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MICROPROCESSOR APPLICATION ENGINEERING PROGRAMME

DP/IND/84/030

INDIA

Technical report: Present development status and proposals for future advancement of the application of microprocessor based systems*

Prepared for the Government of India
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Mr. C. Allan Hobson,
expert in microprocessor based systems

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Vienna

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* This document has not been edited.

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ABSTRACT

This report describes the work of a UNDP expert who visited India in November and December 1988. The report contains a description of his activities in two centres - New Delhi and Pune. The main activities in New Delhi were associated with the International Seminar on Microprocessor Applications for Productivity Improvement held at the Ashok hotel from 6th to 8th December, 1988 (INMAP '88), and these are reported upon. In Pune the expert was concerned with the activities of the centre and its progress since his previous visit in November 1987. For Pune the report contains details of progress over the past year, and proposals for future development of both courses and products. Some problems of the centre are identified.

The report contains details of the recommendations of the expert for the future development of the Microprocessor Applications Engineering Programme as well as his conclusions resulting from the mission.

CONTENTS

1. RECOMMENDATIONS

These recommendations are based on the experiences of the expert at the New Delhi and Pune centres and at the International Seminar on Microprocessor Applications for Productivity Improvement. The recommendations of a group of experts who attended the seminar are given on the following page.

a. It is essential that specific expertise in instrumentation be established in all centres and desirable that one of the centres should be assigned to maintain a data base of transducers and associated signal processing systems, possibly with a requirement that the centre should undertake instrumentation development on a national basis.

b. Products should not be developed until their specification has been established and a market is known to exist.

c. Centres should develop a methodical approach to all project work, and should always complete a full feasibility study before any hardware or software development takes place.

d. There should be an increase in the use of CAD techniques in the centres. Many PCB's, for example, are designed using tapes which are laid out manually. If CAD techniques are applied then modifications become easier, full documentation for the design is readily available and considerable time savings result.

e. Centres should extend their contacts with private industry, and should undertake development work for private industry as consultants. Only when this is done will the full benefits of MAEP be realised.

f. A portable word processor should be made available to visiting experts who spend considerable amounts of time in hotel rooms, and could make productive use of that time for producing, papers, reports, etc. if suitable facilities were available.

g. Experts should be assigned to one or possibly two centres, and should make periodic visits to those centres. This would provide continuity and experts would be familiar with the work of the centres, this enabling them to have a more positive input to the development of centres.

h. Centre staff should continue to be offered fellowships but the staff travelling abroad should normally be based in one establishment only, and that establishment should be accessible to an expert associated with the centre.

i. Junior staff not having experience of industry should be offered the opportunity of secondment into private industry in India for short periods, possibly of 3 months. This would increase the awareness of staff of the needs of industry.

The following recommendations were compiled by the UNIDO experts who attended the discussion session at the conclusion of INMAP '88. They are based on the comments of delegates at the discussion session.

The UNIDO experts concerned were:

C. A. Hobson	UK
A. M. Norton	Mexico
J. L. Peters	Netherlands
D. Popovic	FRG
W. R. Slater	USA
B. G. Taylor	Switzerland
E. J. Wightman	UK

1. Sensors. There is a need to define what is available in India, possibly in the form of a data bank. Sourcing is a major problem affecting the whole microprocessor application engineering programme. Consideration should be given to forming an indigenous sensor development centre.

2. Co-operative projects are recommended between:

   - Industry.
   - MAEP.
   - Universities and Research Establishments (CERI, etc).

3. During the MAEP to date, results show that centres which are industry based have a better track record of achievement than MAEP centres which are part of DoE or are university based. Examples - Bangalore and Ranchi have performed better than Pune and Jabalpur.

5. MAEP should promote <u>software</u> with system engineering and <u>applications</u> of microprocessor based systems.

6. There is a need for pilot projects for future systems development to develop project management expertise.

7. There is a need for awareness and education programmes for <u>all</u> organisational levels from chief executive to directors, managers, development engineers and shop floor with emphasis on senior management levels.

2. INTRODUCTION

This report covers the first month of a 2-month split mission. Although it was indicated at the pre-mission briefing that a full report is not necessary at this stage, the expert believes that some of the findings of the mission are so important that they must be reported immediately and consequently a full report is presented.

The objectives of the mission were detailed in job description DP/IND/84/030/11-07/J13315. They specified duty stations as New Delhi/Pune/Ranchi/Bangalor/Jabalpur, and stated:

"The expert will work under the guidance of the National Project Director and Chief Co-ordinator and will specifically be expected to:

i. Appraise himself of the current status of microprocessor applications in Indian industry.

ii. Appraise himself of the objectives, status and the results of various systems engineering development projects going on in various centres.

iii. Help project personnel in hardware and software development for various projects.

iv. Train project personnel as well as centres, on new Methodologies for microprocessor-based system engineering systems."

A report was to be prepared setting out the findings of the mission and making recommendations to the Indian Government on any further action which may be taken.

These objectives were very broad, and it was clearly accepted that they were for guidance only and that the actual detail of the mission would be agreed between the Project Co-ordinator and the expert when the expert arrived in New Delhi. In practice the primary reason for the expert undertaking this part of the mission was so that he could take part in the International Seminar on Microprocessor Applications for Productivity Improvement (INMAP '88) held at the Ashok Hotel, New Delhi from 6th to 8th December 1988.

The mission took place from mid-November to mid-December 1988, with the itinerary described below.

21 November	Depart from home.
22 November	Briefing at UNIDO, Vienna.

24 November-11 December	New Delhi Centre. Further seminar paper written. INMAP '88 attended.
12 December-16 December	Pune Centre. Reviewing projects in centre. Visit to the Centre for the Development of advanced Computing (C-DAC).
17 December-19 December	New Delhi Centre. Reviewing progress in centre.
20 December	Return home.

This report provides an update on an earlier report prepared by the same expert, in the period mid-October to mid-December 1987, as far as the New Delhi and Pune centres are concerned and reports on INMAP '88.

3. INMAP '88

The International Seminar on Microprocessor Applications for Productivity Improvement (INMAP '88) was held at the Ashok Hotel, New Delhi from 6th to 8th December 1988. There were almost 400 participants, although many of them were very selective about the sessions they attended. Slightly in excess of 300 participants were not employed by the Department of Electronics nor were they United Nations Experts. Less than 50 participants were from private industry.

The expert believes that the seminar organisers are to be commended. The conference was generally well received by participants and the proceedings, which were published by Tata-McGraw Hill, will form a valuable work of reference in the future.

Facilities at the Ashok Hotel were generally adequate, with the exception of provision for the projection of 35mm slides and overhead projector foils. The use of visual aids is an essential part of most conference and seminar presentations and the provision of inadequate projection facilities is an affront to authors who have put a considerable effort into the preparation of their presentations.

Projection facilities should include:

i. Large screens which can be seen from any point in the auditorium. The actual screen was very small.

ii. 35mm projectors with telephoto lenses so that they can be located to the rear of the auditorium. An experienced operator is also required. The actual projectors had short focal-length lenses and so had to be located close to the screen which required them to be tilted, causing them to jam. An operator was provided on the final day of the conference.

The standard of most seminar papers was very high and the range of subjects covered was considerable. The full programme is given in appendix 1. It shows that papers were presented on a variety of microprocessor applications including medicine, railways, service industries, communications, process industries, steel, agriculture, education, test and measurement, industrial control and manufacturing. Unfortunately a few papers were not presented because their authors failed to attend the seminar.

An important part of any conference is the provision of time so that participants can meet and discuss issues related to the topic of the conference. There was adequate provision of time for discussion, both in the lunch period and in the evenings when participants were quests at dinners.

The United Nations Experts produced a number of general recommendations based on their work at the seminar and particularly on the discussion held as the final seminar session. These collective recommendations are included in the recommendations section of this report.

4. WORK OF THE MAEP CENTRES

The expert has reviewed the work of the New Delhi and Pune MAEP centres, as far as time allowed. The period of the mission prior to INMAP '88 was spent at the New Delhi centre producing an additional paper for the seminar, and there was little opportunity to discuss the work of the centre since its staff were very involved with the final preparations for the seminar. The expert was, however, able to visit an exhibition associated with the Seventh Biennial Convention of the South East Asia Regional Computer Confederation (SEARCH 88).

The SEARCH 88 exhibition was very impressive. It demonstrated that there is a high level of competence in South East Asia, and particularly in India, in the development and application of computer systems.

After the seminar the expert went to the Pune centre where he spent 4 1/2 days. (The first 1/2 day of an expected 5 day stay was lost due to the cancellation of an Indian Airlines flight). After his return from Pune to New Delhi the expert was able to spend one day reviewing the progress of the New Delhi centre.

4.1 NEW DELHI CENTRE

The expert has previously reported on the work of the MAEP centre, New Delhi, in a report covering the period October to December 1987. On the mission now reported he had a restricted time to investigate the work of the New Delhi centre, and consequently little more than an update on his previous report is presented.

There has been little change in the staffing of the centre over the past year. One officer has resigned from the centre and one has joined it. The new staff member has expertise in the control aspects of irrigation, and so should be of particular value to the MAEP. There are several vacancies for staff in the centre, both technical and non-technical.

No new equipment has been purchased over the past year, and consequently the equipment deficiencies reported by the expert at the time of his 1987 mission still remain. In addition to the previously reported deficiencies the expert must now report that existing equipment is becoming both dated and unreliable. The reasons for this are as follows:

i. The working environment is not of the standard required by modern electronic systems. The atmosphere is dusty, the main work area not having air conditioning and using ceiling fans for air circulation in hot weather. These fans tend to add to the dust. Some of the side rooms do have air conditioning, but they are still very dusty and air filtering should be provided.

ii. Some of the equipment dates back to the last half of 1985 and so is becoming rather dated. (With the present rate of development in information technology, equipment becomes obsolete in a period of 4-5 years).

The expert therefore believes that a programme of investment is essential to bring accommodation up to the required standard, provide suitable test equipment and to progressively replace existing equipment.

4.1.1 Work of the expert at New Delhi

The expert has reviewed progress on the projects which were in progress at the time of his 1987 visit. An assessment of training courses was also carried out but unfortunately it was not possible to obtain detailed information about courses to be operated over the coming year.

Status of the 1987 projects

a. Development of equipment for instrumented car.
All instruments have been interfaced to the computing equipment and the system is now at the stage of undergoing field trials. The direction of travel is entered manually since problems associated with the gyrocompass have not been resolved - the only lasting solution to this is the importing of a gyrocompass having a computer interface. Problems of contact bounce were overcome by using low-pass filters with monostables.

b. Development of a cross assembler for the 8051.
The work is almost complete. Testing remains to be completed and some documentation is required.

c. Hardware design for an 8051 board.
The hardware is complete and working. The equipment has been used on courses along with the 8051 in-circuit emulator. It is now intended to produce a monitor for the board.

d. Water treatment plant.
The development is in progress with both Texas Instruments and United Nations experts involved. There is an agreement between the United States Government through their Technology Development Programme and the Department of Electronics, Government of India, for some financial assistance from the USA with the development work.

e. Interface cards for IBM-PC's.
The expert is pleased to report that this work was not followed through.

f. Development of a Data Acquisition system for the gas dispatch station of Bhilai steel plant.
This work was reported in the experts' 1987 report since he was involved in attempts to solve some problems associated with the RMX-86 operating system. However, the project is the responsibility of the United Nations funded Appropriate Automation Promotion Programme and is not reported further here.

Courses operated by the New Delhi centre

The centre has developed notes for a variety of courses. The notes are of good quality and are bound in book form. In the opinion of the expert the centre is to be commended in this effort which makes the operation of repeat courses relatively simple.

Course notes exist as follows:

- The 8051 Processor
- The 8085 Processor
- The 8096 Processor
- Microprocessors and their Applications - An Introduction.

As well as INMAP '88 with its 375 participants (of which less than 50 were from private industry) the centre has operated a number of courses over the past year. These include a three week 8085 course and a course for waterworks engineers.

4.2 PUNE CENTRE

The expert has previously reported on the work of the MAEP Centre, Pune, in a report covering the period October to December 1987. On the mission now reported he visited Pune for only 4 1/2 days and consequently the amount of work covered was limited to a review of the progress of the centre over the past year, and to some discussions about its future. A visit to the centre for the Development of Advanced Computing, C-DAC, is also reported upon.

There has been little change in the staffing of the centre over the past year. This is pleasing since the increased stability can only prove beneficial. The co-ordinator continues to be Professor A. M. Dhake, who is Head of Electronic Engineering at the Pune College of Engineering. Technical staff employed by the centre are:

- 2 Principal System Engineers
- 2 Senior Project Engineers
- 3 Junior Project Engineers
- 2 Engineering Assistants

This is an increase of one staff member over the past 12 months, but the improvement is partly offset by the centre having dispensed with the services of a consultant. A few staff vacancies remain but are proving difficult to fill.

