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HUMAN CENTRED SYSTEMS: AN URGENT PROBLEM FOR SYSTEMS DESIGNERS

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ABSTRACT
Systems, machines and organisation of forms developed in the Engineering and Manufacturing sectors frequently lay the basis for systems design philosophy at a general level. An analysis of technological change in these sectors reveals that the resultant deskilling is not limited to the shop floor and is now spreading to intellectual work. The impact of 'machine based systems' on designers is explored in some detail and suggests the need for alternatives which are based on 'human centred systems'. Some attempts to design sub-systems are described.

KEYWORDS
human-centred systems, machine-based systems, systems design, computer aided design, expert systems, deskilling

1 INTRODUCTION

One of the most precious assets any company, organisation or country possesses is the skill, ingenuity, creativity and enthusiasm of its people. Yet, far from optimising human resources, we seem determined to design systems such as to marginalise human intelligence and tacit knowledge and even seek to preclude them as a form of systems disturbance.

Good design is generally regarded as that which reduces uncertainty. However, if we regard human decision making processes in narrow systems terms we will indeed perceive it to be an uncertainty and are thereby driven to the (false) conclusion that good systems design is that which reduces human intervention to a minimum. A richer way of viewing this would be that the human capacity to handle uncertainty actually contributes to systems robustness.

Conventionally, we do not regard a system as being 'scientific' unless it displays the three predominant characteristics of the 'natural sciences', namely predictability, repeatability and mathematical quantifiability. These characteristics do, however, tend to preclude human judgement, intuition, subjective knowledge, sense of feel and imagination. These problems of systems design are highlighted rather than diminished by many of the new technologies.

One of the founders of cybernetics, Norbert Wiener, once cautioned: 'Although machines are theoretically subject to human criticism, such criticism may be ineffective until long after it is relevant'.[1]

Probably at no time in history has the need for an examination of the underlying assumptions of science and technology been more relevant than it is today. We are, I submit, at a unique historical turning point. Decisions we make in respect of technological developments during the next five or ten years will have profound effects upon the way our society develops; the manner in which human beings relate to machines and to each other; and the relationship between human beings, their built environment and nature itself.

The introduction of computers, their enabling technology and accompanying organisational form has given rise to expressions of fundamental concern as to where these forms of technology are taking us.[2,3] Fears are expressed that by failing to examine the range of technological choices open to us, we are permanently closing off technological options and alternative forms of human organisation which reflect 'a loss of nerve' on the part of engineers and designers.[4] Rosenbrock has described the process by which we eliminate these choices as the 'Lushal Hills effect'.[5]

Integral to these expressions of concern is the notion that we may be about to repeat, in the field of intellectual work, many of the mistakes we made at such enormous cost at earlier historical stages when skilled manual work was subjected to the introduction of high capital equipment.[6] This is perceived to be part of an historical process in which the manner we currently apply science and technology will inevitably lead to deskilling.[7] Against this historical background, techniques such as computer aided design are regarded as a Trojan horse with which to introduce Taylorism into the field of design.[8]

Scientific Management is, as its founder Frederick Winslow Taylor explained, a process in which 'the workman is told minutely just what he is to do and how he is to do it and any improvement he makes upon the instructions given to him is fatal to success'.[9]

Initially, Taylorism on the shop floor actually increased the intellectual activity of designers and others in the offices. Taylor himself explained that his technique is aimed at establishing a clear cut and novel division between mental and manual labour throughout workshops. 'It is based upon the precise time and motion study of each worker's job in isolation and relegates the entire mental parts of the task in hand to the managerial staff'.[10]

Seventy years of Scientific Management have seen the fragmentation of skills grind through the spectrum of workshop activity, engulfing even the most creative and satisfying manual tasks such as that of toolmaking. Throughout that period, most industrial laboratories, design offices and administrative centres were the sanctuary of the conceptual, planning and administrative aspects of work. In those areas, one spur to output was a dedication to the task in hand, an interest in it and the satisfaction of dealing with a job from start to finish.

Viewed retrospectively, it now seems naive to have believed that Taylorism would stop at the design office door. It should have been obvious that, the more science and technology ceased to be an amateur gentleman's affair and was integrated into the productive process, the more those involved in it would become part of the workforce itself. Consequently, it has been suggested that as high capital equipment, such as computers, becomes available to them, scientists, technologists and design staff will be paced by the machines and, eventually, their intellectual activities will be subdivided into routine tasks and will be work-studied to set precise times for its synchronisation with the rest of the 'rational process'.

