ELECTROTECHNOLOGY AND MANKIND

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INTRODUCTION

It is a well known fact that medicine, law, engineering — all the great professions — began as needed arts or craft. Their evolution makes it impossible to really identify a particular day, or even a year, when they emerge as full-blown learned pursuits. In the case of electrical engineering, at least in the United States of America, it has been said that the profession was formalized more than a century ago.

In the period since that beginning, electrical engineering has spawned major developments in electrical power, radio and television, computers, radar etc. and has been the root technology for such industries as telecommunication, aerospace, medical electronics, defence etc.

The vast changes brought about by electrotechnology to homes, offices, schools and health-care units, though largely positive, have not been exclusively so, nor will they be in the coming decades, despite the high expectations of electrical and electronics engineers and computer scientists.

One must be concerned about the dichotomous effects on the individual and as such I present some open-ended views relative to the impact of high technology on both the citizen at large and the engineering professional, in the hope of provoking further thought and maybe critical examination of the practice of our worthy profession in our relatively small regional area.

No one can truly predict the future, but during the relatively short history of electro-technology, professional work has already undergone radical changes. The forces that produce change are increasing, and the rate of change is quickening. I believe it is safe to predict that advances in electrotechnology — and especially in automated decision making systems or so-called knowledge systems — will dramatically alter the nature of professional work as we know it. Some professions will be made obsolete and disappear while others will change substantially, and other new professions will emerge to exploit and support new applications of electronics.

What defines the category of "professional" occupations? Many people would classify doctors, lawyers, accountants, engineers and others as professionals. However, a modern, basic, general definition of a professional is someone paid to make well-informed decisions.

It now appears that research professionals in the classical area of electromagnetic fields, have so far produced some of the most dramatic results in the recent past. e.g. "Destruction of cancerous tumors through heat-inducing electro-waves".

BIOLOGICAL EFFECTS OF ELECTROMAGNETIC FIELDS

Within the past few years, the study of the biological effects of radio-frequency electromagnetic (EM) fields has taken a new turn. At the start of the 1980's researchers still argued about whether all the effects of fields on organisms were caused simply by the heating induced by intense radiation or if some effects also occured at field strengths too low to produce even localized heating.

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* Invited paper based on the inaugural lecture delivered by A. J. Parris, Professor of Electrical Engineering on April 24, 1985 in the Faculty of Engineering, U.W.I. St. Augustine.

Although laboratory results had by that time convinced some researchers that athermal effects — those that could not be explained by heating — did in fact occur, a vocal group of scientists still doubted that these laboratory results were valid and repeatable.

Now, a growing mass of evidence has virtually ended that debate. Few scientists now question that some such weak-field effects exist. In fact, one such effect — the influence of weak, pulsed EM fields on bone growth — has now found widespread use as a treatment of bone fractures, with thousands of individuals treated successfully since the method gained approval in 1979.

The study of the interaction of EM fields and organisms remains intensely controversial, with many questions not yet fully answered. For example, under what conditions and at what frequencies and field strengths do interactions with organisms occur? What are the mechanisms by which weak fields can influence organisms? Which biological effects are just harmless changes, which are beneficial, and which are harmful? How might weak-field effects be taken into account in setting safety standards for exposure to EM fields? The outcome of these controversies has a bearing as well on potential therapeutic use of EM fields. In the opinion of some scientists, those studies can aid in the understanding of basic biological processes such as how growth is controlled, how cells communicate with one another, and how the nervous system really works. Weak fields are defined as

(a) electromagnetic fields too small to produce measurable elevations of temperatures in organisms, and
(b) fields that only raise the temperature of an organism within its normal range of fluctuation.

Biological hazard, however, is defined as the capability of some agency to cause deleterious changes in the health of an organism.

The study of EM-field interactions with organisms is wide-ranging, drawing on the knowledge and research of biological and physical scientists as well as electrical engineers. It covers the effect of fields ranging in frequency from 0 to 1,000 gigahertz, the boundary of the infrared range.

Most attention, however has been focused on two frequency ranges; one is the micro-wave and short-wave frequency range widely used by the military and for communications, which extends from a few megahertz to 100 GHz. The other range includes extremely low frequencies, especially power-lines frequencies of 60 Hz and lower frequencies that are of interest in naval communications.

Let us consider the possible effect of low frequency fields!