The 4 senior staff all have significant industrial experience, but the more junior staff are short of experience of industry, with one having 2 years experience, one having 1 year and the others having none. A program of secondment of the junior staff to industries having relevant activities could be of benefit to those staff not having recent or relevant experience of industry.

The centre continues to occupy rooms in the Pune College of Engineering. The proposed new building is not expected to be available for at least another year. While the delay in providing the new building is not causing any serious problems, some of its effects are undesirable. Three staff, one senior and two junior project engineers, are having to share one desk which would normally be sufficient for only one person, lecture accommodation is not of a standard sufficient for managers of industry attending courses and there is insufficient space for any significant expansion of facilities.

Equipment remains essentially as reported one year ago. Two new IBM compatible 286-AT computers have been purchased and the HP9000 system, providing 4 workstations has been delivered. Two more workstations can be added to the HP system if this should prove necessary in the future. The centre wishes to purchase additional software for use with the HP system, enabling it to be used for the development and application of knowledge-based software systems. The centre is also considering the purchase of PCB design software. The expert urges that some priority be given to this purchase - it was recommended as item e, page 1, of his 1987 mission report. Present proposals do not involve the centre in purchasing a plotter of the quality necessary to produce its own artwork. This is probably a wise decision providing it is confirmed that suitable high quality plotters, able to utilise the files of the cad system, exist within local companies and can be made available for the centre to use at a realistic fee.

A policy decision has been taken that the centre should cease to be involved in the development of medical electronic systems. The reasons for the decision are as follows:

i. Lack of interest from the medical profession, who have generally refused to support the work of the centre and have not collaborated with it.

ii. The increased availability of imported medical electronic systems, which do not have large import duties levied upon them. Since the centre must use imported electronic components, which are subject to import duty, its products are not competitive.

The expert supports the decision to withdraw from medical electronics. It was evident to him in 1987 that this area of work was proving difficult, and he believes that without the support of the medical profession in India the centre can not succeed in this activity.

4.2.1 Work of the expert in Pune

4.2.1.1 Assessment of progress of centre.

In the course of his 1987 visit the expert reviewed the work of the centre. He has now assessed the centres' progress since his previous visit. The assessment had various components. It started with a consideration of the work reported in the 1987 report and then advanced to work carried out since then and to work proposed for the future. There are some very important points which arise from the analysis.

Status of the 1987 projects

a. Gas turbine monitoring system.
This was a software development for Meltron Electronics, a company owned by the state of Maharashtra. It is now complete, has been installed and is working to specification.

b. Relay parameter tester.
The development work, including a version having an improved current source, has been completed. The product has been made available for manufacture by private industry using the Federal Governments' arrangements for Technology Transfer, but no companies have shown interest.

c. CO monitor.
Development work has been completed. There have been problems associated with the sensor, but one suitable for the particular application has been identified, the design modified to accommodate it and a quotation for its supply has been invited. The design has been submitted for Technology Transfer.

There must be some doubt about the viability of the product since there are competing and proven products available (Free emission checks were advertised on a bill board across the road from the College of Engineering at the time of the visit of the expert).

d. ECG unit.
Both stages are complete. Software to enable the various phases of an ecg trace to be identified was available in December 1987 and automatic diagnosis software became available at the end of July 1988.

In September 1988 a group of doctors in Pune expressed an interest in the product. Technology transfer was applied for so that they could have it available by 15 December 1988 for an exhibition. The Pune doctors had not received a response to their request for Technology Transfer at the time of the visit of the expert (12-16 December 1988). However, there are others interested in the product and it is the task of DoE to ensure that they get the best possible deal in technology transfer. It is unfortunate that a group with a specific deadline on their requirement could not be notified of the reason for this justifiable delay. It is understood by the expert that a committee is to meet early in 1989 to discuss which offer should be accepted.

e. Patient Monitoring System.
Temperature and pulse-rate measurement systems have been completed and technology transfer has been applied for. The measurements associated with k-sounds have been abandoned due to difficulties in identifying suitable transducers and with the removal of background noise by appropriate signal processing. This must be a matter of some regret since the overall attractiveness of the instrument has been reduced.

It will therefore be appreciated that all projects which were in progress when the expert visited Pune in late 1987 have been virtually completed, but that only one of them has been put to any practical use. That one project was carried out for a customer under contract. No work of a speculative nature has been a commercial success so far although it does appear that the ecg unit will become successful in the near future.

Projects started in 1988.

In the past year a number of projects have been started. Details are given below:

a. Single chip microcontroller card.
This card uses an 80C31 microcontroller along with CMOS logic (It is not really a single chip circuit design). Its features include:

* 1-bit ttl level digital input.
* Analog input which is converted to a 12-bit number by a cmos adc.
* 8-bit parallel port. this is designed to be used with a printer but with appropriate software other uses

are possible.
* 3 1/2 digit liquid crystal display.
* a single switch to allow two different software options to be selected.

Various software is under development. This will provide a variety of measurement and display applications for the board, including the following:

i. Digital measurements based on the period of the signal at the 1-bit input, or on its frequency. An example quoted is the measurement of the period of a signal from a tachometer, allowing speed in R.P.M. to be calculated.

ii. Analog measurements allowing the board to be used in a variety of situations including measurement of voltage, with filtering, and measurement of temperature. The processor will be able to allow for any non-linearities in transducers.

When the various software items have been written and linked together, so that some software selection is possible using the switch, the product will be submitted for technology transfer. The expert hopes that the product will find a market, but has some doubts about it unless the promotion of it through technology transfer is of a high standard. The product will not sell itself unless its applications are made very clear.

b. ATE for bare-board testing
Software development is under way by two students from the final year of the BE course in the College of Engineering. The only hardware so far available is a board to enable a bed-of-nails tester to be interfaced to an IBM compatible computer. The actual bed-of-nails remains to be produced!

Difficulties associated with the bed of nails were discussed with the expert. the basic problem is that to test a board measuring ten by twelve inches (254mm x 305mm) with nails on an 0.1 x 0.1 inch (2.54mm x 2.54mm) matrix requires 12,000 nails. If a future extension into surface mount technology is catered for this must be increased to at least 48,000 nails since surface mount integrated circuits have pad spacing of 0.05 inches and some passive components are even smaller. A solution providing so many nails, although desirable, is costly and alternatives were considered.

i. Have a number of small bed-of-nails type arrangements to allow testing at the sites of different circuit packages. For example, 1/4 Watt resistor, 14-pin dual-in-line, 14-pin small outline, 16 pin dual-in-line, etc. These various small assemblies could then be attached to a jig in positions corresponding to the position of matching components on the circuit board to make a tester for the full board.

ii. Use two probes, each mounted on a 2-axis slideway and driven by stepper motors. Test the board with the probes manipulated by the computer system. This method would be slow but relatively cheap, and would work providing the mechanical systems can be designed so that the probes can be moved close together. Software would need to optimise the probe movements so that they can be minimised to reduce processing times to a minimum.

The expert suggested that the software should be developed so that it will interface to the file formats of various pcb design packages. This will enable the product to be used without the need for manual entry of design data, and so will reduce errors.

c. Image processing system.
An image processing cardset has been developed. The cards are compatible with an IBM personal computer. The cards use emitter coupled logic for the 64 kbytes of image memory. This use of ecl is unfortunate because it adds to cost and complexity, but it has been forced upon the centre due to the non-availability in India of suitable components, flash adc and fast memory, working at ttl logic levels.

Commissioning of the cardset was in progress at the time of the visit of the expert. It was expected that the development of software would commence within two weeks. Students from the Engineering College were involved in the commissioning of the board and they would then commence work on the software. A facility of this nature could be very important to the centre as discussed below.

d. Development of an 8051 kit.
The basic principle of this kit is that software should be developed using an IBM-PC and then downloaded through the IBM serial port into the memory of an 8051 hardware system The IBM then acts as a terminal to the hardware, allowing it to be driven using the monitor facilities which are contained in a ROM forming part of the hardware. The equipment was produced for a course run by the centre in December 1988 and evidently proved very popular with people attending the course.

Some documentation work remains to be done.

The cost of components in the kit is less than 1000 Rupees and so it should be possible to market kits for about 4000 Rupees, which is considerably cheaper than any other kit known to be available. The expert strongly recommends:

i. The remainder of the development work should be completed quickly.

ii. The kit should be submitted for technology transfer immediately.

iii. People attending courses and using the kit should be provided with one at reduced cost, if they so wish. By providing only the components and board to participants, and extending the course by one or two days, it may be possible to reduce the cost to a level which would allow many participants to obtain a working kit, while gaining experience of working with microprocessor integrated circuits.

Courses operated in 1988 and proposed for 1989

In his 1987 report the expert stated that the centre operates about 11 courses per year. This amount of courses has not been operated in 1988, but a major National Seminar was organised.

Details are as follows:

The 8051. A one week course attended by 16 people.

P.C. Hardware and Software. A two week course attended by more than 20 people.

Microprocessor Development Tools. A one week course to be run in the week following the visit of the expert. 12 people were expected to attend.

National Seminar on Microprocessors in Measurement and Control. A two day seminar held in August 1988 and attended by more than 100 people.

4.2.1.2 Relationship between Centre and Engineering College

The relationship between the centre and the College of Engineering is important, since there are possible benefits to both the college and the centre. Consequently the expert has reviewed the relationship.

As stated above, Professor A. M. Dhake has a role relevant to both the college and to the centre. There are no other staff, either in the college or centre, having a specific commitment to both.

The centre does have an involvement with students in the college through their project work. Staff of the centre have been involved in the supervision of final year BE student projects. Brief details follow:

i. An 8052 based adaptive controller. The 8052 has limited memory and consequently only a simplified version of an adaptive controller could be implemented.

ii. An artificial limb. The majority of the work was of a mechanical nature. Some stepping motor drives were required.

iii. Test jig for power supplies. The work was sponsored by Digitronics Ltd. of Pune, and consisted of the development of test equipment for the companies power supplies. It has been completed.

The centre does not expect to have any further involvement with any of these projects.

Students from the college have carried out work for the centre as part of their college course. Details are given elsewhere in this report. This is an important activity, providing the slower progress which can be expected from a student can be accepted.

Staff of the Engineering College have attended various courses operated by the MAEP centre.

4.2.1.3 Future development of Centre

The expert has discussed the application work to be carried out by the centre in the future.

It is accepted that the centre has responsibilities for the development of automatic test equipment and for measuring instruments, but there is a problem in determining the type of equipment which should be developed. The centre is quite a small organisation and its products are expected to compete with those of large companies having large budgets. It is expected to carry out work of a speculative nature and then to use a system of Technology Transfer to get its products manufactured and sold. Past experience shows that this does not work as effectively as hoped for. The only successful project from MAEP Pune has involved industry from the start, and was in fact proposed by industry, although it is acknowledged that the ECG unit should prove successful in the near future.

The experiences of other MAEP centres support the view that industrial collaboration is very important for success. Bangalore and Ranchi centres, located in Indian Telephone Industries and The Steel Authority of India respectively are very successful. Lucknow, based in the Indian Railways' Research, Design and Standards Organisation has good potential although it was started later than other centres and the Delhi centre, with its less specialised activities has been able to carry out contracted work for RDSO, CRRI and the water supply authority among others.

The expert believes that there is a need for the expertise of the MAEP centres to be made available to industry in general and that this will benefit both the MAEP centres and industry, and therefore the Republic of India. He is also aware that the Project Summary states "The immediate objectives are.....and guide industries in the development of hardware and software in specific areas of microprocessor engineering." This is not been done as well as it could be since it is Government Organisations which are benefiting and the centre is not carrying out any significant work for private industry.

He therefore strongly recommends that the following should be used as a framework for discussion about the way the centre should operate in the future:

i. MAEP centre, Pune, should be required to carry out work of any nature related to the application of microelectronics in small and medium sized industries within the Western Region of India as consultants to those industries. It is clear that the overall task is very large and consequently the work may need to be restricted to a feasibility study, with the centre then giving help in later stages of the work.

ii. Companies should pay a commercial rate for the services of the centre.

iii. For small companies, a reduced rate, possibly 1/4 of the normal rate, should be payable for the feasibility study.

iv. All development work paid for by a company should become the property of that company when they pay for the work completed. At all times the work should be confidential to the company.

v. The present system of technology transfer, as it applies to MAEP, should be discontinued.

vi. The centre should accept financial penalties if it fails to deliver on time.

vii. The centre should continue to develop its expertise in automatic test equipment and quality assurance as well as measurement systems. This may be in a modified form with the centre acting as a demonstration centre and giving advice about equipment available from various sources.

vii. If, and only if, proposals similar to those listed

above are accepted, then the centre should have its performance measured according to some agreed formula.