This should have been all the more obvious when it is realised that in fact it was one of the founders of the computer industry, Charles Babbage, who actually anticipated Taylorism, and did so in the field of intellectual work when he wrote: 'We have already mentioned what may perhaps appear paradoxical to some of our readers, namely, that the division of labour can be applied with equal success to mental as well as mechanical operations, and that it ensures in both, the same economy of time'.[11, 12]

The notion of the division of labour and the efficiency which is said to flow from it is normally associated with Adam Smith.[13] Adam Smith's specific arguments were anticipated by Henry Martyn almost a century earlier.[14] However, the basic concepts of the division of labour are so intertwined with western philosophy and scientific methodology that they are identifiable as far back as Plato, when he argued for political institutions of the Republic on the basis of the virtues of specialisation in the economic sphere.

If we are unable to quantify something, we like to pretend that it does not exist. To pretend this, we have to rarify it away from reality and this leads to a dangerous level of abstraction, rather like a microscopic Heisenberg principle. Such techniques may be acceptable in narrow, rarefied mathematical problems but, where much more complex considerations are involved, as in the field of design, they may give rise to very real problems and, indeed, to questionable results. 'The risk that such results may occur is inherent in the scientific method which must abstract common features away from concrete reality in order to achieve clarity and systematisation of thought. However, within the domain of science itself, no adverse results arise because the concepts, ideas and principles are all interrelated in a carefully structured matrix of mutually supporting definitions and interpretations of experimental observation. The trouble starts when the same method is applied to situations where the numbers and complexity of factors is so great that you cannot abstract without doing some damage and without getting an erroneous result.'[15]

2 PROBLEMS OF HUMAN-MACHINE INTERACTION

Within the design process there is a contradiction at the level of the human - machine interaction itself. The human being may be viewed as the dialectical opposite of the machine in that he or she is slow, inconsistent, unreliable but highly creative. The machine on the other hand may be regarded as fast, consistent, reliable but totally non-creative.[16] Initially these opposite characteristics were perceived as complementary and regarded as providing the basis for a human - machine symbiosis.[17] Such a symbiosis would however imply dividing the design activity into its creative and non-creative elements. The notion then is that the non-creative elements may be allocated to the machine and the creative elements left to the human beings. This is a Taylorist notion and implies at the level of design the equivalent of separating hand and brain within the field of skilled manual work.

The design activity cannot be separated in this arbitrary way into two disconnected elements, which can then be added and combined like some kind of chemical compound. The process by which these two opposites are united by the designer to produce a new whole is a complex and, as yet, ill-defined and ill-researched area. The sequential basis on which the elements interact is of extreme importance. The nature of that interaction and indeed the ratio of the quantitative to the qualitative depends on the commodity under design consideration. Even where an attempt is made to define the portion that is non-creative, what cannot readily be stated is the stage at which the creative element has to be introduced when a certain part of the non-creative work has been completed. The very subtle process by which designers review the quantitative information they have assembled and then make the qualitative judgement is extremely complex,[18] and much freedom must be left to the designer in doing it.

But there are further problems. The computer can produce quantitative data at an incredible rate. As the designer seeks to keep abreast of this and cope with the qualitative elements, the stress upon him or her can be truly enormous. In certain types of mechanical engineering design examined by the AUEW instances were found where the decision making rate is forced up by approximately 1900. Clearly, human beings cannot stand this pace of interaction for long. Experiments have shown that the design efficiency of an engineer working at a visual display unit decreases by 30-40% in the first hour and 70-80% in the second hour.[19]

Since employers, particularly those in a non-academic environment, will expect the equipment to be used continuously, the situation can be extremely stressful. Indeed, in 1975, the International Labour Office recommended safeguards against nervous fatigue of white collar workers.[20]

An International Federation of Information Processing working party has suggested that mental hazards 'caused by inhumanely designed computer systems should be considered a punishable offence just as endangering the bodily safety'.[21] Furthermore, in order to optimise the human - machine interaction, measurements are being made of the peak performance age and response time of intellectual workers.[22]

3 COMPUTER-AIDED DESIGN (CAD) - DESKILLING OR LIBERATING TECHNOLOGY

I have described elsewhere how CAD tends to deskill the designer, subordinate the designer to the machine and give rise to alienation. Indeed, most computerised design environments begin to display those elements which are regarded as constituting industrial alienation, in particular powerlessness, meaninglessness, and loss of self and normality.[23,24]

