plants currently in operation. It is open to individuals, groups or companies. Patent rights will remain with the prizewinner.

Entries will be examined by a small panel which will include the Chairman of the Institution's Engineering Practice Committee, and a representative of ICI Limited as well as experts in the field of diagnostic techniques and non-destructive testing. A brief outline of the technique, together with an indication of possible applications and the industries in which it would appear to be most useful, should be sent by 31st October 1977 to: Senior Technical Officer, The Institution of Chemical Engineers, 165–171 Railway Terrace, Rugby, CV21 3HQ.

Part-time Degrees for Technician Engineers

An opportunity for technician engineers to study for a degree is to be provided by the North East London Polytechnic who are starting a part-time course for the B.Sc. in Engineering this September. It will prepare the student for a career as a graduate engineer in industry, offering general engineering education as well as the opportunity to specialize in the final years.

The course, which is located at Barking precinct, lasts four years, involving attendance for one day and one other evening each week. Assessment throughout the course is by yearly examinations and applicants must be over 21. A Higher National Diploma or a good Higher National Certificate in an appropriate subject will normally be required to qualify for entry and all candidates will be interviewed.

Further information can be obtained from the Engineering Faculty Registrar, North East London Polytechnic, Longbridge Road, Dagenham, Essex RM8 2AS (Telephone 01-599 5141 ext. 37).

The Engineering of Microprocessing Systems

ERA is undertaking a major investigation into the engineering of microprocessor systems, the need for such a project having been indicated by the views of a sample survey of both experienced and first-time users carried out by ERA early in 1977. The work will be tackled on a multi-client basis and firm support has already been given by several major companies. ERA is inviting further organizations to join the project.

Three important but unresearched areas of microprocessor system development are being investigated. These are:

the economics of microprocessor-based systems

microprocessor development unit hardware

microprocessor support software

These three areas are of particular importance because the development of a microprocessor-based product can be very expensive, typically involving two man-years of effort and a capital expenditure of about £10,000 on equipment and support software. As the quality of both hardware and software support varies tremendously from manufacturer to manufacturer, so the final cost of developing a product is heavily influenced by the choice of development unit and the software support available.

ERA will therefore be examining the development of microprocessor-based systems in order to generate comparative data and guidelines to assist in the choice of the best development units. In addition, in the first phase of the project, ERA will prepare more general guidelines on how to assess and manage a microprocessor project and its attendant software problems. This part of the work will be based on the experiences of both users and manufacturers.

The major part of ERA's effort will be devoted to a laboratory-orientated investigation of a number of development units and software support programs. These will be selected to cover the range of most commonly used microprocessors. This work is considered to be of special importance because support software in particular is normally not very well specified. In addition, it is only through a 'hands-on' investigation that the performance of support software can be properly evaluated.

The project will be of special interest to companies developing microprocessor-based products, users of such systems, and the microprocessor industry and its associated supporting companies. It will begin in September 1977 but before that time it is planned to consult further with sponsors to consolidate the details of the programme of work. Interested companies should contact Chris Nabavi, ERA Ltd, Cleeve Road, Leatherhead, Surrey KT22 7SA. (Telephone: Leatherhead 74151).

IBC 78

The next International Broadcasting Convention—IBC 78—will take place in London from 25th to 29th September 1978, at the New Wembley Conference Centre instead of Grosvenor House which has been the venue for the past five Conventions. This move, announced in May last year, to London's first purpose-built convention centre will enable the IBC to benefit from the first-class facilities at Wembley while still being based in London, one of the main centres of broadcasting in the world, and able to offer all the amenities of the Capital.

IBC 78 is the seventh in a series of biennial broadcasting conventions which have become firmly established as an international forum for new techniques in broadcasting and allied services and one of the world's leading international market places for the latest broadcasting equipment and systems. Each of these events has shown a dramatic growth in the number of delegates attending and countries participating. Records were again broken at IBC 76 when more than 2600 delegates from 51 countries attended and at the complementary exhibition, 72 exhibitors representing leading manufacturers of the world displayed and demonstrated the latest professional broadcasting equipment and services. It is expected that this growth will be continued at IBC 78.

The IBC is organized by UK Committees with the support of Corresponding Members worldwide and is sponsored by the Electronic Engineering Association, the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers, the Institution of Electronic and Radio Engineers, the Royal Television Society and the Society of Motion Picture and Television Engineers. The IERE members of the IBC 78 Management Committee are Mr P. L. Mothersole and Mr R. S. Roberts.

Enquiries in connection with IBC 78 should be addressed to the Secretariat, International Broadcasting Convention, IEE, Savoy Place, London WC2R 0BL.

Engineering Industry Training Levy Order

Mr Albert Booth, Secretary of State for Employment, has approved proposals submitted by the Engineering Industry Training Board for a levy on employers within the scope of the Board equal to 1% of their payroll in the year ended 5th April 1977. The Order (SI 1977 No. 849, H.M.S.O., price 25p) came into operation on 24th June 1977.

Employers in the Engineering firms who employ no more than 60 people will be exempt from the levy which is used to finance a wide variety of training in the industry. Employers who satisfy the Board that they adequately meet their own training needs may seek exemption from the levy.

The Engineering Industry Training Board was constituted in July 1964 and covers approximately 25,000 establishments and 3·1 million employees.

Standard Frequency Transmissions—June 1977

(Communication from the National Physical Laboratory).