The alternative to the acceptance of proposals of the above nature must be a non-viable centre.

Since it is likely to be some weeks before proposals of the type listed above can be implemented, the following is proposed for work of an interim nature:

i. The centre should obtain an expert system shell for PCB testing. Suitable shells do exist and details of one have been supplied to a member of the centres' staff undergoing training as a UN fellow at the experts' institution. The application of the shell to PCB testing should then proceed. The staff of the centre have carried out a literature survey with the intention of writing their own shell, but the expert recommends that this work is not undertaken at the present time. It is, perhaps, more important to apply available software rather than to spend several months developing software of a type which already exists.

ii. The centre staff member undergoing training at the experts' institution has been investigating the application of an expert system shell in the diagnosis of faults in the process industries. This work should be assessed when the fellowship is complete, and if it is found to be applicable in India then the work should continue. The expert would like to continue collaboration on this activity.

iii. The work on image processing should continue, with centre staff experienced in software design becoming more actively involved. Vision systems have many applications, including the following:

a. Identification of missing or wrongly orientated components on a pcb.

b. Using an infra-red camera system, it is possible to identify components which are hotter or colder than expected, and so are potentially faulty. Also leakage across PCB tracks, which causes local heating, may be detected.

c. Many mechanical systems can be inspected. For example, the proposal for a consultancy contract to carry out gear inspection would be able to proceed.

The purchase of a commercial vision system, with pre-written software for carrying out many fundamental image processing operations, could benefit the centre.

iv. The centre has submitted proposals for the development of IBM-PC based instrumentation and signal processing systems. The expert believes that the proposal may be of interest to the educational sector, but is not convinced that it has industrial applications. The expert therefore suggests that the centre should:

a. Carry out a survey of both industry and educational institutions to determine the possible market.

b. Submit detailed specifications relating to its proposals. This should utilise information from the survey recommended above.

Both the survey and the detailed specification are essential if the "best" product is to be produced.

4.2.1.4 Seminar presented by the expert

The expert presented a seminar on "Design". This was a subject he chose himself as a result of a request from the centre staff that he should present a lecture. The reason for his choice of design as a subject is his belief that the centre must sell its expertise to industry with a consequent need for the centre to adopt a commercial approach to its project management.

4.2.2 Centre for the development of advanced computing

The Centre for the Development of Advanced Computing (C-DAC) is located on the campus of Pune university. Its Executive Director is Dr Vijay P. Bhatkar who is also the Senior Director of the Department of Electronics with overall responsibility for the MAEP.

The centre has a mission with a primary objective of designing, developing and delivering a supercomputer by mid 1991. Work started on 1st August 1988.

The expert was asked to give an impromptu lecture on Transputers. It was hoped by staff of the centre that the lecture may be on the subject of Transputer networks, with particular reference to large cubic structures. The expert explained that such networks are not a subject of which he has any experience, and gave a presentation on his own research interests and how he has used transputers to solve time critical processing operations in actual engineering environments.

Since the completion of his mission, the expert has contacted members of his research group to determine if there is information available within it which may be of interest at C-DAC and if there are any possibilities for collaboration.

Following the lecture the expert had a lengthy discussion with Dr Bhatkar in his capacity as a Senior Director in the Department of Electronics.

5. CONCLUSION

Through INMAP '88 and his discussions at the MAEP centres the expert has become convinced that there are two major problems with MAEP in its present form, and that these must be addressed to remedy the situation in the future. There is considerable evidence of a high degree of competence in the application of modern technologies in the larger industries of India, but many smaller and medium sized companies must be in need of assistance in applying these technologies. MAEP does not seem to be addressing this problem so far as private industry is concerned, nor does it seem to take problems of instrumentation sufficiently seriously.

It is evidently a matter of policy that MAEP centres do not assist private industry except for the help given through short courses. Such a policy is difficult to understand. Government should be concerned with the generation of wealth and this requires a partnership between public and private industry, not the creation of a situation in which the two appear to be on opposite sides. It must be in the interests of the country for private industry to remain competitive, and consequently the expertise of MAEP should be made generally available to private industry.

The problem of instrumentation is long standing. It has been identified by UNIDO experts in the past, and many speakers it INMAP '88 also identified it. Any industrial application of microprocessors will involve the measurement of variables within the application system. It should therefore be evident that the development of a knowledge of instrumentation systems, as well as an expertise in their development, must be an integral part of any programme concerned with the application of microprocessors.

MAEP is achieving some good results. It now has a nucleus of trained and experienced staff who should be able to lead it into the future, training new staff as vacancies are filled. The training courses offered by MAEP have produced good quality hand-out material and equipment on which practical work is carried out. There has been collaboration between centres in the production of training courses, but further developments are possible in this respect.

INMAP '88 was well organised, with a good coverage of the subject area which presented by a variety of organisations. While the projection facilities at the seminar were extremely poor, the organisation of a seminar on this scale was a new experience for the staff of MAEP and they have learned from the experience. The few problems in organisation are understandable, and they will not be repeated in future. The final discussion session was very informative for all concerned with the future of MAEP, and was documented by UNIDO experts as a set of recommendations.

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APPENDIX 1

Programme for INMAP '88

In practice there was some changes to the programme presented below because some Chair Persons and authors did not attend the sessions allocated.

INTERNATIONAL SEMINAR ON MICROPROCESSOR APPLICATIONS FOR PRODUCTIVITY IMPROVEMENT

INMAP '88

(6th - 8th December, 1988)
Hotel Ashok, New Delhi

Organised by:
Microprocessor Application Engineering Programme(MAEP)
Department of Electronics(DoE)
(A joint DoE - UNDP Project)
4th Floor, A-Block, CGO Complex,
Lodi Road, New Delhi - 110 024.
INDIA

6th December, 1988

09.00 - 10.00 - Registration/Inauguration

10.00 - 10.30 - Tea

10.30 - 12.30 - Session I - Microprocessor Architectural Advancements

Chair Persons - Dr. V.P. Bhatkar
Sr. Director(DOE)
Dr. C.A. Hobson
UNDP Expert, UK

Paper I : Microprocessors : Present and Future
Dr. C.A. Hobson, UNDP Expert. UK
Paper II : Artificial Intelligence Using Micros
Prof. D. Popovic, UNDP Expert, FRG
Dr. V.P. Bhatkar, Sr. Director(DoE)
Paper III: The Age of the Microprocessors
Dr. A. Paul Raj, C-DAC, Pune
Paper IV : Artificial Intelligence Using Micros
Mr. E.J. Wightman, UNDP Expert, UK

12.30 - 13.30 - Lunch

13.30 - 15.30 - Session II - Microprocessor Applications in Medicine

Chair Persons - Dr. R.D. Lele, Chief Physician,
Jaslok Hospital, Bombay
Prof. S.Guha
IIT, Delhi

Paper I : Computers in Cardiology
Prof. S.N. Tandon, IIT, Delhi.
Paper II : Microprocessor Applications in Medicines
-State of the art
Dr. R.D. Lele,
Chief Physician, Jaslok Hospital, Bombay.
Paper III: Medical Electronics-Status in India
Shri H. Vijay Kumar, SCTIMST, Trivendrum
Paper IV : Image Processing and its Medical Applications
Dr. C.A. Hobson, UNDP Expert, UK.

15.30 - 16.00 - Tea

16.00 - 17.30 - Session III- Microprocessor Applications in Railways

Chair Persons : Shri V.C.V. Chenulu
Member(Electrical),Railway Board
Shri Desh Deepak
Project Co-ordinator,
MAEP, Lucknow.

Paper I : Microprocessor Applications in the sector of Railway Transportation for Productivity Improvement
Dr. Ananthnarayanan, ADG, RDSO,Lucknow

Paper II: Z80 Based Central Processor Unit for field stations in Metro Railway Systems
Shri P.V. Prasada Rao,Manager
Shri B.V. Bajaj,ECIL, Hyderabad.

Paper III: Indigenous Microprocessor based systems for Indian Railways -Survey Report
Shri Desh Deepak, Project Co-ordinator, MAEC, Lucknow
Shri V.V. Singh, MAEC, RDSO, Lucknow

<u>7th December, 1988</u>

9.30 - 11.30 - Session IV A: Microprocessor Applications in Service Sector

Chair Persons: Dr. M.P. Dhir, Director, CRRI
Dr. W.R.Slater, UNDP Expert, USA

Paper I : Automation of Water Treatment Plants-The systems approach
Dr. J.L. Peters, UNDP Expert, Netherland

Paper II : A distributed Control system implementation for a waste water Treatment plant
Dr. W.R. Slater, UNDP Expert, USA
Mr. James M. Black, CH2M Hill Inc, USA
Mr. Virgina B.Erickson, CH2M Hill Inc, USA

Paper III : Microprocessor applications in Road Technology
Sh. Y.R. Phull, CRRI
Sh. S.R. Vijayaraghvan, CRRI, New Delhi

Paper IV : Use of Microprocessor based equipments in testing and evaluation of motor vehicle drivers
Dr. D.M. Sarin, CRRI
Sh. Alind Saxena, CRRI
Sh. B.L. Suri, CRRI, New Delhi.

9.30 - 11.30 - Session IVB : Microprocessor Applications in Communications

Chair Persons: Dr. M.V. Pitke
Director, C-DOT
Dr. A. Prabhakar
ITI, Bangalore

Paper I : Microprocessor in C-DOT - DSS
Sh. S.Shankarnarayan, C-DOT, New Delhi

Paper II : Microprocessor Interfacing techniques - using programmable logic devices
Mr. A.M. Norton, UNDP Expert, Mexico

Paper III : High Performance Token bus local area network
Sh. S. Rajaram
Sh. Chidambara
Sh. K.J. Somashekhara
Sh. Roopchandar, ITI, Bangalore

Paper IV : Microprocessor for ISDN applications
Sh. S.Shankarnarayan, C-DOT, New Delhi

11.30 - 12.00 - Tea

12.00 - 14.00 - Session VA : Microprocessor Applications in Process Industries

Chair Persons : Prof. D.Popovic
UNDP Expert, FRG
Dr. G.N. Acharya
Director, CEERI, Pilani

Paper I : Microprocessor based electronic systems for modernising of the sugar industries
Dr. G.N. Acharya, CEERI, Pilani

Paper II : Advanced control and supervision of utility systems in petroleum industries
Dr. J.K. Pal, EIL, New Delhi

Paper III : Microprocessor based instrumentation for the paper and pulp industry
Dr. P.E. Shankarnarayanan, CEERI, Madras

Paper IV: Microprocessor applications in process industries for simulation and control
Sh. Ajay B. Pathak, SattControl (India) Ltd., Pune

12.00 - 14.00 - Session VB : Microprocessor Applications in Agriculture & Education

Chair Persons: Dr. D.K. Sharma,
Vice Chancellor, JNKVV, Jabalpur
Dr. J.H. Agarwal
Project Coordinator(MAEP), Jabalpur.

Paper I : Microprocessor and computer based electronics applications in agriculture - World wide scenario
Dr. J.H.Agarwal, Project Coordinator, MAEP, Jabalpur.

Paper II : Microprocessor based agricultural instrumentation in agricultural research and production
Prof. Jag Mohan Singh
Punjab Agriculture University, Ludhiana.

Paper III : Microprocessor Applications in Agriculture
Sh. G. D. Pethe, RCF Ltd., Bombay

Paper IV : Some developments in Microprocessor applications in Agriculture
Dr. J.L. Peters, UNDP Expert, Netherland

Paper V : Teaching microprocessor based process control - experience at IIT , Kanpur
Dr. D.N. Saraf, IIT Kanpur
Dr. Sanjay Gupta, IIT, Kanpur.

14.00 - 14.30 - Lunch

15.00 - 17.00 - Session VIA: Microprocessor Applications in Steel

Chair Persons : Dr.S.K. Gupta
Director,SAIL, Ranchi
Dr. J. Bhattacharya
Project Co-ordinator(MAEP),Ranchi.

Paper I : Microprocessor in steel plant modernisation
Dr. J. Bhattacharya,Project Coordinator
Sh. M. Satyaranjan, MAEP, Ranchi.

Paper II : Microprocessor based distributed control system using optical link
Dr. A.K. Ray,IIT, Kharagpur
Sh. Tathagata Biswas, IIT, Kharagpur
Sh. Sumantha K. Ghosh, IIT, Kharagpur

Paper III : Real Time system for Gas management for steel plants
Shri S.K. Roy, NIC, New Delhi.
Sh. R.Pitchiah, AAPP, New Delhi.
Sh. Pradeep Chopra, AAPP, New Delhi.