Can human exposure to power-frequency (i.e. 60 Hz) electromagnetic fields have significant health consequences? Few people would have given this question a second thought 30 to 40 years ago, when electricity was considered, the clean, safe marvel of the modern world.

Today, however, the question of exposure to power-frequency fields is the subject of serious scientific study.

There is a very persuasive evidence that under some circumstances, power frequency electric and magnetic fields can have biological ~~effects.~~ But there is no definite evidence of significant health consequences. A biological effect is not necessarily a significant health consequence.

However there are two mechanisms by which extremely low-frequency fields apparently can interact with living systems to produce effects. The first is the stimulation of neural receptors at or near the surface of the skin, such as through the vibration of hair. In high intensity fields, people report a tingling sensation on exposed skin.

The second mechanism involves some direct interaction between the field and individual cells, probably through a nonlinear transductive mechanism at the cell membrane.

And so, the fact is that researchers do not know conclusively whether power-frequency (60 hertz) fields can significantly affect human health. One of the main problems in trying to assess possible health risks from exposure to 60 Hz fields is what physical quantity to measure and how to collapse the time function of this quantity into a single number, or dose.

However, if does as it relates to such power frequency fields, is defined as the time integral of the unperturbed electric-field strength, the average electric-field exposure from household sources exceeds that from power-distribution and transmission lines. On the average, electric blankets are the largest single source.

Let us consider the possible effects of higher frequency fields. Among the results of experiments performed dealing with the indications of genetic effects by electromagnetic fields are the dramatic findings that indicated that microwaves may, in some circumstances, induce chromosomal damage in live animals. These experiments, which are still preliminary in nature, were performed by researchers at the National Centre for Devices and Radiological Health of the U.S. Public Health Service in Maryland.

The experiments indicated that when male mice were exposed to ~~microwave~~ radiation of 0.915, 2.45 and 9.4 GHz, chromosomal defects were induced in from 4 to 12 percent of the sperm percursor cells. In normal animals such defects occur only .05% to .09%. At 27 MHz, however, no such changes were ~~observed~~. The mice were exposed for 30 minutes a day, six days a week, for two weeks at an average rate of energy absorption of only 50 microwatts per gram — eight times less than the specific absorption rate (SAR) recommended as a safety limit for humans by the American National Standards Institute (ANSI).

While the researchers cautioned that the results could not at present be generalized to other frequencies or to humans, one must recognise that chromosomal defects are quite serious.

A major concern of recent research on electromagnetic effects has been how to measure them — what constitutes the dose for an imposed field? The commonly accepted measure of power absorbed per unit mass, averaged over the entire animal is not itself an appropriate measure. While the specific absorption rate calculated by antenna theory does give some idea of how efficiently the energy is coupled from the field to the animal, not all radiation with the same absorbed power-levels is equally effective.

Modern man has learned to utilize, and indeed, to depend for his personal, social, economic and political well-being on devices that generate microwaves and other radio frequency (300 KHz to 300 GHz) electromagnetic fields (RFEM).

Applications of such fields in radio and television broadcasting, communications, radar etc. are readily recognized. Applications of these fields in the home (cooking), industry (sealing) and medicine (diagnosis) are increasing.

The prevalence of these man-made fields and their relatively recent introduction to the human environment could lead to public concern over the possible health implications. The answer to this question must lie in rigourous research and dispassionate assessment of laboratory and epidemiological data. Present knowledge is not complete enough to supply final answers, but what is known is reassuring for our general population, that is, the strengths of fields to which our population is exposed normally, are well below current international guidelines. Is there a need for regulation of EM fields in our region?

A few years ago, the electronics and communications industries were more than content that, in the United States of America there was no compulsory regulations limiting human exposure to electromagnetic fields. In the view of many industry spokesmen, the dangers of such fields were minimal in any case. Today many corporations and trade groups, ranging from broadcasters to radar manufacturers, are urgently demanding that national standards be set up.

The direct application of further successful research in E-M fields has led to many advances in the field of medical electronics.

A recent article from the London Observer Service dated April 13, 1985 under the headline "Major Breakthrough against Cancer" reads in part as follows.

Japan is claiming a major victory against cancer with a new machine that helps destroy tumours through heat-inducing electrowaves. More than one-third of cancer deaths result from failure in treating localised tumours. This death rate could possibly be reduced by sixty per-cent with the aid of the new "Thermatron" heat treatment machine, in conjunction with conventional radiation or chemotherapy, claims its chief researcher Mitsuyuki Abe, Professor of Radiology at Kyoto University.