June 1977	Relative Phase Readings in Microseconds NPL—Station (Readings at 1500 UT)		
	MSF 60 kHz	GBR 16 kHz	Droitwich 200 kHz
1	6·2	6·0	30·6
2	6·0	6·0	30·2
3	5·7	6·0	30·1
4	5·6	5·6	30·4
5	5·4	5·8	30·9
6	5·3	5·8	31·2
7	5·1	5·8	31·7
8	5·1	5·8	31·9
9	5·2	5·9	32·0
10	5·0	5·7	32·1
11	5·0	5·8	32·2
12	5·1	5·8	32·0
13	4·9	5·6	31·8
14	4·9	5·6	31·8
15	4·8	5·7	31·8
16	4·9	5·7	31·8
17	4·7	5·8	31·8
18	4·9	5·9	32·0
19	4·9	5·8	32·0
20	4·9	5·9	32·0
21	4·8	5·7	32·0
22	5·0	5·4	32·2
23	5·2	5·5	32·4
24	4·6	5·3	33·2
25	4·7	5·1	34·0
26	4·5	6·2	34·8
27	4·4	5·3	35·5
28	4·3	5·3	36·2
29	4·1	5·2	36·9
30	3·9	5·1	37·5

Notes: (a) Relative to UTC scale (UTC_{NPL}–Station) = +10 at 1500 UT, 1st January 1977.

(b) The convention followed is that a decrease in phase reading represents an increase in frequency.

(c) Phase differences may be converted to frequency differences by using the fact that 1 μs represents a frequency change of 1 part in 10^{11} per day.

Members' Appointments

CORPORATE MEMBERS

Mr. D. W. Hinde, B.Sc. (Fellow 1963, Member 1956) who has been Head of the Department of Electrical and Electronic Engineering at Huddersfield Polytechnic since 1960, latterly as Dean of Engineering, has recently retired. After reading electrical engineering at the University of Leeds he held posts in industry between 1937 and 1946 when he began his teaching career with the Huddersfield Education Committee as a full-time Lecturer in Electronics and Radio Engineering in 1946. He was the first Chairman of the Yorkshire Section, having played a leading part in its formation and in this capacity he was a member of Council from 1965 to 1967.

Sqn. Ldr. D. R. Ainge, RAF (Member 1973, Graduate 1967) has served as Electrical Engineer 1A at RAF Rheinahlen in West Germany for the past two years, and has now returned to the UK to take up an appointment as Senior Project Officer, Tactical Communications, at the School of Signals at Blandford Camp in Dorset.

Wing Cdr D. G. J. Breadner, B.Sc., RAF (Member 1968, Graduate 1963) has taken up an appointment as Officer Commanding No. 30 Maintenance Unit, RAF Sealand after leaving RAF Valley, Holyhead, where he has been Officer Commanding Engineering Wing, since 1975.

Sqn. Ldr. B. V. Canton, RAF (Member 1973) has been posted from the Computer System design team at Support Command Signals Headquarters at RAF Medmenham and is now a Member of the Air Defence Environment Team (RAF), at the Ministry of Defence.

Mr. S. J. Morris, B.Sc. (Member 1977, Graduate 1973) has been appointed Senior Physicist in the Department of Medical Electronics, Royal Devon and Exeter Hospital. He was previously at the University Hospital of Wales, Cardiff.

Mr. J. A. Ferla (Member 1973, Graduate 1961), formerly a Senior Lecturer in charge of Electronics at the Zambia Institute of Technology, Luanshya and Head of the Department of Electrical Engineering at the Morrison Hill Technical College of Hong Kong, since 1975, is to read for an M.Sc. degree in Educational Studies at the University of Aston in Birmingham in the coming academic year.

Major J. A. Hall, M.Sc., REME (Member 1974, Graduate 1965) has left RSRE to take up a similar post as Officer in Charge 9 Maintenance Advice Group at the Telecommunications Branch REME, in Malvern.

Mr. D. L. Hopkins (Member 1973, Associate 1971) has left the Marconi International Marine Company to take up an appointment as Senior Controller (Telecommunications) in the Hong Kong Post Office. He has been Technical Manager with Marconi Marine since 1975 having joined the Company as a Radio Officer on the Marine Staff in 1956.

Mr. M. W. Molyneaux (Member 1973, Graduate 1968) has joined Langner-Parry, London, as Assistant Chartered Patent Agent. He was previously a Chartered Patent Agent with The Marconi Company Limited and before joining the Patent Department in 1960 had been employed as a Research and Development Engineer on h.f. receiver design.

Sqn. Ldr. C. W. Pratley, RAF (Member 1973, Graduate 1969) has moved from an appointment at the Ministry of Defence to take up the post of Engineer (Electrical) 1 at HQ 38 Group, RAF Upavon, Wiltshire.

Mr. I. L. Rubery (Member 1973, Graduate 1970) has been appointed a Section Leader at Rolls Royce and Associates Limited, Derby; he joined the company in 1972 as an Electrical and Control Engineer.

Mr. R. Stevens (Member 1973, Graduate 1970) who has been with the British Broadcasting Corporation for some 14 years, since 1974 as Supervisor of the Electronics Workshop of BBC Wales in Cardiff, has taken up an appointment as a Test Engineer with RCA (Jersey) Ltd.

Mr. C. Winspur (Member 1973, Graduate 1970) has been appointed Senior Consultant Inspection Engineer at J. H. Haggie Patterson and Associates Ltd., Birmingham. For the past 6 years he has been with Newman Electrics Ltd., first as Chief Engineer in the Control Gear Division and subsequently as a Director.

Lt. Cdr. A. Woodward, RN (Member 1973, Graduate 1968) has moved from HMS *Excellent* where he was a Management Lecturer to the Royal Naval Engineering College, Manadon, as Head of Management Studies.

NON-CORPORATE MEMBERS

Mr. T. Sundararajah (Graduate 1971) is now an Application and Contract Engineer with Plessey Telecommunications Ltd., Beeston.

Mr. R. J. Roberts (Associate Member 1976) who joined the Mitel Corporation of Ottowa, Canada in 1976, and subsequently worked with Mitel International, Shannon, is now Telecom Engineering Manager for Mitel Telecom in Slough.

Mr. R. J. Weston (Graduate 1970) has been appointed Head of Environmental Noise Cell at the RAF Institute of Community Medicine, Halton. He was previously at the RAF Department of Clinical Measurement.

Obituary

The Institution has learned with regret of the deaths of the following members.

Dr. Wernher von Braun (Honorary Fellow 1974) died on 16th June 1977 aged 65 years. He leaves a widow, one son and two daughters.