Paper IV : Fine gauge control of strip using microcomputer based systems in five in stand in cold rolling mill
Sh. R.V.S. Lakshman, MAEP
Sh. S.B. Chowdhury, MAEP
Dr. B. Puthal, MAEP
Dr. J. Bhattacharya, MAEP, RDCIS, SAIL, Ranchi.

Paper V : Microprocessor based SCADA systems for an electric arc furnace
Prof. V.V. Athani, IIT, Bombay

15.00 - 17.00 - Session VIB : Microprocessor Applications in Test & Measuring Instruments

Chair Persons : Dr. B.G.Taylor
UNDP Expert, Switzerland
Prof. A.M. Dhake
Project Coordinator, MAEC, Pune

Paper I : Microprocessor applications in yarn testing
Sh. S.B. Dholakia,
Sh. H.S. Mazumdar
Sh. O.N. Soni
Sh. R.S. Chhajed
Sh. Kirti J. Thakkar, AAPP, Ahmedabad

Paper II : Microprocessor based field operated instruments for geophysical applications
Sh. M.A. Shamshi,Astt. Director
Sh. B.K. Sharma,
Sh. S.K. Mittal,
Sh. V.P. Sharma, CSIO, Chandigarh

Paper III : Microprocessor based ATE for productivity improvement
Sh. H.M.Pathak,
Sh. A.M. Dhake, MAEC, Pune

Paper IV : Microprocessor based cross correlation type flow meter
Sh. D.P. Goel, Head, PID
Ms. Sushma Aggarwal, CSIO, Chandigarh

8th December, 1988

09.30 - 11.30 - Session VII - Microprocessor Applications in Industrial Control

Chair Persons : Prof. S.S. Lamba,
IIT, Delhi
Mr. E.J. Wightman
UNDP Expert, UK

Paper I : Real Time Control and monitoring by Microcomputer
Dr. B.G. Taylor, UNDP Expert, Switzerland

Paper II : Distributed control systems - Implementation strategies
Dr. Purkayastha, DESIN, New Delhi

Paper III : Microprocessor based state feed back controlled Rotor Fed Induction Motor Drive
Prof. S.S. Lamba,
Sh. J.K. Chatterjee,
Sh. J.K. Mendiratta, IIT, Delhi

Paper IV : Experiences of DCS utilisation at MRL
Shri P. Jayabal, MRL, Madras

11.30 - 12.00 - Tea

12.00 - 13.30 - Session VIII: Microprocessor Applications in Manufacturing Automation and Standardization

Chair Persons: Dr. J. L. Peters
UNDP Expert, Netherland
Mr. A.M. Norton,
UNDP Expert, Mexico

Paper I : Standardisation in Microprocessor field - Review
Prof. D. Popovic, UNDP Expert, FRG

Paper II : Microprocessor Bus standards make life easy/difficult for designer
Shri H.S. Mazumdar,
Sh. R.S. Chhajed, AAPP Ahmedabad

Paper III : BHEL experience in manufacturing automation
Shri G.P. Dodeja
Dr. Vasantha B.J, BHEL, New Delhi

Paper IV : Manufacturing automation - International scenario
Mr.E.J. Wightman, UNDP Expert, UK

13.30 - 14.30 - Lunch

14.30 - 15.30 - Discussion Session - Microprocessor & Productivity : Technology

Panel Members :

1. Dr. G.N. Acharya,
   Director, CEERI, Pilani
2. Prof. D. Popovic,
   UNDP Expert, FRG
3. Dr. C.A. Hobson,
   UNDP Expert, UK
4. Dr. B.G. Taylor,
   UNDP Expert, Switzerland
5. Dr. D.K. Sharma,
   Vice Chancellor, JNKVV, Jabalpur
6. Dr. N. Ananthanarayanan,
   Addl. Director General, RDSO. Lucknow
7. Dr. V.P. Bhatkar,
   Senior Director, DoE
8. Dr. Krishna Kant,
   Chief Coordinator, MAEP

APPENDIX 2

Papers presented by the expert

While at the International Seminar on Microprocessor Applications for Productivity Improvement (INMAP '88), held at the Ashok Hotel in New Delhi from 6th to 8th December 1988, the expert presented two papers. One of these papers, "Microprocessors - Present and Future", was prepared by invitation before the conference and appears in the bound proceedings. The other paper, "Image Processing and its Medical Applications" was not requested from the author until he arrived in New Delhi and so was not included in the bound proceedings.

A brief synopsis of each of the papers is given below, and the full text of each paper is presented on the following pages.

Microprocessors - Present and Future

This paper reviews the development of microprocessors and their applications. The reasons for their present state of evolution are considered and some pointers for future development are included

Image Processing and its Medical Applications

This paper reviews techniques of image processing and considers how they may be applied in some medical situations including both diagnosis and fundamental research.
Displayed images are in two dimensions. Consideration is given to ways in which a third dimension may be represented.

MICROPROCESSORS - PRESENT & FUTURE

Dr C A Hobson,

Electrical & Electronic Engineering Discipline,
School of Information Science and Technology,
Liverpool Polytechnic, England.

1. Introduction

Microprocessors are critical components in a wide range of systems and equipment including consumer products such as automobiles, washing machines, televisions and video recorders as well as industrial and commercial equipment. Their range of applications continues to grow as societies become increasingly dependent upon information storage, transfer and retrieval. Some idea of the future developments of microprocessors and their applications can only come about by an understanding of their development so far. Companies involved in microprocessor developments will not reveal details of their strategic planning for an understandable reason - they are in a competitive industry and do not wish to reveal details of their products to competitors. However, we are all of us able to make intelligent guesses about the future if we understand how the present state of development has been achieved.

In making guesses about the future we need to be aware of the risk of getting the answers wrong. In his excellent book, The Mighty Micro (1) Christopher Evans made a number of predictions for the short - term future of 1 to 3 years, middle - term future of 3 to 11 years and long - term future of 12 to 21 years. The book was written in 1979 and now we are towards the end of what he regarded as the middle -term future, it is interesting to see how accurate the predictions were. Three of his claims are considered below:

i. "The 1980s will see the book as we know it, and as our ancestors created and cherished it, begin a slow but steady slide into oblivion".

This has not happened. This paper had to be produced using IBM Wordstar, but printed versions are required by people attending the conference. The IBM Wordstar requirement is to assist in the printing of multiple copies to a consistent standard, not to replace the printed version.

The 1980s have, in practice seen the development of the computer as an aid to the publisher. Old forms of typesetting have been replaced and we have desk-top publishing available to us all. Anyone can produce good quality printed documents and the demand for the traditional printed book continues.

It is, however, true that we do have alternatives to the printed word. Television type systems can be used to transmit the written word. In some respects we have, through teletext and similar services, some element of competition with newsprint, but there is no sign of that replacing the newspaper. "Fax" machines are giving an alternative to the posting of letters but they still rely on the printed word.

ii "The erosion of power of the established professions will be a striking feature".

This was claimed because the professions are "repositories and disseminators of specialist knowledge". It may thus seem obvious that the professions are under threat from computer systems which can store knowledge and should then be able to disseminate it. There has however, been no threat to the established professions, such as medicine, accountancy or teaching. In fact, the real threat has come at the other end of the employment range. It is the manual or skilled worker whose job is either under threat or has ceased to exist.

In the professions computers have become a tool to be used to aid the person. They are widely used in schools, not to replace teachers, but to assist children in learning. We talk of computer assisted learning, and accept that teachers are still required. Accountants use computer systems to store information and to allow fast retrieval of information, but the skills of the accountant are still in demand. Computers are used in the medical profession to aid diagnosis but there is no longer a fear that they are likely to replace the doctor. The special skills of the doctor are still needed and only he can provide a human link with the patient. So at the present stage of development computers are used to aid the professional, not to replace him.

iii "Something very drastic is about to happen to money." This prediction was based on changes already in progress in some parts of the world and to some extent it is true. The use of money is declining with the use of the electronic fund transfer. People have been paid by cheque for many years. This has been followed by credit and charge cards and now by cards allowing immediate debiting of a customer's bank account when a purchase occurs. However, money continues to be widely used in all countries of the world.

Tied to the predication of a reduction in the use of money was a prediction of a reduction in crime. This has not occurred. The desire of the criminal is for possessions, drugs or wealth. These do not depend upon money. A credit card or cheque can be used to make a purchase as can money, so there is now a serious need for electronic means of preventing crime through safeguards built into the plastic which is replacing money in some situations. It is evident that the basic supposition of a reduction in the use of money was correct, but the reduction is not as large as predicted and the consequences predicted to result frcm it have not done so.

To some extent the predictions have been fulfilled, but not in the way suggested. The computer has become a tool, an aid to mankind. We have not been replaced by it, but have learned to live with it. It is true that the ability of the computer to be used as a tool has replaced the need for men to manipulate tools in many situations. We are, for example, now able to think of robots, controlled by computers, building cars. However, the computer is still a long way from replacing man in many situations where intelligence is required, and the ability of man to use his own intelligence can be of prime importance. Consequently, we continue to have the need of a doctor and other professionals, and the criminal will always be with us. With this thought in mind, the remainder of this paper traces the development of the computer and looks briefly at the future. In the short and medium term we are likely to witness a development of the situation we have at present. The long term future becomes more uncertain and we will see new developments we have not considered at present.

2. The early days

We tend to think of the computer as a 20th century invention, but in fact it has a history of development extending back to the 19th century.

Charles Babbage, who lived from 1792 - 1871, was the father of Digital Computing. When he was in his 20's and 30's, Babbage was involved in the development of a "Difference Engine". This was a mechanical machine which was intended to calculate tables of logarithms using the "Method of Differences". Although Babbage had quite large grants from the British Government he was not able to make his mechanical machine work because the techniques of Mechanical Engineering available at the time did not allow sufficient component accuracy. The Difference Engine was not a computer, for it was not programmable. However, in 1334, Babbage began work on a machine with the possibility of establishing an infinite variety of "patterns of action". The machine had ways of feeding instructions into it, there was a "mill" which we would know as an arithmetic unit and there was what we would identify as a control unit, memory and output device. The machine was proposed to be made from wheels with 10 teeth connected together by various linkages. Once again Babbage did not have the mechanical engineering technology to build the machine.

It was left to Ada, Countess of Lovelace, to write about the Analytical Engine and this she did very well in a series of 'Notes' entitled "Observations on Mr Babbage's Analytical Engine". In these notes she wrote:

> *"The Analytical Engine has no pretensions whatever to originate anything. It can do whatever we know how to order it to perform. It can follow analysis; but it has no power of anticipating any analytical relation or truths. Its province is to assist us in making available what we are already acquainted with."*

This statement is true of today's computers.

The work of Babbage was not exploited to any significant extent until the second world war. In those years, 1939 - 1945, various developments occurred which utilised recent developments in technology. These developments included electro-magnetic relays, vacuum tubes or valves and an advancement of the ideas of Babbage. In Bletchley, England (2) work was undertaken to enable German messages to be deciphered. The first machine to do this work was known as BOMBE. It was made from relays. A later machine built using valves was COLOSSUS.

The first COLOSSUS had 1,500 valves. It was installed in December, 1943 and worked well with most valve failures occurring as the machine was switched ON and OFF. Some two years after COLOSSUS, ENIAC was built at the Moore School of Engineering, Pennsylvania (3). ENIAC contained 18,000 valves and was more general purpose than COLOSSUS. An important contributor to the development of ENIAC was von Neumann, who is known for his work on computer architecture. ENIAC worked with decimal numbers and was programmed on a plug board. In the post war years there was rapid developments in computing, both in the USA and in England. By 1953 it was estimated that about 150 digital computers were in the process of being built (4). These were generally developments of university and other research laboratories. It was implied that keeping the machines running was a sufficient challenge and that decisions did not need to be made as to what should be done with the machines when they started to work. The early computers were pushing the available technology to its limits. They were large, consuming considerable amounts of power and unreliable. There were problems in data storage, and in input and output techniques as well as in the development and testing of software.

The development of the transistor was a big step forward.

Reliability increased, there was no longer a need for high voltages or for large power dissipation in the heaters or valves, and size reduced considerably. The computer became a useful tool and there was added incentive to develop memory systems, input and output devices and programming languages.

It is evident that from the time of Babbage, the developments in computing resulted from developments in the technologies which enabled them to be developed. Each advance in an enabling technology resulted in considerable advances in computer systems and their applications. Since the development of the transistor and its application to computers, the process has been one of evolution and a continuing association of digital electronics with computation.