The "Thermatron RF-8" induces heat at 42-43 degrees Centigrade in the cancer area by bombarding it with high-frequency electronic waves. Unlike an earlier machine developed in the United States of America, the Thermatron RF-8 heats up to a depth of about 25 mm which is four times that of earlier machines, without harm to normal tissue.

The only localised cancers it cannot be used against are in the bone, where patients complain of pain caused by the heat. Otherwise, the Thermatron's deep penetration allows it to reach almost any deep-seated part of the body.

MEDICAL ELECTRONICS

The ongoing electronics revolution has triggered a corresponding surge in the ability of physicians to peer into and better understand the human body. Almost daily, break-throughs in imaging technology are reported that promise major benefits to vast numbers of individuals. Perhaps no recent development exemplifies the breadth of electro-technology's potential better than the use of positron-emission tomography (PET) to study Alzheimer's disease, the leading cause of senility, in the United States of America and one of the leading causes of death.

Technology in health-care is all-pervasive today. Drugs and such diagnostic devices as X-rays and computerized axial tomography (CAT) scanners have immense impact.

Another of the more widely used electronic techniques in medicine today is ultrasound; another application of EM fields theory. Physicians using it can now measure the velocity of blood flow in high-risk pregnancies; examine the brain of newborn babies; take motion pictures of a patient's heart; and detect cancerous tumours and the plaques in blood vessels that cause arteriosclerosis. Although the primary use of ultrasound is in diagnosis, it is also being used increasingly in bio-medical research, therapy and even surgery.

Also medical interest in the human heart, intensified recently, and electronic equipment manufacturers, pressing to keep up, reported new development in several areas.

However, in the United States of America in 1984, the health-care industry also faced public and governmental concern about the costs and safety of medical technology. It has become so expensive, that in certain areas of the United States the infant mortality rate, due to poverty and limited access to health-care facilities, is still no better than in some under-developed or undeveloped countries. High costs thereaten to undo years of steady progress in the medical front.

Achieving better, affordable health care though is within our reach, but only if society and the powers that be, have the will to reform the present system by taking full advantage of technology. Any delay will only force the wasteful investment in an inefficient system of resources that should be committed to change. The engineer has a pivotal role to play in creating, operating and maintaining the efficient technology that can meet the needs of the consumer. A characteristic of medical technology in our region is that it has not significantly altered our system of health-care delivery. Though technology in general has revolutionized the make-up of the factory and the office, here in health care it has not yet done so.

The most important challenge to the engineer is to lay possible emphasis on prevention rather than repair in health care. Several major difficulties must be resolved before greater emphasis on prevention is fully established, prevention is bound to be viewed as benefitting the young at the expense of the old — the active population at the expense of the retired. A concurrent and inevitably costly commitment must be maintained to the older population. The challenge to policy-makers is to avoid insensitivity and yet still confront the issue forthrightly and creatively.

A recent article in Trinidad Guardian of 13th April, 1985 entitled "Doctors Choose Who's to Live" highlights the problem of choice. The article reads: "British doctors use social as well as medical criteria in life-and-death decisions on whether to treat patients who suffer from kidney failure, a research study has found.

Under the British National Health Service, Kidney dialysis is free, but demand outstrips supply.

The matter hit the headlines last week when a mentally retarded patient was disconnected from his machine and sent away to die, although in fact his life was saved by a machine provided by a private charity.

To find out what is happening over the whole field, medical researchers sent a questionnaire to 700 kidney specialists and general physicians in which they outlined the medical and social details of 16 fictitious patients with renal failure.

The answer just published in the "British Medical Journal", shows that doctors tend to make value judgements on non-medical grounds. As one respondent, Dr. Sabri Challah, of London's St. Thomas's puts it: "success or failure in dialysis so often depends on what the patient has between the ears".

Another big problem is that the prevention model will necessitate more health-care screening. This, in turn, during the transition period, is bound to identify more people with health-care problems and thus over burden our present system.

Yet another problem is the fact that at present the skills and rewards of the physician are in health repair rather than prevention. But the shift in emphasis from repair to maintenance and prevention is but one aspect of how our health-care delivery system must be restructured to make it more efficient, economical and meaningful to us. Even the teaching of medicine must undergo some related changes to stress the importance of the laboratory — and hence technology — in medicine.