A graduate and doctor of the University of Berlin, Wernher von Braun developed an interest in the possibilities of rocket propulsion while still a student, carrying out experiments with liquid fuelled projectiles in 1930. For two or three years this activity continued with a 'Spaceship Travel Club' of enthusiasts like himself, but in 1932 the German Army became interested, provided funds and facilities, and von Braun became Rocket Development Engineer in the Ordnance Department. Subsequently the Liquid Fuel Rocket and Guided Missile Centre was set up at Peenemünde and as Technical Director he developed a series of rockets which culminated in the V-2: changes in Government priorities meant that this formidable weapon was not produced in sufficient numbers to affect the outcome of the War.

Together with members of his team and some 100 complete V-2s, von Braun went to the United States and between 1946 and 1951 a programme of upper atmosphere research using these rockets was carried out in New Mexico. Von Braun became Project Director of Guided Missile Development and his subsequent work as Director of Development Operations for the US Army Ballistic Missile Agency led in 1956 to the *Jupiter* ICBM and, two years later, to the launching of the first US satellite *Explorer*.

In 1960 von Braun was appointed Director of the NASA Space Flight Centre and his finest achievement was seen in the development of the *Saturn V* rocket which launched the *Apollo* series of manned lunar missions, crowned by the first landing in 1969.

It was his direction of this great project, depending so much on the association of electronic techniques of extraordinary complexity, that influenced the Institution in inviting Dr. von Braun to give the Eighth Clerk Maxwell Memorial Lecture which, typical of his forward looking approach, he entitled 'Our Space Programme after *Apollo*'*.

The Lecture in London in March 1974 attracted a record attendance and a year

The Radio and Electronic Engineer*, **74, No. 6, pp. 297–306, June 1974.

later he came back to sign the Roll of Honorary Fellows of the IERE. He received many other recognitions by academic and learned bodies throughout the world of his great contributions to the technology of space flight.

Following his retirement from NASA as Deputy Associate Director, Wernher von Braun joined Fairchild Industries to become Corporate Vice-President for Engineering and Development. He retired early this year, soon after the onset of his final illness.

William Frederick Bonage (Member 1969, Associate 1954) died on 10th January 1977 aged 56. He leaves a widow, a son, a daughter and a step-daughter.

Born and educated near Portsmouth, William Bonage served as a radio mechanic in the RAF from 1941 to 1946 and on demobilization entered the Colonial Service. He held the appointment of Assistant Signals Officer with the Government of Sierra Leone from 1946 to 1954 and for the next two years was Station Superintendent Engineer at the Nigerian Posts and Telecommunications Department's Experimental Station at Jhagi, Lagos. On returning from the Colonial Service Mr. Bonage joined the Marconi Company, first as Assistant to the Chief of Sales and Project Engineering and subsequently becoming Chief of Contracts (Engineering) with the Communications Division, where he was concerned with supervision of a variety of h.f. and v.h.f. point-to-point systems. At the time of his death he was Commercial Manager (Home Sales) with Marconi Communication Systems Ltd.

Commandant Matthew Murphy, Irish Defence Force (Member 1960, Student 1947) died on 13th February 1977, aged 54 years. He leaves two sons and a daughter.

Matthew Murphy was born in Charleville, Co. Cork, and enlisted in the Defence Forces in 1941. He was commissioned in the Permanent Defence Force in 1944 and after passing the Long Course for Signals Officers at the Curragh Camp he was appointed a Signal Section Officer. Following study at the Dublin College of Technology and passing the Foreign Officers Radar Course at RAF Yatesbury, Wiltshire, he was appointed Officer Commanding Air Signals with the rank of Commandant. In 1964 he took up the appointment of Officer in Charge of Workshops, Depot Signal Corps, the post he held up to his death.

Commandant Murphy held his membership of the IERE in high regard and he sat several parts of the Graduateship examination to gain full exemption prior to his election to Corporate Membership. It was a matter of regret to him that proposals for a Dublin Section of the Institution had not been realized.

Michael Francis Keating (Graduate 1970) died in April 1977 at the age of 47 years, leaving a widow.

Following his initial technical education in Harrogate, Michael Keating entered the Army Apprentices School at Arborfield in 1946 and served in REME eventually becoming a Warrant Officer 1. During his Army career he obtained the HNC in electronic engineering and he held both workshop and instructor posts. For two years prior to his retirement from the Army he was an Assistant Project Officer in the Radar Branch, Technical Group REME at Malvern, concerned with automatic test equipment for the *Rapier* guided missile system. In 1972 he was appointed Lecturer Grade I in telecommunication and electronics at Exeter College of Further Education and he helped to set up the College's courses for the OND (Technology) for which he taught electrical subjects.

Michael Doyle (Member 1971, Graduate 1967) died in May 1977, aged 39 years, leaving a widow.

He had been with the Research Department of the Post Office since he entered it as a Youth-in-Training in 1955 and for the past eight years he was an Executive Engineer. He had been working on line aspects of digital transmission systems for most of this time and had been investigating 120 Mbit/s p.c.m. at the Martlesham Research Centre since 1975.

Frank Hardman Fryer (Member 1954, Associate 1946) died on 2nd June 1977, aged 57 years. He leaves a widow.

Born and educated in Oxford, Frank Fryer served in the Royal Navy during the War, and qualified as Lieutenant in 1945 after completing the Long Radar Course. He returned to civilian life to join the Kodak Research Laboratory and after two years transferred to the Engineering Division as an Industrial Electronics Engineer. In 1954 he moved to the Midlands to take up an appointment as an Engineer with Lancashire Dynamo Electronic Products Ltd.

Professor Gerald Norman Patchett (Fellow 1954, Member 1951, Associate 1943) died on 19th July 1977, age 60 years. He leaves a widow, a son and a daughter.