3 Microprocessor developments

With advances in the technology of semiconductors, it soon became possible to manufacture complete logic circuits in a single piece of silicon. Advances in the technology were quite rapid with a doubling of the complexity of circuits each year. Since many of the early integrated circuits were utilised in computer systems it was natural that eventually a complete processing unit should be produced in a single piece of silicon. This was done in 1972 by a new company, Intel, in the form of their 4004 processor. The processor was simple and only processed 4-bit numbers, but it was the start of what we now know as the microprocessor. The merging of the technologies of computing and electronics in the microprocessor resulted in establishment of a useful and powerful device, capable of a wide range of applications providing suitable software could be developed.

Developments since 1972 have been rapid. There has been an interaction between semiconductor technology, computer architecture designers and software systems to produce a range of products suitable for a variety of applications. These include business systems, scientific research, industrial control and consumer goods such as washing machine controllers. It is important that the processor used in a particular situation is optimised for that application.

The developments in processors since the 4004 was produced may the summarised as follows:

3.1 Semiconductor Technology

The technology of semiconductor devices has developed rapidly. The number of components on an integrated circuit has continued to increase, for many years doubling yearly. This has been combined with advances in the technology of manufacture so that smaller geometry components have been produced, speeds increased and power dissipation reduced. New substrate materials have been developed allowing further increases in speed and hybrid circuits (combined analog and digital) have been produced so easing the problem of getting information into and out the the computer.

3.2 Architecture

Investigations into the architecture of computer systems have continued. The original von Neumann architecture is no longer accepted to be the natural architecture. For many years it was assumed that complex instruction set computers (CISC) were desirable. In these devices operations which may be defined by a macro are coded into the hardware of the processor. The resulting Micro-code is quite complex and a measure of the effectiveness of a microprocessor may be how many instructions it has. With recent advances in software techniques it has been appreciated that the CISC machine may not be the best, and alternative systems have been considered. One such system is the reduced instruction set computer (RISC) which has few instructions, generally of a very simple type, and allows optimisation of complete instruction sequences in programs.

3.3 Co-processing

Along with the development of the microprocessor there has been a development of integrated circuits which fit into systems with the microprocessor, rather like a set of building blocks, to make up a complete system. As well as a variety of special functions such as timer-counters, input-output interfaces and system controllers there has been a range of special purpose chips developed which allow the computing power of a system to be increased by giving some parallel operation through the use of a range of processors in a system. Processors of this type are known as co-processors.

One example of a co-processor is a device which performs mathematical functions in parallel with the main processor. While the time consuming mathematical operations are in progress the main processor is able to continue with other tasks. Some examples of other operations which may be performed by co-processors are input-output, particularly involving direct memory access, graphics control and communications control.

3.4 Software

In many systems, the applications software is the most expensive and least reliable component. As a consequence of this it is natural that a considerable time should be devoted to researching and developing new methods of providing software.

In the early days of microprocessors they were programmed in machine code or possibly assembly language. Modern processors are complex and it is natural that they should be programmed in a more natural (to the user) language. Such languages require translation into machine code. Consequently, language translators, particularly compilers, are under continual development and the architecture of both systems and processors is being matched to the needs of compilers.

3.5 Number of bits

The number of bits which can be processed by a microprocessor in a single instruction determines the value of the largest number which can be processed without chaining instructions together. Since a chain of instructions takes longer to execute than a single instruction, the number of bits is an important consideration when arithmetic on large numbers is required. There has been an increase in the number of bits available on microprocessors over recent years. At present 32 bit processors are available. There are maths co-processors available which operate on 80 bit floating point numbers. The transfer of numbers to and from the co-processor must be carried out as a sequence of transfers whose word length will depend upon the host microprocessor. Thus a 16 bit processor will need to transfer 5 words to present an 80 bit floating point number to a maths co-processor.

3.6 Scale of Integration

As the technology of semiconductor fabrication improves, so the possibility of producing more components on a single silicon chip is increased. The way the additional components are utilised is important. Typically they have been used for:

a. Increasing the word length.

b. Integrating the facilities normally provided by co-processors onto the processor circuit.

c. Integrating a number of peripheral functions such as interrupt controllers, timer counters and peripheral decoding onto the processor.

d. Partitioning the processor into a number of parallel units, each of which has an element of independence from the others. The effect of this is to increase the overall operating speed since the units are able to operate, at least for a short time, in parallel. A typical system allows the fetch and execute sequences to be independent, so that while an instruction is executed the next will be fetched.

3.7 Single chip systems

A single chip system has all of the functions of a computer on a single silicon chip. Devices of this type are designed to be used in embedded systems. They make ideal controllers for washing machines, intruder alarm systems, etc. The basic principle of their design is that the user should not need to add any additional circuits, since one additional integrated circuit would double the chip count.

3.8 Parallel systems

The operating speed of a processor is limited by the technology of integrated circuit fabrication. Many of the developments listed above are designed to increase the overall speed of systems. However, the greatest increase in speed is achieved by a multi-processor system. There are many ways in which this can be achieved, two of which are described below:

a. An array of processors operate on data stored in a common memory system. Each processor has its own program and consequently the programmer has the task of organising how the complete system operates.

b. An array of processors operates on common data from a single program. The language translator must be able to function with parallel structures. The programmer is not concerned with the detail of the portions of software running on each processor since the translator is able to take care of the parallel capabilities of systems. This is a clear example of a situation in which hardware systems are very dependent upon the software associated with them.

3.9 Packaging Technology

Early microprocessors were constrained by the number of pins available on the package. This led to a number of design compromises such as the multiplexing of address and data lines. There had to be an increase in the complexity of peripheral hardware to compensate for the limitations caused by the limited number of processor pins. The early attempts at increasing the number of processor pins was based on the dual-in-line package. This resulted in large packages. More recently there has been the development of new package formats such as the pin grid array and surface mounted components. Microprocessors are now available with well in excess of 100 pins.

3.10 Associated Hardware

The microprocessor is only one element of a system. Technology advances in the microprocessors have been matched by advances in other parts of the system. This has seen the development of very large semiconductor memory, high speed cache memory, magnetic and optical systems for mass storage of data, communication systems and a wide range of input-output devices. Research leading to developments in semiconductor technology has been matched by developments in instrumentation systems and other components of the interface to external systems.

4. Present Development Status

The range of processors currently available is very large. It is not the purpose of this paper to present a catalogue of processors, although some processors are mentioned as examples. The purpose is to attempt to categorise processors according to their intended application. The categories used are by no means unique, and many other divisions by application are possible, but that is not particularly important. What does matter is that processors are considered in ways which assists in the selection of the "best" processor for the task in hand.

4.1 Embedded Processors

Embedded processors are intended to be used within a hardware system without the user of the system knowing that the processor exits. They frequently have their programme stored in Read-Only Memory, and possibly possess only a limited amount of memory. Typical systems containing embedded processors include SMART sensors and management systems for car engines as well as a wide range of domestic and industrial equipment.

Clearly any processor can be used in embedded applications, but some processors are better than others in such situations.

Processors optimised for embedded applications:

a. Have features which reduce the number of components external to the processor.

b. Have as few pins as possible on the integrated circuit. This allows the circuit board on which components are mounted to be as simple as possible.

The most obvious processors to use in embedded applications are microcontrollers, but in the experience of the author a number of other processors are very suitable for such applications.

The majority of readers will be familiar with single chip microcontrollers, but it is appropriate to review some of their characteristics. A primary consideration is the way the processor is programmed. Typically there are four methods:

i Mask programming. This is only suitable when there are to be a considerable number of identical systems built. This is because mask programming is carried out by the manufacturer of the integrated circuit, using program code generated by the user; and the manufacturer requires masks to be paid for as an overhead prior to production.

ii Field programming using, for example, EPROM technology. Devices of this nature tend to be expensive, but their use has advantages since they make the microcontroller viable for use when only a small number of systems are required. The high cost of the microcontroller is balanced by the reduced cost of peripheral hardware.

iii Use of an external memory. While this is often provided for it is not desirable since it is necessary to utilise pins normally providing facilities such as input-output for address, data and control buses.

iv A combination of i or ii with iii. This is used when the memory required in greater than the memory available on the integrated circuit.

Typical single chip microcontrollers are the 8051 (8 bits) and 8096 (16 bits).

The 8051 has 32 input-output bits, timers, counters, a serial port, interrupts with two levels of priority and a complex instruction set which includes multiply/divide. Both RAM and ROM are on chip although this capacity is limited. The processor does not have features such as direct memory access and so is not suitable for use with high data rates.

There are few purely digital systems. Providing data conversion on a microprocessor chip has significant advantages since it reduces both the system chip count and the demand for pins to interface digital signals to the processor. A number of devices include data conversion at least within the family. For example, one version of the 16-bit 8096 processor has analog inputs.

The 80186 microprocessor is ideally suited for embedded applications. It has on-chip decoding for memory and peripheral devices, timer/counters, an interrupt controller, clock generation and a dma controller. Input-output ports and memory must be provided externally, but the high integration device can be used in systems containing few components.

Recent developments in 32 bit processors for embedded use include the 80376, which has evolved from the successful 80386 processor, and the 80960. Processors of this nature are intended for situations where fast processing is required. These include robotic control, vision systems applied in real-time and telecommunication network control. The 80960 is particularly interesting. It is a RISC based machine having an extension in the form of a floating-point processor operating on 80 bit numbers. It can sustain an execution speed of 7.5 MIPS making it ideal for high speed processing. Due to the large number of pins its use is not recommended unless the high speed is essential. (It is manufactured on a 132 - lead pin grid array).

4.2 General-Purpose Processors

Processors of this type have a wide range of general purpose facilities such as interrupts, direct memory access and the ability to interface to a range of memories of different speeds. They are usually in small packages of 40-64 pins making their application fairly easy. They may form a subset of more powerful processors. Typical processors in this category are the 6502, 8085, Z80, 6800, 8086 and 68000. For many years they have been the key elements in digital systems and personal computers.

4.3 High performance processors

Processors of this type are intended for use in the personal computer and other general purpose systems. They involve a range of facilities, including memory management, designed to make multi-user and multi-tasking applications realistic. Frequently the hardware is designed to give an optimism operation with compilers.

Processors of this type include the 80286 and 80386, as used in IBM PC's, and their clones. Such processors are fast and powerful, but their use in industrial applications is not generally recommended except under very specific circumstances. The processors have many connecting pins on a small package. Printed circuit board design using them is expensive and the resulting multi-layer boards are costly to produce. Most industrial applications do not need the processing speed or power of these high performance processors, and their use should be avoided.

There is, however, a developing way of reducing system costs based on the use of IBM-PC type machines with interface cards. Many companies manufacture a range of interface cards including analogue input-output and digital input-output. A range of cards for special purposes is becoming available, for example it is realistic to produce a laser Doppler velocimeter on an IBM card (5). It may be of interest to note that the card has an embedded 80186 processor.

The application of the IBM type machine in real-time industrial applications does have an associated problem in the software. Its usual operating systems, DOS and OS2, do not support real-time software. For this reason an established real-time operating system, RMX, has recently been made available for some IBM-PC models.

4.4 Digital Signal Processors

The development of the microprocessor and its subsequent application in a wide range of systems has been paralleled by research into methods of processing information digitally. The result has been seen recently by the publication of a wide range of books on the subject which has come to be known as 'digital signal processing'. See references (6) and (7), for example.

In order to apply these new theoretical techniques it has been necessary to develop a new range of processors. These processors are not as versatile as the general purpose microprocessor, but they are able to perform high speed arithmetic, including multiplication, on parallel data.

The need for these operations can be seen by considering a typical digital filter, whose output at time t = kT is given by:-

$$y(kT) = C(0)x(kT) + C1x((k-1)T)+ \ldots \ldots + C(N-1)x((k-N+1)T)$$

where C(0), C1, etc. are coefficients associated with an N stage digital operation, and x(kT) is the filter input at time kT.

The use of a conventional microprocessor in the evolution of a function of this nature has obvious problems associated with it, due to the time delays caused by a sequence of multiplication and addition operations. Through its parallel hardware structures a signal processor integrated circuit is able to perform the filtering function quickly and in real-time as is essential.

Typical signal processors are the INMOS A100 and Texas TMS320 family.

Taking the A100 as an example, it is found that if 4 bits are used for the co-efficients then a 10 MHz throughput is possible with a 20MHz clock frequency. The throughput reduces if the number of co-efficient bits is increased, so that with 16 bits the throughput is 2.5 MHz. The processor has a 32 stage Multiplication-Accumulator array based on a 24 bit wide shift register and producing a 36 bit result. The devices can be cascaded if additional stages are required.