It seems imperative that medical schools take another major step and encourage the development of physicians like that of the engineers that is — systems oriented. A systems-oriented view of health care implies acceptance of far greater input from engineers, technologists and other constituents of the health-care field (nurses, paramedics).

Another development is telecommunications networks connecting physicians and patients via personal computers. Such networks allow patients to communicate directly with the doctors from their homes. The physician then receives over the network the patient's case history, a description of symptoms, and certain measurable parameters — and thus "make the rounds" from the office electronically.

Today's hospital is not designed for efficiency, but rather for medically effective delivery of health care at whatever cost. There appears to be little hope of containing hospital costs until the way in which they function is changed. Changes in the interaction between patients and physicians, made possible by telecommunication and health-care networks, can by themselves reduce the burdens on hospitals by reducing the number of admissions and possibly the length of patient stay. An internal reorganization of the hospital is imperative to take advantage of labour-saving and cost-reduction technologies.

The hospital of the future, with the help of technology, can become not only more medically effective, but also personnel-efficient, energy-efficient and information-efficient.

In this electronic hospital, computers will modernize virtually all operations — clinical laboratory analyses, emergency treatment, radiology, intensive care, and record keeping — and integrate them into a smooth-running unit. This system is safer, faster and more responsive to the needs of patients. It also reduces or eliminates many tedious tasks for doctors and nurses, thus freeing them for more personal attention to patients.

However, probably the most important criterion for any system used in health care is reliability. A loss of data or a shutdown of a computer-controlled life-support system could result in a patient's death. To achieve reliability, computers are deployed with both built-in hardware redundancies and soft ware intelligence to keep the system operational in the event of a hardware failure. Reliability is also maintained by the storage of information in a central data base.

The success of such a system hinges to a large degree on acceptance by its users, especially doctors and nurses. The systems interpretative and decision-making capabilities should be viewed not as threats to doctors, but rather as a safety net.

Today it is difficult to get a physician to make house calls. Hence what is being envisioned in the not too distant future is an electronic house call.

Here is an example of a typical electronic house call. It is 7:00 a.m. and Mrs. X wakes up not feeling well. She goes to her personal computer and, by typing a few words, initiates a dialogue with the computer in her doctor's office. After receiving a reply, she connects herself to a variety of telemetric sensors. These sensors monitor her blood pressure, pulse rate, temperature and other critical parameters. The information is fed directly into her personal computer, which through a modem sends it to Mrs. X's doctor.

Sitting in his office some distance away, the doctor reads the data, as well as the symptoms that the patient has typed in herself. The doctor then turns this information over to the expert system built into his own computer, which has the patient's medical history in its memory. The expert system displays several possible diagnoses. The doctor favours one, but decides he needs more information from Mrs. X. In response to the query that appears on her screen, she types out a more detailed description of how she feels. Then, after consulting his expert system again, the doctor decides upon a diagnosis and prescribes a therapy. (Had he any doubts about Mrs. X's safety or a need for further analysis of her condition, he would have asked her to join him at the hospital). The doctor calls a pharmacy to order a prescription for Mrs. X. The pharmacist sends a messenger to Mrs. X's home with her prescribed drug, stored in an automatic drug dispenser. After Mrs. X plugs the dispenser into her computer, it begins releasing the drug to her, with the size and timing of the dosage determined by a program transmitted from her doctor's office. Meanwhile, over his computer terminal, the doctor monitors the operation of the drug program and its effect on Mrs. X's critical functions. Here, the electronic house call is made possible mainly because of advances in computer technology and telecommunications. Basically, the electronic house call is nothing more than the transfer of information (medical information).

COMPUTER TECHNOLOGY

It has been said that we are in a new age — an information age — brought about in large part by the computer and telecommunications. Information is a major commodity. Since the earliest days of industrialization more than a century ago, information has been a valuable commodity — ever since there have been bank balances, credit records, research on secret weapons, industrial trade secrets and corporate marketing strategies. Even in those days people realise that whoever controlled certain information had a useful monopoly and was thus in a position of power over those without the information, and so precautions were taken, to safeguard that information.

The advent of the computer and telecommunications have not really introduced new issues as much as they have transformed the nature of old ones. Historically, paper money and hard currency have been sequestered in steel and concrete vaults, with combination locks on the door. Later, money was transferred via paper cheques that were processed manually. Today, most money is stored in electronic form inside computer systems, which are the new vaults. So the current focus is on making computer systems more secure to protect electronic money as well as sensitive information.