Professor Patchett who was Head of the Department of Electrical Engineering at the University of Bradford played a major part from the beginning in the development of the Bradford Institute of Technology and the University. He established the first successful sandwich course at degree level at the Institute, and this became the basic pattern of undergraduate work in the University, ensuring the close co-operation of the University and industry. As Dean of the Board of Studies in Engineering of the University in its formative years, he helped in the development which made the University a major centre for a spectrum of engineering sandwich courses in the UK.

His entire education and career were associated with Bradford since 1933, when he attended the Bradford Grammar School. In 1934 he embarked on a course at the Bradford Technical College leading to the external London degree of B.Sc., which he gained with first class honours. At the same time he received the Bradford Technical College Diploma in Electrical Engineering, together with the Harlow Memorial Medal, awarded to students of outstanding merit. In 1946 he obtained a Doctorate in Engineering from the University of London.

Apart from early posts with the Bradford Electricity Department Gerald Patchett spent the whole of his professional life in the service of electrical engineering education in Bradford, first with the Technical College, where he was appointed to the full-time temporary staff in 1942; in 1945 he became an Assistant Lecturer and a Senior Lecturer in 1951. He was appointed Head of the Department of Electrical Engineering in the following year and held this position in the Bradford Institute of Technology on its establishment in 1957. On the founding of the University of Bradford, nine years later, he became the first Professor of Electrical Engineering.

To many engineers Professor Patchett's name will be associated with his numerous books, papers and articles, many on power supply stabilization and timebases, but above all he will be remembered with appreciation for the highly effective introduction to colour television which he gave to literally thousands. These lectures were given at centres throughout the country during the 'fifties and early 'sixties and were characterized by the highly professionally stage-managed demonstrations (requiring a small furniture van as transport) which supported the admirable oral presentation; this formed the basis of a paper in the Institution's Journal† and subsequently he published a book on the subject.

Professional bodies associated with Gerald Patchett's research interests all benefited from his efforts and he co-operated with the IERE Education and Training Committee on numerous occasions. He also served as a representative of electrical/electronic engineering on the Regional Educational Advisory Committees.

A tribute by the Vice-Chancellor of the University of Bradford to Professor Patchett referred to his devoted service and the deep sense of loss which his death has left—sentiments which all who knew him personally or through his writings will share.

Douglas Rowland Willis (Graduate 1958) died on 7th April 1977, at the age of 52 years, leaving a widow.

He entered the General Post Office in 1942 as a Draughtsman-in-Training and then served ten years in the Royal Navy as a Petty Officer radio/radar mechanic. He returned to the Post Office in 1948, and after part-time study at Borough Polytechnic gained the H.N.C. in radio-engineering in 1950. At the time of his death he was a Senior Draughtsman at the Post Office Research Centre, Martlesham.

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† 'Colour television', *J. Brit. Instn Radio Engrs*, **16**, No. 11, pp. 591–620, November 1956.

New Books Received

All the books which are described below are available in the Library and may be borrowed by members in the United Kingdom. A postal loan service is available for those who are unable to call personally at the Library.

Secondary Radar: Fundamentals and Instrumentation

PETER HONOLD. Siemens, Munich, and Heyden, London. 1976. 21·5 × 15 cm. 224 pages. £9·50 (UK), $19·00 (US), DM61·00 (W. Germany).

CONTENTS: Coding for an SSR secondary radar system. Evaluation and presentation of the response information. Combination with the primary radar unit. The problems of antennae. Side-lobe suppression (SLS). Fruit and defruiters. Garbling. Reliability of the system. Design of interrogator units. The secondary radar transponder. Applications of the secondary radar process: Military; Civil air traffic control.

The use of secondary radar in aviation has grown rapidly in recent years and has reached a point where in those countries having the highest air traffic densities, the air traffic control systems are coming increasingly to depend upon it. In view of the important role now played by secondary surveillance radar, this English translation of Peter Honold's work on the subject is especially welcome.

As the author states, the topics covered are limited to secondary surveillance radar and the book does not attempt to cover other forms of secondary radar such as TACAN, DME, missile tracking beacons or marine applications. However, in its stated purpose of providing a useful handbook for all those engineers, technicians and operating staff who are actually responsible for the development, construction and maintenance of SSR equipment, the book succeeds admirably.

The translation has been well done and the meaning is always clear. The references given for further reading are very useful, although future editions could well include the paper by K. E. Harris entitled 'Some Problems of SSR Systems' published in this journal in July 1956, and the papers given at the conference, Radar—Present and Future, held in London in 1973.

The use of actual equipments to illustrate practice is excellent and one has no hesitation in recommending this book to all with an interest in SSR.

R. M. TRIM

Principles of Digital Data Transmission.

A. P. CLARK (*Loughborough University of Technology*). Pentech Press, London and Plymouth 1976. 21.5 × 14 cm. 246 pages. £4·25.

CONTENTS: Pt. 1—Non-mathematical survey: Data signals. Noise. Transmission of timing information. Modulation methods. Detection processes. Transmission rates. Binary data-transmission systems for use over telephone circuits. Multi-level data-transmission systems for use over telephone circuits. Data-transmission systems for use over h.f. radio links. Pt. 2—Digital-signal theory: Matched-filter detection. Rectangular baseband signals. Partial-response channels. Modulated-carrier signals.

At a time when the main trend in communications is towards digital techniques Dr. Clark has drawn on years of experience as a university lecturer to write a handbook for the communications student in this topic. The result is a useful aid which recognizes that in both learning and reference three levels of information are often required. The first half of the book describes qualitatively the principles involved and has some reference to practical digital communication systems. The second part provides deeper support through mathematical derivation and analysis, and then 474 references are given to provide a broad background reading which describes many practical applications.

In the first part of the book I found the system block diagrams and associated signal status illustrations clear and helpful. The logical teaching progression makes the book a good basis for a correspondence course. The references include papers published up to 1975 and they are well grouped under headings so that current practice in any particular application is soon established.

The communications engineer is deeply concerned in increasing intelligence transfer in minimum bandwidth. At only £4·25 this book sets a good example in bits per £ and should form a useful instructive book which the practising engineer would not be ashamed to have on his bookshelf.