Typical applications of digital signal processors include digital filters, adaptive filtering, correlation and convolution, Fourier Transformation, speech and image processing, waveform synthesis, and many more.

4.5 Application Specific Integrated Circuits (ASICs)

In general ASICs are not microprocessors, but they do have a very important role in digital system design and may, in some cases, replace the microprocessor. The ASIC has become available as a result of developments in semiconductor technology and the general availability of computer aided design tools to research and educational establishments and industry.

In general CAD facilities provide for a full simulation of the circuits and so the designer can be reasonably sure that the circuit he designs will work when it has been manufactured.

ASIC manufacture is only realistic when a large number of devices is required. This is because there is a large masking change before any circuits are manufactured. Some field programmable devices are available to make application specific integrated circuits more generally available, but they have very restrictive architectures and limited applications.

It is interesting to note that the application specific integrated circuit owes its existence to the developments of technology in producing microprocessors, and that to some extent it will replace the microprocessor. However, the microprocessor is not under threat and its re-programmable nature will ensure that it will be with us for a long time.

4.6 Parallel Systems

Parallelism has already been consider from the point of view of co-processing and faster circuit design, but more can be done to increase the overall processing speed. In general two different techniques have been applied:

a. Multi-processors. More than one processor operates in a system, possibly on common data. Each processor runs its own program and some mechanism is provided to enable messages to be passed between the processors. Quite often the messages are passed through memory and the messages provide synchronisation between the processors. In a multi-processor situation, it is the task of the programme to share the workload between the processors. This must be done in a way which ensures that no processor spends long periods in which it is idle.

b. Transputers. The transputer is a device designed so that arrays of them can work in parallel. For maximum benefit it must be programmed using a language able to handle parallel structures. In the case of the transputer it is recommended that the language OCCAM should be used, although a serial language such as 'C' or Pascal can be used for procedures within an occam program.

Occam programs produced to run on a transputer enable the programmer to write and test his software using one or more transputers, and to then be sure that the software will run on a large transputer array. The programmer must identify which operations can be carried out in parallel, but to a large extent he need not concern himself with the task of actually allocating hardware until he knows his principles are correct.

5. A look to the future

In this paper it has been shown that the microprocessor results from a merging of the technologies of electronics and computation. The role of software and its integration as part of a system has been made clear and examples have been given of developments resulting from the availability of microprocessors. One important development resulting from the advances in semiconductor technology has been the introduction Application Specific Integrated Circuits. These are devices which to some extent will be replacements for microprocessors in particular applications.

The future is likely to see continual developments in semiconductor technology bringing higher speeds, new architectures and possibly more bits. There will continue to be developments of processors optimised for particular features of their performance. The probability is that embedded systems, parallel processing, digital signal processing and business applications will feature strongly in such developments.

As engineers concerned with industrial applications of microelectronics it will be our task to ensure that we use the best device for the task in hand. With publicity drawing attention to the "best" features of a processor we shall need to be careful in making selections. Speed and other high performance features may, in many cases, take second place to cost.

The industrial environment is becoming more complex. There are automated assembly lines consisting of interconnected machines, working in parallel, with vision systems for control and inspection. Many of these systems still require considerable development to occur and the microprocessor must play an important role in this. Vision systems, for example, are still in their infancy. The amount of data they produce demands fast parallel processing but this is beyond the ability of the present day microprocessor with the possible exception of the transputer. As a consequence the processing times are generally slow or expensive hardware must be used.

Perhaps the most important future developments will be peripheral to the microprocessor. Sensors continue to be a major problem in many situations. Accuracy and the need for calibration are major problems which are subjects of widespread research, as are the fundamental principles involved in instrumentation. Quite often measurement difficulties limit our ability to apply microprocessors, and these difficulties must be overcome.

Data storage has developed considerably over the years. Optical disks seem likely to take over from magnetic devices in the fairly near future, but their efficient application awaits the low cost availability of the erasable disk.

There are many social implications in the development of further microprocessor applications. In general the microprocessor replaces people. This is true of banking, manufacturing, offices, etc. There are benefits such as improved efficiency but they are paid for in terms of social problems.

In order to be competitive the new technologies resulting from microprocessor applications must be applied, but there are serious social consequences for this. If people don't work they don't get paid. If they don't get paid they don't have money to spend in shops. If they don't spend money in shops then the shops are less profitable and could close ... A long chain of events results and there is large scale unemployment. These serious issues need to be addressed continually for we, all of us, are extending the amount of automation in our societies. It is not the province of the engineer to address the issues, but he does need to be concerned about them, and to ensure that local and national Government is aware of the difficulties.

In the longer term it could be that the electronic computer will see competition from optical devices and other developments. A particular characteristic of optical devices is their ability to operate in parallel and at very high speed. It is possibly natural for them to be applied in systems where fast parallel operation is essential such as vision processing. Optical systems are expensive, and consequently the low-cost electronic system is not in any immediate danger.

6. Conclusion

The Microprocessor has come of age. It is now an electronic component available for use by an engineer in just the same way as a NAND gate is available for his use. The difference is that the microprocessor, given suitable input data and instructions, can perform any defined task.

The difficulties in many situations relate to:

a) Providing the data for the microprocessor.

b) Determining the instructions it should be given.

c) Ensuring that it can complete the instructions in a specified time.

Consequently the present-day engineer should accept the microprocessor as a device and be concerned with its application in a cost effective way.

There are many social issues raised by the application of microprocessors. These relate to the replacement of people by machines, and they must be addressed . Mankind finds it difficult to deal with the consequences of his actions, and there seems to be no exception in the case of his application of electronic systems to automation.

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IMAGE PROCESSING AND ITS MEDICAL APPLICATIONS

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1. INTRODUCTION

Man has senses of taste, smell, touch, hearing and vision. Of these senses vision is probably the most important so it is not surprising that he should attempt to utilise vision in the machines which he produces. Thus a robotic arm system able to 'see' is likely to be of far more value than one able to operate only by a combination of open-loop positioning with final location by means of sensors, simulating touch.

The use of imaging techniques is by no means new. For example, the utilisation of X-rays, with an image produced on a photographic film, has long been a valuable form of assistance in the diagnosis of disorders within the body. Through the use of X-rays the need for surgery is either eliminated or the magnitude of the surgery is reduced. The X-ray photograph makes the work of the physician easier by aiding in diagnosis.

The human body is a 3-dimensional object, but the X-ray photograph has only two dimensions. This is a common problem of imaging systems, and quite often it is necessary to find methods of enabling the third dimension to be represented

The use of X-rays has delays associated with it. The patient must be prepared, placed in line with the source of the X-ray beam and then the photographic plate must be exposed. After exposure the plate must be processed before it can be used by the physician. If the photographic plate can be replaced by some form of electronic detection system and if the detected image can then be processed through a computer then more speedy diagnosis may be possible and the computer may be used to enhance features of the image.

The author is a member of a research group which works on the development and application of imaging systems for a variety of industrial and medical research applications. Much of this paper is based on the work of that group; in addition brief descriptions are provided of some other medical imaging systems. Since the paper has been produced at short notice, while the author has been in India, it has not been possible for the resources of the research group to be utilised in its production, nor has it been possible for the work of the individual members of the group to be properly referenced.

2. IMAGING SYSTEMS

Figure 1 shows a general imaging system. The radiation may be light, X-rays, infra-red, sound, an electron beam or anything else which will interact with the object under investigation. The object will scatter the radiation in a way which depends upon its structure, or it may be stimulated so that it emits some other form of radiation. If the radiation is scattered this may be at the surface of the object or it may occur within its atomic structure. The detector must be sensitive to the radiation scattered or produced by the object. Thus, if the radiation is light which is scattered from the surface of the object then a video camera may be useful, but a video camera could not be utilised in an ultra-sound field.

The output of the detector may be a fast changing signal. If, for example, the detector is a video camera then its output will probably be a video signal having a bandwidth of at least 6 MHz. The signal, however fast it may be changing, must be sampled and entered into a computer system for subsequent storage, display and possibly processing. It is possible that, prior to its entry into a computer, some real-time pre-processing of the data may be carried out.

2.1 The Stored Image

In order to store an image in a computer it is divided, into a number of elements as shown in figure 2. Each of these picture elements, or *pixels,* is identified by its x and y co-ordinates. In a typical monochrome image there is a gray level assigned to each pixel, this gray level corresponding to the intensity, I(x,y), of the image at co-ordinates x and y.

A typical system has 256 columns and 256 rows of pixels, giving the value of 256 for both x and y. The number of pixels will depend upon the resolution required in the image as well as the need to sample sufficiently often so that no useful data is lost. It will be appreciated that a pixel is, in practice, a sample of the image at the point x,y.
The number of *gray levels* is also an important consideration. Two gray levels give what is known as a binary image and usually represent black and white while 64 gray levels are able to represent black, white and 62 shades of gray between. The number of gray levels determines the number of bits required to represent them. Thus, a 64 gray level system requires 6 bits, while a 256 gray level system requires 8 bits. A typical system will have at least 64 gray levels, although binary images do have some specific applications.

Colours can be represented in a way similar to the representation of gray levels, except that more bits may be required to store the additional information. Some systems use 'false colours' as an alternative to gray levels since the human eye can identify colours better than shades of gray.

A typical image will have 512 x 512 pixels, each having 256 gray levels. To store an image of this size 1/4 Mbyte of memory is required. If the number of pixels is reduced to 256 x 256 then the memory requirement is reduced to 64 kbytes.

2.2 Processing Operations on Images.

The processing of an image is carried out in order to remove unwanted information or noise, to enhance required features or to identify deviations from the expected image. While it is possible to carry out operations over the entire image, in many situations it is better to operate over a small window which is moved across the image. The window can, in principle, be any size, but will typically be 2 x 2, 3 x 3 or 5 x 5 pixels. Figure 3 shows a 3 x 3 mask. The window contains a mask which is combined with the image intensity information, according to some predefined rules, to evaluate the intensity of a pixel in a new image.

A typical 3 x 3 mask used for filtering has the form:

$$\begin{matrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{matrix}$$

The numbers, in this case -1 and 8, are weighting factors. By adjusting their values different operations are performed. For a 3 x 3 mask centred at co-ordinates x,y the mathematical calculation is:

$$I(x,y) = \sum_{i=-1}^{+1} \sum_{j=-1}^{+1} I(x+i,y+j)W(i,j) \quad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

By adjusting the value of W(i,j) across the mask many different operations are possible. These include high and low-pass filtering, edge detection and image enhancement. In some situations it is possible to use multiple masks to give additional information [1].

Equation 1 relates to the calculation of the intensity of just one pixel in the modified image. This must be done over the entire image, giving a software structure as follows:

```
x = 1
Repeat
  y = 1
  Repeat
    Evaluate I(x,y) using equation 1.
    y = y + 1
  Until y = y(max)
  x = x + 1
Until x = x(max)
```

It will be evident that, with a single sequential processor performing the calculations, the processing times will be long. Ways of reducing the processing time include the use of dedicated hardware and the division of the image into a number of sections which can be processed in parallel.

A dedicated hardware system forming the pre-processor, and able to operate on a 3 x 3 window is shown in figure 4. In this system the incoming serial data is fed through shift registers giving some storage. Outputs from the shift registers are fed into a fast arithmetic circuit which carries out the calculation defined by equation 1. The arithmetic circuit output then forms the input to the computer. Due to the shift registers there will be some delay between input and output, but this will generally be much less than the time required to achieve the same result using software. A transputer based system is shown in figure 5 [2].

In some forms of processing it is necessary to work on the entire image. For example, a fast Fourier transform of an image operates on all of the data. The normal sequential processor takes a considerable time to carry out operations of this nature and consequently special purpose hardware is likely to be used. The faster systems are based on array processors and are very expensive.

Fourier, and other transform techniques, have specific applications in image processing [3]. They can, for example, be used as a means of filtering the image. The Fourier transform is a representation of an image in the frequency domain, so by adjusting the amplitudes of the various frequencies according to some set of rules, and then reconstructing the image, a filtering operation can be performed. If different sets of rules are used, then different filters, or other operations, are realised.

3. PROBLEM OF THE THIRD DIMENSION

The majority of objects with which we are concerned have 3-dimensions - depth, width and height. An image viewed on a visual display screen has only two dimensions, width and height - the depth has been lost. It is essential that this problem be overcome and a number of ways of doing this have been developed.

a. Take sections through the object.
A section is essentially a 2-dimensional view effectively taken by slicing through an object. At the position of the slice, the detail hidden within an object is revealed. The concept of taking sections will be familiar to engineers who have produced or used drawings of 3-dimensional objects. They are of value in medicine since they allow, for example, sections to be taken of the human body.

b. Use some form of perspective.
The concept of perspective is familiar to artists who make their 2-dimensional drawings appear to be 3-dimensional by drawing more distant objects smaller. A consequence of this is that parallel edges of objects may need drawing so that they converge.