Information — wherever it is and whatever form — must be looked upon as a resource and an asset of an organization, just as surely as actual money or raw materials. Any organization today can be viewed in part as an information factory. Consequently an organization's information must be managed and protected as an asset. In many of our local organizations, however, efforts to protect information are usually limited to simple password access-control and a little physical security around the computer. Is that enough? In keeping with the much broader concept of information as an asset or resource, organizations should be dealing instead with information security, not just computer security. It could be argued that the potential for protecting business and government data is far greater with reasonably secure computers than it ever was with the previous manual and physical systems. It is much harder to break the rules of confidentiality once they are set up efficiently in a computer system than it is in a manual system.

Although the potential for security is much greater today, there are practical limits to the level of security that can be attained. Though it is true that many of the vulnerable points in computer systems are known and appropriate safeguards for them are also well known, there are still a number of unsolved problems. The fundamental reason for this is that complex systems are unpredictable, and no one can predict how a system will perform under all configurations of data and logic states. In other words, there is no assurance that even security specialists know all susceptibilities of a computer at all times.

On the other hand, overvigilance in computer security may also affect the work of authorized users. Because most computer-system managers are more concerned with security than with convenience, necessary work may often be delayed and user morale may suffer.

The real point of computer security is not how one group can keep information away from others, but rather how a computer system can be trusted by groups who do not necessarily trust each other. Twenty years ago anyone who committed a crime that involved a computer was probably employed by a data-processing facility. The only computers that existed at that time were mainframes and the crimes fell into one of four main categories:

(a) Physical destruction (ruining the computer or the tapes);
(b) Information destruction (erasing tapes),
(c) Data diddling (changing data input or the data in the computer; e.g. changing the names on pay cheques); and
(d) Unauthorized use of computer services.

Prevention of such activity centred mainly on physical controls. Ten years ago, timesharing systems allowed people to access mainframe computers from remote sites. Networks of computers separated the users even further from the mainframe and the system operator. Then along came mircomputers and cheap modems that put more modems in the hands of people. In addition to giving more people access to computing resources and computer networks, the microcomputer has become a computer crime accomplice.

Today's children are being weaned on video games and quickly move up to computers. Society has high hopes for this technically literate generation, but the proliferation of microcomputers and computer literacy also means that more and more assets will be stored on computer systems and that the community of potential computer criminals will possibly increase.

The computer is the most effective detection tool of crime that man has invented and can also be the most effective tool of the computer criminal. And so, we look at the laws of our land.

In general, law is reactive, not proactive. As such, it tends to lag behind what society deems to be appropriate behaviour (ethics) and what society generally requires as business practice (technical standards and procedural safeguards). To be most effective, however, law in the computer-security field must be combined with technical procedures and ethics to prevent wrongs, not merely respond to them. If people are convinced of the need to act with care and to respect the rights of others in a computer system, many losses will not happen. Once system operators and users are informed of their responsibilities, the law can allocate responsibility for safety precautions and set the boundaries of acceptable behaviour of users and maybe suppliers. Safeguards then can perform as a safety net to catch negligent and malicious acts, and our judicial system can allocate the burden of resulting loss or damage, punish intentional wrong doing accordingly.

On the much larger scale, the prospect of what is referred to in electronics as an "information war" is threatening the international telecommunications grid on which modern business depends for moving data around the world. For most of its history, this grid has operated reasonably well, through the cooperation of national telecommunications agencies and companies. But in the last few years, certain developments have started to disrupt this cooperation and have led to growing confrontation and conflicts.

Firstly, the United States Federal Communications Commission in the last five or so years has begun to extend the deregulation of domestic telecommunications in a way that affects the international network. Since virtually all other countries run their telecommunications through state-owned monopolies, and most oppose any weakening of those policies, the FCC's attempt to encourage international competition has put U.S. and foreign policies in direct conflict. In 1979 the U.S.F.C.C. said that data-processing services are distinct from communications, and therefore would not be regulated either domestically or internationally. Because a number of data-processing services, however, clearly involved both data processing and other communications, the F.C.C. in 1980 further distinguished between "basic" and "enhanced" communications services. Only basic services, the F.C.C. determined, are to be regulated.

Secondly, there are fears that protectionist policies, already present in the trade of goods, are starting to spill over into the exchange of information services.

Thirdly, the Council of Europe, an organization of European States, in 1983, ratified a treaty regulating privacy protection in the international exchange of information. It is feared that the disclosure provisions of this treaty may infringe upon certain of the business activities, such as gathering of marketing and financial information about other companies.