L. A. BONVINI

Electronic Inventions 1745–1976

G. W. A. DUMMER. Pergamon Press. Oxford 1976. 27·5 × 19 cm. 158 pages. £4·00 (UK), $7·50 (US).

This is a compilation of original or (usually) subsequent survey descriptions of 295 inventions selected for their significance in the development of electronics. Despite, or perhaps because of, the inevitable differences in style, it is very readable, indeed compulsive, for once one dips into it, perhaps to check a date or reference, the eye is led on to the next fascinating entry, and so on! For those wishing to establish the antecedents of a device, or a system or even a theory, Mr. Dummer will almost certainly provide a useful starting point. It is interesting to note how many of the basic or subsequent review entries given are from the Journal of this Institution.

F.W.S.

Radio Communication Handbook Vol. 1 (Fifth Edition)

The Radio Society of Great Britain. London 1976. 19 × 25·5 cm. 460 pages £7·50.

CONTENTS: Principles. Electronic tubes and valves. Semiconductors. HF receivers. VHF and UHF receivers. HF transmitters. VHF and UHF transmitters. Keying and break-in. Modulation systems. RTTY.

First published in 1938, the Radio Communication Handbook is the world's largest and most comprehensive textbook on the theory and practice of amateur radio. The text has been completely revised and reset for this edition, and chapters on image and satellite communication have been added which reflect the current interest in these fields. Although written primarily for the amateur radio operator, the authoritative treatment of the subject matter will also ensure that the book finds a place on the shelf of the professional radio engineer.

Video Yearbook 1977

ANGUS ROBERTSON (*Editor*). Dolphin Press, Poole 1976. 22 × 14·5 cm. 286 pages. £4·75.

CONTENTS: Aerials—TV. Amplifiers—audio. Audio tape. Audio tape recorders. Books on TV topics. Camera mounts. Camera tubes. Cameras, broadcast and industrial. Caption scanners and devices. Character generators. Discs—video. Distribution systems—r.f. and h.f. Film recording—colour. International TV standards. Jargon. Lenses. Light meters. Lighting equipment—control equipment. Luminaires. Media. Links—video. Loudspeakers—monitor. Microphones. Mixers and effects generators—video. Modulators. Monitors—TV. Production companies and facilities (Broadcast and industrial). Projectors for TV. Prompters. Retailers, dealers and hirers of video equipment· Software suppliers and Libraries. Surveillance equipment and contractors. Talk-back equipment. Telecines broadcast and industrial. Teletext and Viewdata. Television broadcasting stations. Television training. Test equipment—audio and video. Timebase correctors, synchronizers and standards converters. Transmitters—broadcasting and communications. Tuners. Video tape, duplication facilities. Tape editing controllers. Video tape recorders.

Contains mainly descriptions of products and services available in the UK.

Computer Interfacing and On-Line Operation

J. C. CLULEY (*University of Birmingham*). Edward Arnold. London 1975. 23·5 × 16 cm. 181 pages. £7·95.

CONTENTS: Introduction. Principles of interfacing. On-line computer architecture. Interrupt handling. Communication circuits and data links. Signal processing. On-line applications.

Applicants for Election and Transfer

THE MEMBERSHIP COMMITTEE at its meeting on 11th July 1977 recommended to the Council the election and transfer of the following candidates. In accordance with Bye-law 23, the Council has directed that the names of the following candidates shall be published under the grade of membership to which election or transfer is proposed by the Council. Any communication from Corporate Members concerning the proposed elections must be addressed by letter to the Secretary within twenty-eight days after publication of these details.

Meeting: 11th July 1977 (Membership Approval List No. 236)

GREAT BRITAIN AND IRELAND

CORPORATE MEMBERS

Direct Election to Fellow

COEKIN, John Anthony. *Kingston-on-Thames, Surrey.*

Transfer from Graduate to Member

CARRUTHERS, Alexander Ralston. *Ipswich, Suffolk.*
FONG-YAN, William. *Harrow, Middlesex.*
HOLLINS, Graham William. *Birmingham.*
LOGAN, John Howard. *Uxbridge, Middlesex.*
MAGEEAN, James. *Wembley, Middlesex.*
NUTKINS, Terrence Stanley Joseph. *Hayes, Middlesex.*
ROWLEY, John Graham. *Fetcham, Middlesex.*
SEIGNOT, Philip Francis. *Newport, Gwent.*

Direct Election to Member

CROUCHER, Donald James Harry. *Blackhill, County Durham.*

NON-CORPORATE MEMBERS

MONYE, Andrew Okonkwo. *London.*

Direct Election to Associate Member

EGGAY, George Atta. *London.*
GOLDING, Everard Winston. *Birminghom.*

OVERSEAS

CORPORATE MEMBERS

Transfer from Member to Fellow

TOULL, Geoffrey Richard. *Latina, Italy.*
WISHART, Dean. *Boroko, Papua, New Guinea.*

Transfer from Graduate to Member

CHAN, Pui Lam. *Hong Kong.*
FERNANDO, Hettiakandage Michael Sunil. *Uyana Moratuwa, Sri Lanka.*
RAMASUNDARA, Mahinda. *Dehiwala, Sri Lanka.*
TAYLOR, David Edward. *Pinetown, Natal, South Africa.*

Direct Election to Member

CHAN, Kam-Shing Joseph. *Hong Kong.*

Direct Election to Graduate

MOHAMED, Ishtiaque Rashad. *Bangalore, India.*

Direct Election to Associate Member

AKALUSI, Joseph Blankson. *Lagos, Nigeria.*
ARMSTRONG, Ronald Hugh. *Christchurch, Barbados.*
CHEUNG, Kwong-Kuen. *Hong Kong.*
LIANG, Yew Jen. *Bintulu, Sarawak, Malaysia.*
OLADIMEJI, Isaac Bode. *Ilorin, Nigeria.*
VENKATARAMANAN, Srinivasan. *Calcutta, India.*