Care is needed in attempting to use perspective. This can be appreciated by considering the drawing in figure 6, The drawing is intended to represent a cube, but it is ambiguous since the position of point 'A' is not exactly located by our brains. As the cube is viewed, point 'A' can switch in our mind from the front of the object to the back. There is insufficient information for us to make an absolute decision about the orientation of the object.

Ambiguity is not unusual in image processing. It is encountered in many situations and the development of image processing applications should ensure that no serious problems of this nature occur.

c. By addition of contour information to the image.
The concept of contour lines drawn on a map will be familiar to many people. They consist of lines drawn on the two dimensional surface of the map, the lines joining points on the surface which are of equal height.

In image processing, the addition of contour lines can be done optically. Quite often the lines are not true contours, but providing they can be defined mathematically that is not important.

4. MEDICAL APPLICATIONS OF IMAGE PROCESSING

Any measurement system depends upon some physical property of a transducer which can be used to produce an electrical or other signal whose magnitude is dependent upon the input to the transducer. Thus, a strain gauge is a length of wire whose resistance changes according to the strain placed upon it. If the wire is attached to an object which will be strained, then the strain gauge will undergo resistance changes whose magnitude depends upon the magnitude of the strain in the object. By use of an appropriate electrical circuit, a voltage or current can be produced as the object under investigation is stressed.

In image processing, the requirement is to produce an electrical signal which may be used for image processing and which results from some property of the object under consideration. When, for example, surface topology is under consideration light is an obvious choice for the detection medium since it is convenient and a wide range of detectors is available. However, light is not suitable for use within an object unless that object has light transmission properties. Imaging of solids may be based on a variety of physical phenomena, including ultrasound, X-rays and magnetic effects since solids can be penetrated by these forms of radiation or field.

The information in this section is by no means complete. It is intended only to give an overall impression of how vision systems can be utilised in medicine. Some of the reported applications are based on the work of the author or his research group while others are based on published material.

4.1 Durability measurements on replacement parts.

The author and members of his research group have been involved in the measurement of the durability of replacement parts used in the human body. Specifically these parts consist of artificial knee and hip joints and dental restorations.

In the case of dental restorations the work involved taking casts of restored teeth at regular intervals and assessing the rate of wear from the casts. This was done by projection of a fringe pattern onto the teeth, giving contour information which could then be used to assess wear rates. Three parameters were of interest:

* Depth of wear
* Volume of worn material
* Plastic flow of materials

The purpose of these measurements was to enable new plastic materials used in restoration work to be compared with each other and with traditional amalgam.

The work on artificial knee joints involved a similar measurement technique. In this case the joints were removed from the patient when they failed or possibly after the death of the patient. The purpose of the measurements was to compare the effectiveness of different materials and geometries used in the construction of the artificial joints.

4.2 Fracture fixation.

A common method of fracture fixation involves the attachment of metal plates to the bone by use of screws. The bone is then subject to stress for two reasons:

i. The screws must subject the bone to stress if they are to hold into it.
ii. As plates are attached to the bone they cause it to twist.

The use of contouring methods using fringe projection can assist in the understanding of the deformities created in the bone. Unfortunately it is not possible to make the measurements with the bone still in the patient.

4.3 Surface topology measurements

Figure 7 shows a method for the measurement of surface topology. It is useful for a study of deformities in, for example, the human back, particularly of the infant. Light is projected through a grating onto the section of the body under consideration and the resulting fringe pattern is viewed through the grating. Interference occurs between the grating and the projected fringes, giving a result to the viewer corresponding to Moire fringes and having some equivalence to contour lines. From the contour lines deformities can be identified.

4.4 Deep body measurements

Measurements within the body utilise radiation which can pass through body material. Typically the radiation may originate from radio-active tracers injected into the body, or it may be from external sources such as X-rays, ultra-sound or magnetism. The radiation will undergo some intensity and possibly phase changes due to effects such as absorption and diffraction. Detectors can then be used to record the emissions from the body and the signal can be processed by a computer to give an image suitable for viewing by a doctor.

The kind of processing required to produce a useful displayed image depends upon the situation. For example, if the radiation has been subject to diffraction then the detected radiation probably represents a Fourier transform of the region of the body causing the diffraction. In a situation such as this a useful form of processing may be an inverse transformation so that an image of the actual region of the body causing the diffraction may be reconstructed.

By taking many readings at different angles, it is possible to build up cross-sectional images of the body. The technique is used in Computer-aided Tomography (CAT). Participants requiring more detailed information on this, and other techniques, are referred to the technical press.

5. CONCLUSION

In this paper an attempt has been made to show how image processing is utilised in medicine. Imaging techniques have become common in the diagnosis of illness and seem destined to become even more important in the future.

Many of the principles applied in medicine are equally useful in industrial situations. In metrology, for example, the measurement of surface topology is very important and image processing techniques can be combined with some form of surface contouring to give the required measurements [4].

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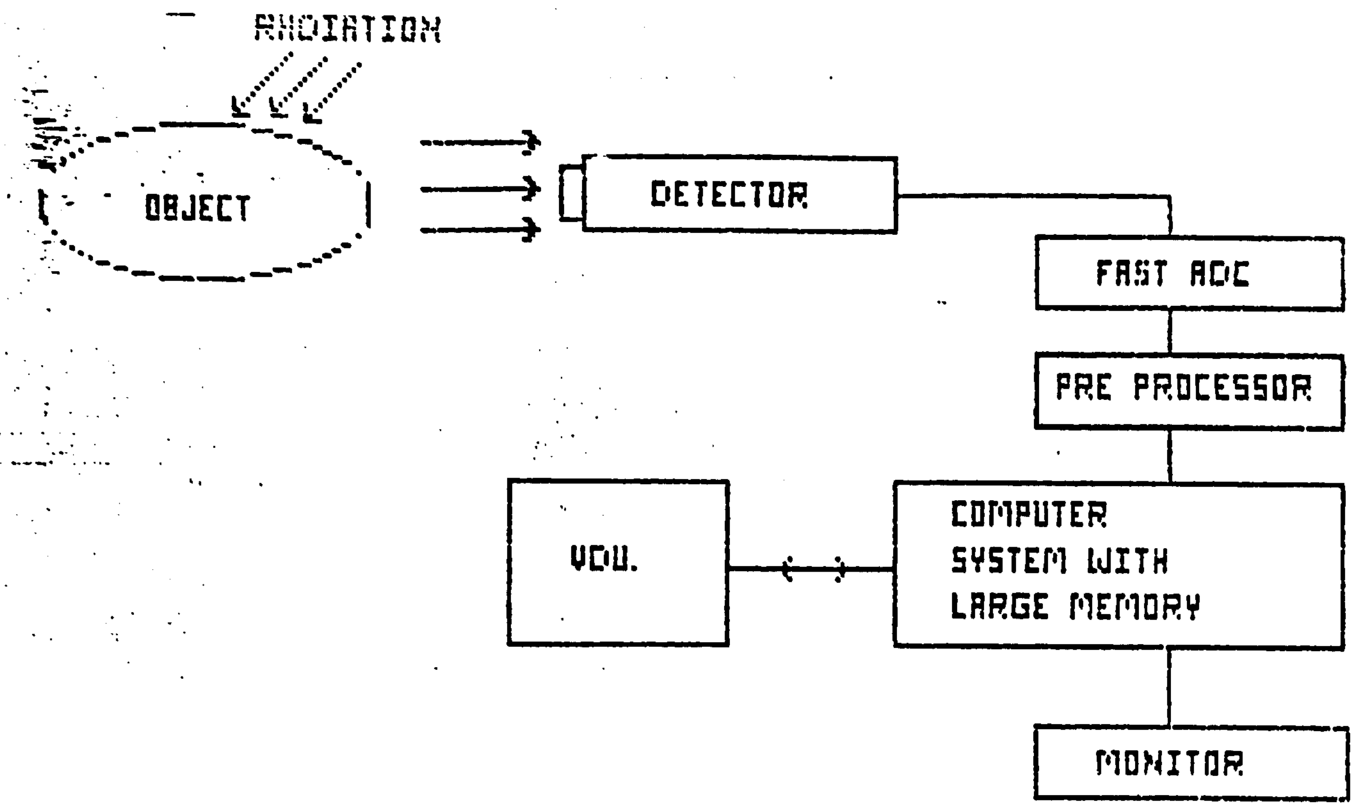