Today, the international flow of data is crucial to a host of economic activities. No one knows even roughly the volume of data transmitted daily around the globe. Computers have altered traditional data flow.

As computers have been linked to international data networks that receive, process, sort and transmit data, the line between data processing — an essentially unregulated, mainly private activity — and telecommunications — a regulated activity — has been blurring. So computers as they now exist seem to be, indirectly, the cause of the problem. Can computers be made to think like people? Attempts to automate various types of human activity, from assembling an automobile to diagnosing a patient, have often been impeded by the gap between the way humans reason and the way computers are generally programmed. When making decisions, computers usually ask questions that have a clear-cut yes or no answer. Humans don't generally reason in such a precise manner: Rather, most human thinking deals with categories that shade into one another, and so a theory of sort evolved to address itself to such categories of imprecise human thinking, viz. "The Theory of Fuzzy Sets".

Fuzzy sets is a concept that can bring the reasoning used by computers closer to that used by people. Whereas a conventional, or "crisp" set has sharp boundaries (such as the set of all numbers greater than 2), the transition between membership and non-membership in a fuzzy set is gradual rather than sharp. The degree of membership is specified by a number between 1 (full member) and 0 (full nonmember), so that one can ask questions such as "Is John much younger than Harry?"

The theory of fuzzy sets was developed by Dr. Ebrahim Mamdani, a control engineer at Queen Mary College in London. Fuzzy logic uses graded or qualified statements rather than ones that are strictly true or false. The results of fuzzy reasoning are not as definite as those derived by strict logic, but they cover a large field of discourse.

With fuzzy sets, human concepts like "small", "big", "young", "old", "high" or "low" can be translated into a form usable by computers. Indeed fuzzy sets and fuzzy logic are now finding wider and wider application in a broad range of problem solving, from industrial process control and pattern recognition to weather prediction, medical diagnosis, and agricultural planning. Eventually they are likely to become part of the efforts to develop intelligent machines that can "think like people".

In a way not well understood at present, humans have a remarkable ability to assign a grade of membership to a given object without a conscious understanding of how the grade is arrived at. For example, a student in a course would have no difficulty in assigning a lecturer a grade of membership in the fuzzy set of good teachers. Indeed, the assignment would usually be arrived at almost instantaneously without much conscious analysis of the factors that enter into the assessment of the grade of membership in that class. Since the grade of membership is both subjective and dependent on context, there is not much point in treating it as a precise number. Thus in many applications it is sufficient to represent the grade of membership in a fuzzy set as a fuzzy number. The degree of membership might be expressed as "close to 0.8", or "approximately 0.6" or as "quite high" or "very low" and so on.

The grade of membership is not a probability. Basically it is a measure of the compatability of an object with the concept represented by a fuzzy set.

Perhaps most significantly of all, fuzzy sets allow computers to use the type of human knowledge called "common sense". Common sense knowledge exists mainly in the form of statements that are usually, but not always, true. Thus, "Athletes are healthy" may really mean "Most athletes are healthy".

The controversy surrounding the concept of a fuzzy set has several facets. In the first place, some maintain that any kind of uncertainty or imprecision can be handled by probability theory and that there is nothing that can be done using fuzzy sets that cannot be done equally well using probability theory.

Then, there are some who assert that the theory of fuzzy sets is just a theory — that it has not lead and is not likely to lead to any demonstrably useful applications. This group has since been completely silenced.

And then, there are many who are committed to the deeply entrenched tradition of respect for what is precise, rigourous, and quantitative and who view with disdain and suspicion any theory that attempts to arrive at an accommodation with the pervasive imprecision of the real world.

The basic reason for the controversy, is that the concept of a fuzzy set which is natural and simple has an upsetting effect on the established order.

There are times when imprecision has advantages. Although fuzziness is usually viewed as undesirable, the elasticity of fuzzy sets gives them a number of advantages over conventional sets. First, they avoid the rigidity of conventional mathematical-reasoning and computer programming. It is the computers' rigidity, for example, that makes it difficult or impossible for them to read sloppy handwriting. Also, programs for process control that are overly precise in judging when control decisions are to be made often behave far worse than human controllers who use fuzzy rules of thumb.