STUDENTS REGISTERED

ANG, Siew Bee. *Singapore.*
ANG, Yew Hock. *Singapore.*
AU, Pak Ming Hermit. *Hong Kong.*
CHAN, Man Yuen Martin. *Hong Kong.*
CHAN, Muk Chung Timothy. *Hong Kong.*
CHAN, Mun Yeung. *Hong Kong.*
CHAN, Pang Chiu. *Hong Kong.*
CHAN, Sau Yan. *Hong Kong.*
CHAN, Wai-Ming Francis. *Hong Kong.*
CHAU, Chak Hing. *Hong Kong.*
CHENG, Kin Chor. *Hong Kong.*
CHENG, Wan Kwong. *Hong Kong.*
CHENG, Yum Po. *Kong Kong.*
CHEUNG, Shan Tai. *Hong Kong.*
CHING, Siu Bun. *Hong Kong.*
CHOW, Yan-Chi Alexander. *Hong Kong.*
CHU, Kam Hung. *Hong Kong.*
CHU, Kam Yin Albert. *Hong Kong.*
CHU, Pee Tak Peter. *Hong Kong.*
CHUNG, Wai Hong. *Hong Kong.*
FUNG, Chung Hung. *Hong Kong.*
HO, Chun Hung. *Hong Kong.*
HO, King Tak. *Hong Kong.*
IP, Yu Wah. *Hong Kong.*
KO, Wai Sing. *Hong Kong.*
KWONG, Sai Hon. *Hong Kong.*
LAI, Ming Cheong. *Hong Kong.*
LAM, Kai Man. *Hong Kong.*
LAM, Po Yee Alex. *Hong Kong.*
LAM, Shun Fu. *Hong Kong.*
LAM, Siu Kwong. *Hong Kong.*
LAU, Chak Man. *Hong Kong.*
LAU, Wai-Keung Silas. *Hong Kong.*
LAW, Kin Kwok. *Hong Kong.*
LEE, Ka Hung Alex. *Hong Kong.*
LEE, Alexander Kam-Yiu. *Hong Kong.*
LEE, Ting-Wah Stanley. *Hong Kong.*
LEE, Voon Phaw. *Singapore.*
LEE, Wan-Hang. *Hong Kong.*
LEUNG, Kam Cheung. *Hong Kong.*
LEUNG, Yung Choi. *Hong Kong.*
LI, Chi Wai. *Hong Kong.*
LI, Tai Lau. *Hong Kong.*
LIAW, Thiam Song. *Singapore.*
LIM, Eng Hoe. *Singapore.*
LIU, Yan Wing. *Hong Kong.*
MAK, Man Keung. *Hong Kong.*
MAK, Tek Chee. *Hong Kong.*
MOU, Chong Yee. *Singapore.*
NG, Kam Hung. *Hong Kong.*
NG, Kam Shing. *Hong Kong.*
PAU, Pok Kun Kenneth. *Hong Kong.*
SIU, Ka Lam. *Hong Kong.*
SIU, Tung Hung. *Hong Kong.*
SUEN, Fu Foon. *Hong Kong.*
TAN, Kwang Chiang Donald. *Singapore.*
TANG, Chee Hong. *Singapore.*
TO, Shu Sing Sidney. *Hong Kong.*
TONG, Chak Hong. *Hong Kong.*
TONG, Kam Keung. *Hong Kong.*
TSANG, Hin For. *Hong Kong.*
TSUI, Bing Fong. *Hong Kong.*
TSUI, Lap Fung. *Hong Kong.*
WONG, Che Yan. *Hong Kong.*
WONG, Kam Shuen Patrick. *Hong Kong.*
WONG, Sek Kwong. *Hong Kong.*
WONG, Woon Ming. *Hong Kong.*
WU, Yiu Fat. *Hong Kong.*
YEUNG, Sik To. *Hong Kong.*
YIU, Ping Yee. *Hong Kong.*
YUEN, Oi Dong. *Hong Kong.*

Nominations Invited for the Marconi International Fellowship

Learned societies, academies, universities and individuals in industry and public life throughout the world are now being invited to propose candidates for the 1978 Marconi International Fellowship.

The Fellowship—a $25,000 grant—commemorates Guglielmo Marconi's creative contributions to scientific discovery, engineering and technology. Established in 1974 on the centenary of the inventor's birth, the Fellowship commissions significant creative works that will add to the knowledge and understanding of how communications, science and technology can be applied to the improvement of human life.

The Fellowship is granted to an individual in recognition of outstanding contributions towards this goal with the clear understanding that the grant is made to commission work by the recipient or some other person or persons the recipient designates. If the recipient designates another to undertake the work in connection with the Fellowship, both parties will be explicitly identified and appropriately recognized when the Fellowship is presented.

It is customary to invite the Fellowship recipient to deliver a public lecture based on the commission at an appropriate occasion during the twelve months following the presentation of the Fellowship.

The first three Fellowships have been awarded in the fields of communications and electronics to Dr. James R. Killian Jr., Honorary Chairman of the Massachusetts Institute of Technology, in association with Lord Briggs, Worcester College, Oxford University; to Professor Hiroshi Inoso, University of Tokyo; and to Professor Arthur L. Schawlow, Stanford University.

Nominations for the 1978 Marconi International Fellowship must be received by 15th October 1977. All inquiries should be addressed to: The Marconi International Fellowship Council, Aspen Institute for Humanistic Studies, 1919 Fourteenth Street, Boulder, Colorado, 80302, U.S.A.

Forthcoming Institution Meetings

Wednesday, 28th September

EDUCATION AND TRAINING GROUP

Colloquium on TRAINING TECHNICIANS IN ELECTRONICS

No. 3 Radio School, RAF Locking, Weston-Super-Mare, Avon, 10.30 a.m.

Advance registration essential. For further details and registration forms, apply to Project Officer, IERE Colloquium, RAF Locking, Weston-Super-Mare, BS2 74AA.