FIGURE 1 GENERAL ORGANISATION OF A COMPUTER VISION SYSTEM

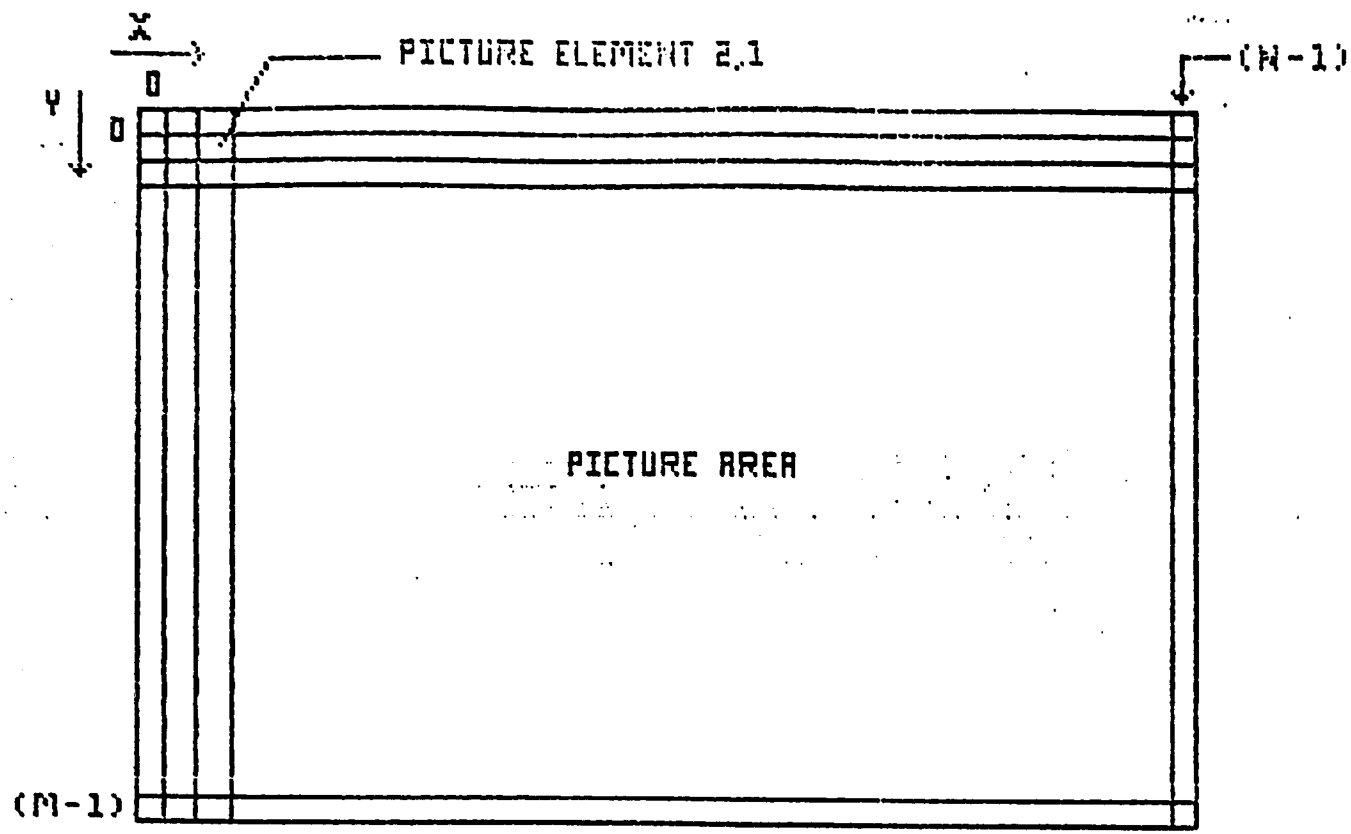

FIGURE 2 **DIVISION OF A PICTURE INTO ELEMENTS**

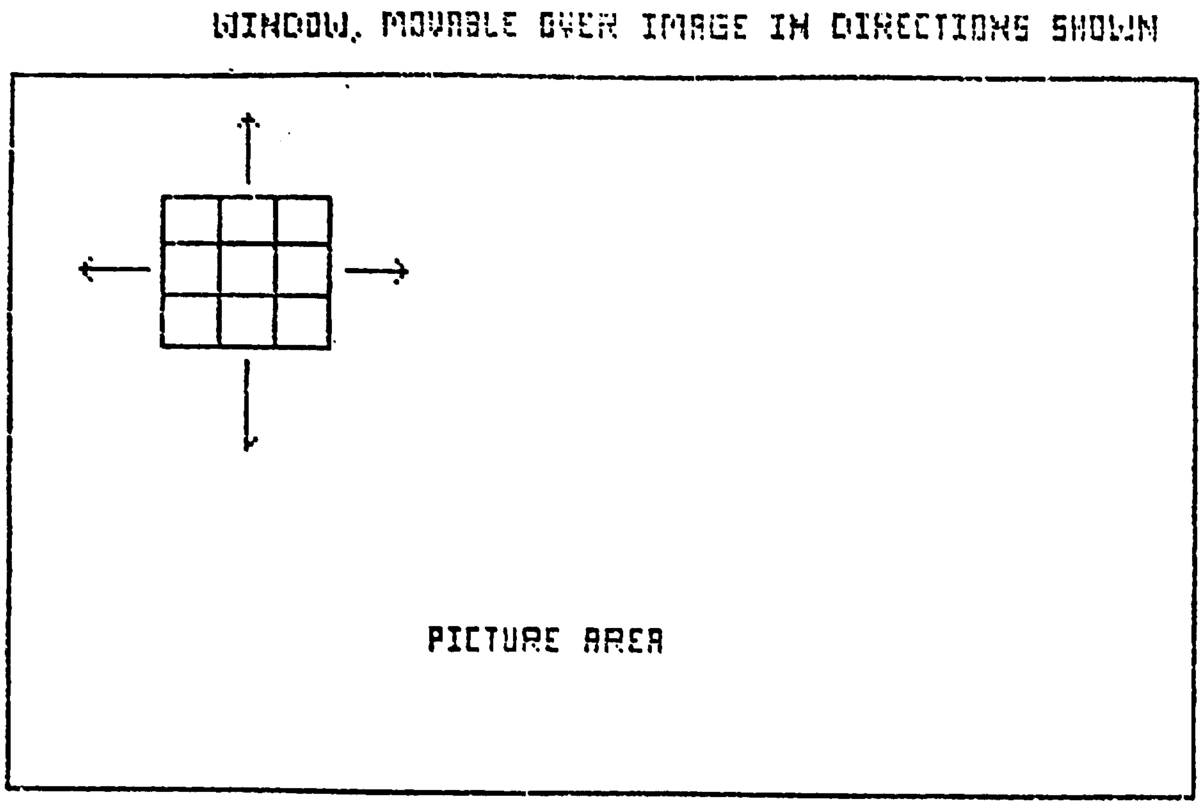

FIGURE 3 **MOVING WINDOW COVERS REGIONS SUBJECT TO CALCULATION**

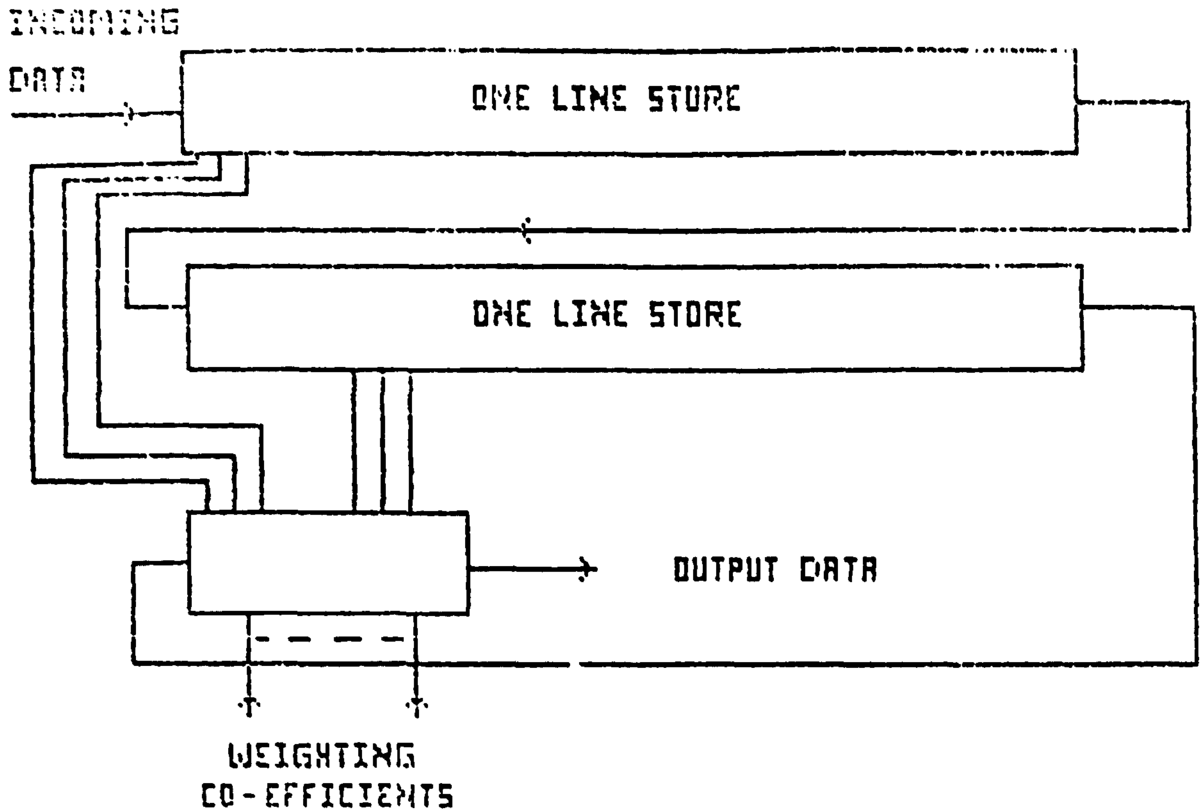

FIGURE 4 REAL-TIME PRE-PROCESSING OF IMAGE

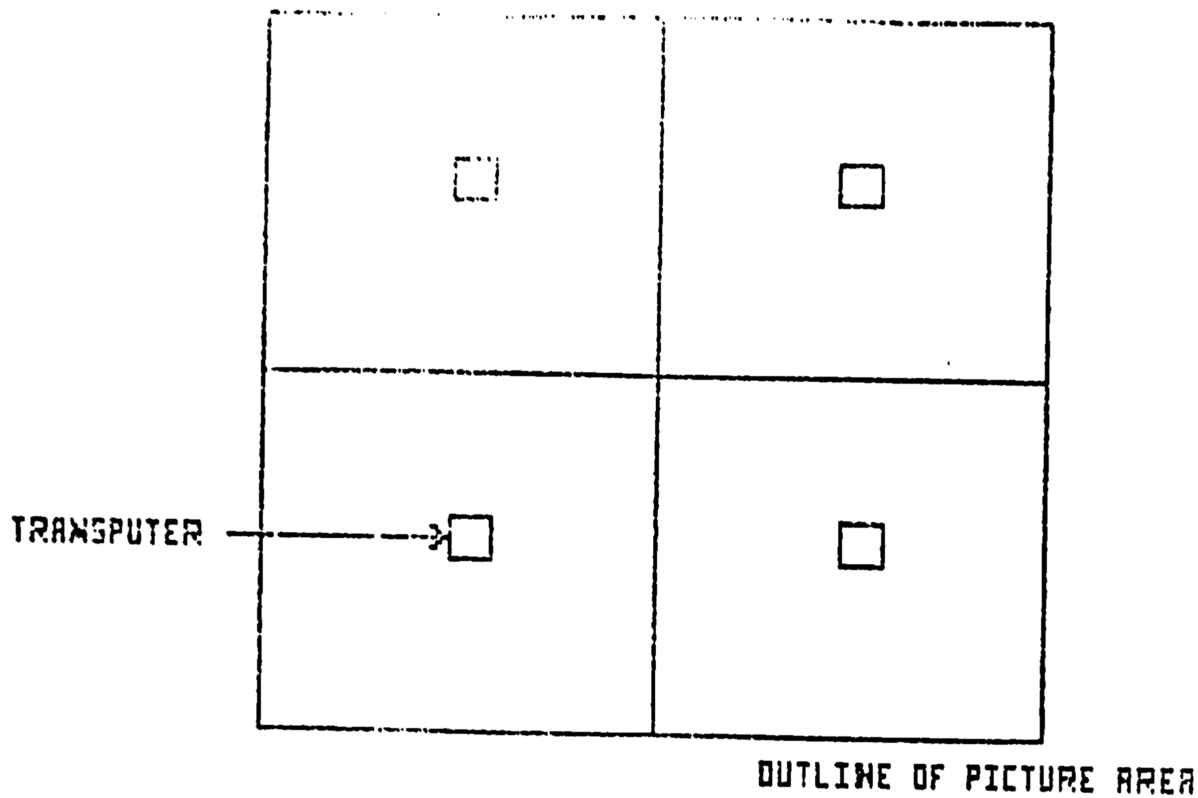

FIGURE 5 **USE OF 4 TRANSPUTERS FOR PARALLEL PROCESSING OF IMAGE**

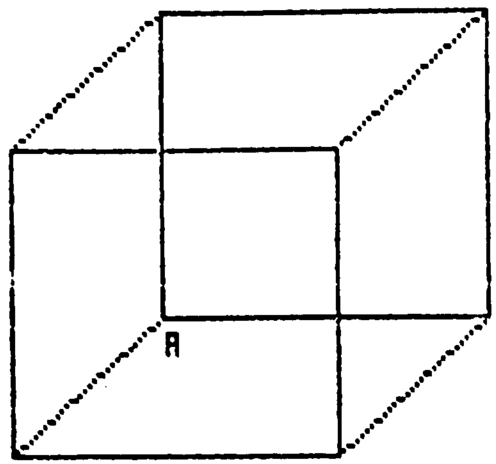

FIGURE 6 AMBIGUITY IN VISION SYSTEMS

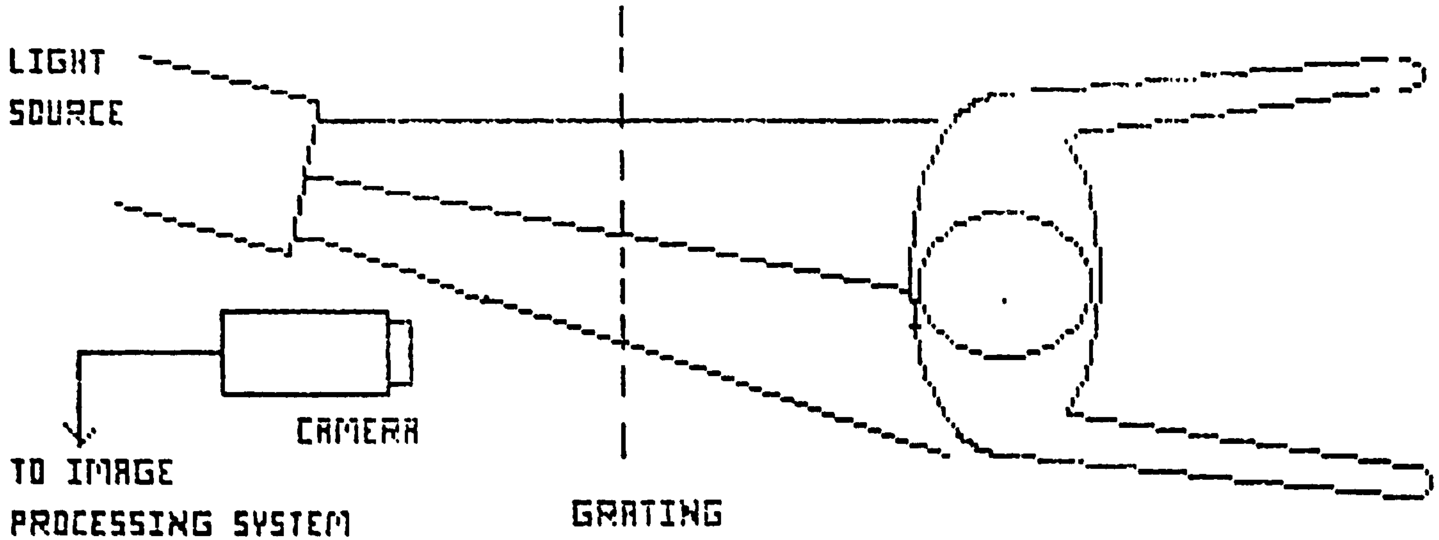

FIGURE 7 MOIRE CONTOURING OF HUMAN BODY