Secondly, fuzzy sets simplify the task of translating between human reasoning, which is inherently elastic, and the rigid operations of digital computers. In particular, in commonsense reasoning, humans tend to use words rather than numbers to describe how systems behave. With fuzzy sets, the programmer can translate these linguistic values — such as "young", "tall", "old", "high", and "low" — directly into a computer program by providing the membership function that defines them.

Linguistic variables are defined as ordinary-language terms that are used to represent a particular fuzzy set in a given problem, such as "large", "small", "medium", "OK" etc. Fuzzy logic and, in particular, linguistic variables provide a systematic basis for qualitative or verbal theories of system behaviour.

Many systems — e.g. complex chemical processes used in industry — are too complicated to be understood fully in terms of exact mathematical relations, and so they cannot be programmed in a precise way, although they may be successfully controlled with rules of thumb. The same is true for most complex concepts. One of the first commercial applications of fuzzy logic to process control was the development (in Copenhagen) of a microprocessor Schmidt controller for cement kilns, now in use in Western Europe and U.S.A.

Another application of fuzzy-logic control is in the automatic operation of a train in Japan by the Systems Development Laboratory of Hitachi.

While many fuzzy logic applications are still in an early stage of development, it seems probable that in the next decade,fuzzy logic will become routinely applied in many areas of artificial intelligence where communication with people or imitation of their thought processes is involved — a new branch of Control System Engineering, i.e. knowledge Systems Engineering.

KNOWLEDGE-SYSTEMS ENGINEERING

Today's instruments are providing more data than the mind can process, and as the amount of relevant information has multiplied, the capacity of humans to store and sort the data has become increasingly taxing and in some cases overwhelming. Thus professionals in many fields have been driven to incorporate computers, data-base systems and communications techniques into their work.

These data-base systems augment the power and range of the professional's grasp, providing him with a kind of auxiliary electronics memory that, for the present, appears to heighten rather than diminish his importance. However, just as this technology today gives the professional relatively easy access to the vast experience of other professionals, so they may provide that experience directly to the non-professional in the future.

More and more, machines will give consumers not only raw information, but also the ideas and decisions that any able or capable human professional might build into it. At least this is the hope of those engineers engaged in the field of knowledge systems engineering or "automated decision-making systems" — ROBOTS.

If this hope is fulfilled, then, in several fields fewer professionals will be needed because many could be supplanted by machines. WHY? Because machines can have infinite memories, and they never forget; because they are stress-free, and thus always produce the best work they are capable of (assuming they do not breakdown entirely); because they are immune to boredom; because they are utterly trustworthy and loyal; and because they are immortal if properly maintained.

However, among the many qualities humans possess that appear to be most difficult to instill in an automated expert system; are individualism, intuitiveness, flexibility and perception to mention a few.

The first step in the possible machine displacement of human professionals is standardization of the professionals's methodology. Professional work generally resists standardization and integration. After some time, however, standard methods of adequate efficiency often emerge. The standards permit industrial processes to supplant the creative work of the professional, removing decision-making from the job. Without significant decision-making responsibility, the worker leaves the ranks of the professional. With this automation of the decision-making process, the former professional becomes at best a technician or just an attendant of the machine. One example of a profession that has undergone these steps is that of navigator. Most navigation tasks are now performed entirely by instruments and related data-processing programs.

One need only to look at what is already happening in the oil industry to discern the trend. Until recently, professionals were needed to decide all vital drilling actions. In 1982, however, a U.S. knowledge-engineering company created a drilling advisor for the French national oil company. It was a knowledge system that provided expert advice on the best way to free a drilling rig that has become stuck. The artificial drilling advisor incorporates roughly 300 rules of thumb concerned with sticking and dragging, rules obtained from the oil company experts in interviews conducted by the knowledge engineers. In this way, the original experts' knowledge was synthesized and syndicated.

Technology also has encroached upon the domain of professionals in more subtle ways, by supplanting a particular skill or two but not threatening the professional's essential role. Medical examples are perhaps most common.

Biofeedback illustrates the use of a novel electrotechnology that competes with the therapeutic alternatives of the medical, psychological, and physical-therapy professions. This technology enables patients to "see" and "hear" their own brain waves, muscular tensions, and other body activities. When given this kind of feedback, the patient learns, among other things to relax and thereby reduce pain, obviating the need for pills or other therapies prescribed by a doctor.

In this century, electrotechnology has in some cases created whole new professions without supplanting anyone. e.g. the field of Radiology which was spawned by X-ray photography. However, based on current trends in technology, one may forecast cautiously which professions are most likely to disappear and which entirely new professions are likely to emerge.