Thursday, 13th October

ANNUAL GENERAL MEETING OF THE INSTITUTION

London School of Hygiene and Tropical Medicine, 6 p.m. (Tea 5.30 p.m.).

Tuesday, 18th October

JOINT IERE/IEE COMMUNICATIONS AND COMPONENTS AND CIRCUITS GROUPS

Colloquium on A COMPARISON OF SAW, CCD AND DIGITAL TECHNOLOGIES

Royal Institution, Albemarle Street, London W1, 2 p.m.

Advance registration necessary. For further details and registration forms apply to Meetings Officer, IERE.

Tuesday, 1st November

AUTOMATION AND CONTROL SYSTEMS GROUP

Colloquium on LABORATORY AUTOMATION

Royal Institution, Albemarle Street, London W1, 2 p.m.

Advance registration necessary. For further details and registration forms apply to Meetings Officer, IERE.

Thursday, 3rd November

JOINT IERE/IEE MEDICAL AND BIOLOGICAL ELECTRONICS GROUP IN ASSOCIATION WITH SOUTH WALES SECTION

Colloquium on MODERN TRENDS IN THE ASSESSMENT OF CARDIO-PULMONARY FUNCTION

Welsh National Medical School, Cardiff.

Advance registration necessary. For further details and registration forms apply to Meetings Officer, IERE.

Tuesday, 15th November

COMPONENTS AND CIRCUITS GROUP

Colloquium on ANALOGUE FILTERS

Royal Institution, Albemarle Street, London W1, 10.30 a.m.

Advance registration necessary. For further details and registration forms apply to Meetings Officer, IERE.

Tuesday, 22nd November

AEROSPACE, MARITIME AND MILITARY SYSTEMS AND COMMUNICATIONS GROUPS

Colloquium on PORTABLE COMMUNICATIONS SYSTEMS

Royal Institution, Albemarle Street, London W1, 2 p.m.

Advance registration necessary. For further details and registration forms apply to Meetings Officer, IERE.

Tuesday, 29th November

JOINT IERE/IEE COMPUTER GROUP

Colloquium on ELECTRONIC SECURITY AND PERSONAL ACCESS SYSTEMS

Royal Institution, Albermarle Street, London W1, 10.30 a.m.

Advance registration necessary. For further details and registration forms apply to Meetings Officer, IERE.

Thames Valley Section

Thursday, 20th October

Microprocessor systems—principles and applications

By L. A. Crapnell (*Ferranti*)

Caversham Bridge Hotel, Reading, 7.30 p.m.

Thursday, 17th November

Viewdata

By K. E. Clark (*Post Office*)

The Caversham Bridge Hotel, Reading, Berks, 7.30 p.m.

Kent Section

Wednesday, 5th October

Microprocessing: Chapter 2

By a speaker from Jermyn Industries

Medway and Maidstone College of Technology, Horstead, Chatham, Kent, 7 p.m. (Tea 6.30 p.m.)

Thursday, 17th November

JOINT MEETING WITH IEETE, IPOEE AND MEDWAY AND MAIDSTONE COLLEGE OF TECHNOLOGY

London's telecommunications—switchboards to satellites

By K. Ford (*P.O. Telecommunications*)

Lecture accompanied by an exhibition of subscribers' apparatus (old and new) and also other telecommunications working systems including microwave equipment, cables and Post Office Tower model etc.

Medway and Maidstone College of Technology, Horstead, Chatham, Kent, 7 p.m. (Tea 6.30 p.m.).

Southern Section

Wednesday, 12th October

JOINT MEETING WITH IEE

Communications – a personal view

By D. L. Cooke

Room AB011, Portsmouth Polytechnic, King Henry I Street, Portsmouth, 6.30 p.m.

Thursday, 20th October

Electronic ignition

By Dr. M. J. Werson (*University of Southampton*)

South Dorset Technical College, Weymouth, 6.30 p.m.

Tuesday, 25th October

JOINT MEETING WITH IMA

Error correction—a simple Golay decoder

By R. A. Croft (*Plessey Co.*)

Lecture Theatre I, Southampton College of Technology, 6.15 p.m.

Thursday, 27th October

Quadraphony

C. Daubney and R. Collins (IBA)

Crawley College of Technology, 7 p.m.

Wednesday, 2nd November

JOINT MEETING WITH IEE

Symposium on The Planning and Design of the IBA's Radio and Television Transmitter Network

Three papers by R. Byrne, D. S. Chambers and R. Wellbeloved, IBA, Crawley Court, Winchester, 3 p.m.

Thursday, 3rd November

Charge coupled devices for analogue signal processing

By C. P. Traynar (*University of Southampton*)

Farnborough College of Technology, 7 p.m.

Wednesday, 9th November

Holographic memories

By P. Waterworth (*Plessey Microsystems*)

Lanchester Theatre, University of Southampton, 7 p.m.

Friday, 18th November

Charge coupled devices for analogue signal processing

By C. P. Traynar (*University of Southampton*)

Isle of Wight College of Arts and Technology, 7 p.m.

Wednesday, 23rd November

Switched mode power supplies

By P. Chapman (*Marconi-Elliott*)

Room AB011, Portsmouth Polytechnic, King Henry I Street, Portsmouth, 7.30 p.m.

Beds and Herts Section

Thursday, 27th October

Automobile electronics—some aspects of research

By Dr. R. C. Codd (*Joseph Lucas*)

Luton College, Luton, Beds., 7.45 p.m. (Tea 7.15 p.m.).

Thursday, 24th November

Electronic calculators—past and current technology

By M. R. Peart (*Commodore Business Machines*)

Hatfield Polytechnic, Hatfield, Herts., 7.45 p.m. (Tea 7.15 p.m.).

South Western Section

Wednesday, 26th October

CEEFAX—A new form of broadcasting

By J. P. Chambers (*BBC*)

Chemistry Lecture Theatre No. 4, University of Bristol, 7 p.m. (Tea 6.30 p.m.)