Design, diagnosis, process control and flying are tasks that seem most susceptible to the current capabilities of knowledge systems. They are composed largely of sensor interpretation (except design), of symbolic reasoning, and of heuristic planning—all within the purview of knowledge systems. The major obstacles to automation involving these jobs will probably be the lack of standardized notations and instrumentation, and, particularly in the case of pilots, professional resistance.

Further in the future are such tasks as software engineering, public accounting. Law, medicine and science are perhaps the most remote candidates for automation. Doctors, while already avid users of electronics technology and even expert systems, are not likely to concede their dominant position in health care to machines. Lawyers, too, are a powerful economic entity, and their skills, particularly those involving litigation, are even less susceptible to standardization and automation than the skills of doctors. Though many subsidiary skills involved in the scientific process have already been automated, the frontiers of scientific knowledge are expanding too rapidly for current knowledge-engineering methods to keep pace with.

I am not predicting the automation of all professions. But the most far-reaching development will be the growth of new professions to fulfill those needs that are never likely to be met by machines. New technologies will emerge that initially resist reduction to knowledge engineering, and for a while provide niches for human professionals. Foremost among these being careers dedicated to improving the performance of knowledge systems and also to integrating them into diversified knowledge networks:- tasks that are likely to elude the capabilities of knowledge systems themselves in the foreseeable future.

Many people will probably find it difficult to adjust to the changes that advancing technology will produce. Many professionals at present derive their greatest satisfaction from their superior intellectual skills. These people may soon face serious challenges from knowledge systems that embody the knowledge of tens or hundreds of experts.

Based on this trend, it may turn out that neither technical skills nor education will affect personal success as much as either one currently does. As the physical standard of living increases, entertainment and style grow in importance to consumers; rewards may increase for such automation-resistant attributes as creativity and athletic prowess. Finally, when expertise is cheap, experts will no longer command as much respect or power — thus reversing a long trend.

Maybe by the year 2100, progress in science and industry may depend more on the inventiveness of machines than of people. It appears likely that with the passage of time, humans will pursue interests that are almost exclusively personal and social rather than economic, due to the takeover by machines of most income-producing tasks. If peace prevails, the greatest tasks for humanity then may be seeking out new challenges, and redefining what it is to be human.

CONCLUSION

And so, in conclusion it seems that a spectre is haunting modern society — the spectre of the computer revolution. Countless books, magazine articles, and new-media specials declare that this upheaval is underway, that nothing will escape unchanged. Such announcements are strongly reminiscent of a recurring ceremonial gesture in popular uprisings of nineteenth-century Europe.

Like political revolutionists, advocates of computerization believe that a glorious transformation is sweeping the world, and that they are in the vanguard. Industrial society, which depends on material production for its livehood, is rapidly being supplanted by a society in which information services will enable people to satisfy their economic and social needs.

Ever-expanding technical capacities in computation and communications will make possible universal, instantaneous access to enormous quantities of valuable information. As these technologies become less and less expensive and more and more convenient, all peoples of the world, not just the wealthy, will be able to use the wonderful services that information machines make available.

Gradually, visionaries say, existing differences between rich and poor, advantaged and disadvantaged, will begin to evaporate. Widespread access to computers will produce a society more democratic, egalitarian, and richly diverse than any previously known. Because "knowledge is power", because electronics information will spread knowledge into every corner of world society, political influence will be more widely shared.

With the personal computer serving as the great equaliser, rule by centralized authority and entrenched social elites will gradually fade. The marvelous promise of a "global village" will be fulfilled in a worldwide burst of human creativity.

With further advances in electro-technology, long lists of specific services are meant to suggest the coming of utopia; interactive television, electronic funds transfer, computer-aided instruction, customized news service, electronic magazines, electronic mail, computer teleconferencing, on-line stock market, shopping via home computer etc. All such services are supposed to add up to a cultural renaissance. Do we really believe that?

The electronic revolution will not do away with work, but it does hold out some promises: most boring jobs can be done by machines; lengthy commuting can be avoided; we can have enough leisure to follow interesting pursuits outside our work, environmental destruction can be avoided; the opportunities for personal creativity will be unlimited; provided space-based antiballistic — missile technology advances by both U.S. and Russia are subject to significant arms — control agreements. Electro-technology advances can lead to STARWARS and maybe the end of humanity.