Tuesday, 1st November

JOINT MEETING WITH IEE

Special effects on TV

By A. B. Palmer (*BBC*)

The College, Swindon, 7 p.m. (Tea 6.30 p.m.)

Tuesday, 1st November

JOINT MEETING WITH IEE

Software engineering applied to stored program control (SPC)

By G. Owens (*GEC*)

Main Lecture Theatre, Plymouth Polytechnic, 7 p.m. (Tea 6.30 p.m.)

Wednesday, 16th November

Page facsimile transmission

By D. F. Banks (*Muirhead*)

Room 5W2.4, University of Bath, 7 p.m. (Tea 6.30 p.m.)

South Midlands Section

Thursday, 10th November

The voltage to current transactor (VCT)

By Professor W. Gosling (*University of Bath*)

Majestic Hotel, Cheltenham, 7.30 p.m.

East Midlands Section

Tuesday, 18th October

JOINT MEETING WITH CEI

Advances in railway technology

By R. Kemp (*British Rail*)

Room J001, Edward Herbert Building, Loughborough University of Technology, 7 p.m. (Tea 6.30 p.m.)

Tuesday, 8th November

JOINT MEETING WITH IEE

Future telephone switching

By J. R. Pollard (*Plessey Telecommunications*)

Department of Electronic and Electrical Engineering, Loughborough University of Technology, 7 p.m. (Tea 6.30 p.m.).

West Midlands Section

Tuesday, 18th October

JOINT MEETING WITH RAES

The spirit of nineteen-o-one (1901)

By Dr. D. McLean (*Loughborough University of Technology*)

An account of the successive application of steam, air, oil, amps and bits to solve the last major flying problem.

Astra Cinema, RAF Cosford, 7.15 p.m. (Tea 6.45 p.m.)

Thursday, 17th November

Energy resources and the mining engineer

By L. J. Mills (*NCB*)

Haworth Lecture Theatre, University of Birmingham, 6.30 p.m.

Yorkshire Section

Thursday, 29th September

The professional, the amateur and the microprocessor

By P. Jackson (*Music Hire Group*)

Synopsis: This lecture highlights the low cost of microprocessors and looks at systems and applications for both professional and amateur users.
Leeds Polytechnic, 6.30 p.m.

Merseyside Section

Wednesday, 12th October

Daresbury nuclear physics facility

By Dr. H. Price (*Daresbury Nuclear Physics Establishment*)

Synopsis: A review of the experimental work being carried out at the Daresbury establishment.

Department of Electrical Engineering and Electronics, University of Liverpool, 7 p.m. (Tea 6.30 p.m.).

Wednesday, 9th November

Marine gas turbine control

By W. S. Brown (*Hawker Siddeley Dynamics*)

Department of Electrical Engineering and Electronics, University of Liverpool, 7 p.m. (Tea 6.30 p.m.).

North Western Section

Thursday, 20th October

Quadraphonics

By Dr. K. Barker (*Sheffield University*)

Synopsis: The lecture will introduce the subject of quadraphonics through the historical development of sound recording and will illustrate the subject extensively with visual and audio demonstrations. All presently available quadraphonic systems will be covered including some new aspects of multi-channel broadcasting.

Bolton Institute of Technology, Deane Road, Bolton, Lancs, 6.15 p.m. (Tea 5.45 p.m.).

North Eastern Section

The development of communication satellites

By J. Hamlet (*British Aircraft Corporation*)

YMCA, Ellison Place, Newcastle upon Tyne, 6 p.m. (Tea 5.30 p.m.)

East Anglian Section

Tuesday, 18th October

ANNUAL GENERAL MEETING

followed by

Microprocessors/microcomputers?

By Robert Robinson (*Jermyn Industries*)

Civic Centre, Chelmsford, 6.30 p.m. (Tea 6 p.m.).

Thursday, 20th October

Microprocessors in action in the home

By D. Leiper (*Motorola*)

Civic Centre, Ipswich, 6.30 p.m. (Tea 6 p.m.).

Thursday, 27th October

JOINT MEETING WITH IEE

C.T. scanning of the brain and body

By P. McAtamney (*EMI*)

Engineering Laboratories, Trumpington Street, Cambridge, 6 p.m. (Tea 5.30 p.m.).

Wednesday, 16th November

Electronic ignition

By Dr. M. J. Werson (*University of Southampton*)

Cossor Electronics, Elizabeth Way, Harlow Essex, 6.30 p.m. (Tea 6 p.m.).

Thursday, 24th November

JOINT MEETING WITH IEE

Development of miniature TV receivers

By Clive Sinclair (*Sinclair Radionics*)

Engineering Laboratories, Trumpington Street, Cambridge, 6 p.m. (Tea 5.30 p.m.).

Wednesday, 30th November

JOINT MEETING WITH IEE

Switched mode power supplies

By P. Chapman (*Marconi-Elliott*)

Civic Centre, Chelmsford, 6.30 p.m. (Tea 6 p.m.).

South Wales Section

Wednesday, 12th October

Quadraphonics

By K. Oliver (*BBC*)

Synopsis: The intention is to discuss quadraphony mainly from the broadcasting point of view covering the following aspects: mono/stereo/quad compatibility, discrete versus matrix quadraphony, and the limitations of matrix quadraphony (BBC Matrix H).

Room 112, Department of Physics, Electronics and Electrical Engineering, UWIST, Cardiff, 6.30 p.m. (Tea 5.30 p.m.).

Wednesday, 16th November

JOINT MEETING WITH IOP

Charge coupled devices and their applications

By Prof. J. Beynon (*UWIST*)

Room 112, Applied Physics Department, UWIST, Cathays Park, Cardiff, 6.30 p.m. (Tea in Refectory 5.30 p.m.).

Northern Ireland Section

Tuesday, 4th October

The professional engineer

By a speaker from UKAPE

Cregagh Technical College, 7 p.m.

Wednesday, 2nd November

Energy conservation

By A. Kane (*Post Office*)

Cregagh Technical College, 7 p.m.