Further, computer aided design environments increasingly tend to induce methods of work and decision making techniques which are remarkably at variance with the circumstances and attributes which have appeared to contribute to creativity, both in the arts and in the sciences when viewed historically.[25,26,27]

It would be quite mistaken to assume that the routinisation is reserved for the 'hack' part of the design activity, thereby liberating the designer to re-engage in more meaningful work at higher levels of creativity. The situation now is that some of the most creative forms of design activity are being engulfed by the type of 'scientific management'. Elitist designers, steeped in their traditional professionalism, believed (and may still believe) that their creative talents provided an eternal sanctuary against the creeping proletarianisation of all white collar workers. Architects, for example, conceded that there might be problems for aircraft designers and civil engineers, but not for them. After all, is not architecture the 'queen of the arts rather than the father of technology'?

However, in the relentless drive to control and exploit all who work, the system has not forgotten architects. For them there have been specifically produced software packages such as (appropriately enough) the HARNESS SYSTEM. The concept behind such a system is that the design of a building can be systematised to such an extent that each building is regarded as a communication route. Stored within the computer system are a number of pre-determined architectural elements which can be disposed around the communication route on a visual display unit to produce different building configurations. Only these pre-determined elements may be used and architects are reduced to operating a sophisticated 'Lego' set. Their creativity is limited to choosing how the elements will be disposed, rather than considering, in a panoramic way, the type and forms of the elements which might be used. Thus the creativity of the architect is constrained, and his or her imagination greatly limited; yet it is precisely our ability to use our imagination which distinguishes us from other animal forms.

As Marx observed, 'A bee puts to shame many an architect in the construction of its cells. But what distinguishes the worst of architects from the best of bees is namely this: the architect raises in his imagination the structure he will ultimately erect in reality. At the beginning of every labour process we get a result that already existed in the consciousness of the labourer at its commencement'.[28]

Systems such as HARNESS do reduce architects to bee-like behaviour and do deskill them. It was recently pointed out at a British Computer Society meeting, by architects working for a local authority, that where their colleagues had used systems of this kind for two or three years, they found it extremely difficult to obtain 'normal' architectural design work, since prospective employers regarded them as having been deskilled by using such systems.

There is clearly a need for research projects to establish if these problems are inherent in the methodology used in the introduction of CAD, or whether it can be explained away as a mere use/abuse model.

It is obvious that many of the advocates of CAD, particularly those working in academic environments, perceive it as a liberating process and a basis for the democratisation of the decision making process within design.[29] Arthur Llewellyn, former Director of the CAD Centre at Cambridge, repeatedly and so correctly asserted that computers should not be used as a means of diminishing or eliminating designers, but rather as tools for improving their ability to carry out creative tasks.[30]

Unfortunately, this is frequently not so in the harsh world of industrial reality, and the consequences spread far beyond the design area. In some systems, not only will draughtsmen as we now know them be gradually phased out, but some of the most satisfying and skilled work will be eliminated by the resultant numerically controlled (NC) equipment. The optimistic predictions of some industrial sociologists that the worker would be elevated to a sort of manager with the computer providing an overview of the labour process are being denied day by day. In the case of NC equipment, it has been reported that the ideal workers are mentally retarded ones, and a mental age of 12 was mentioned.[31]

4 HUMAN-CENTRED SYSTEMS - A WAY FORWARD

Clearly it is not sufficient simply to identify these problems. We have to indicate how these systems can be designed otherwise. Two examples may be given to illustrate the possibilities; one in the field of skilled manual work, the other in the field of intellectual work.

Over the past 200 years, turning has been one of the skilled jobs to be found in most engineering workshops. Toolroom turning is one of the most highly skilled jobs of all. The historical tendency, certainly since the war, has been to deskill this function by using NC machines. This is done by part programming - a process by which the desired NC tool motions are converted to finished tapes. Conventional (symbolic) part programming languages require that a part programme, upon deciding how a part is to be machined, describes the desired tool motions by a series of symbolic commands. These commands are used to define geometric entities, that is points, lines and surfaces which may be given symbolic names.

In practice, the part programming languages require the operator to synthesise the desired tool motion from a restricted available vocabulary of symbolic commands. However, all this is doing is attempting to build into the machine the intelligence that would have been exercised by a skilled worker in going through the labour process.

It is possible, by using computerised equipment in a symbiotic way, to link it to the skills of a human being and define the tool motions without symbolic description. Such a method is called Analogic Part Programming.[32] In this type of part programming, tool motion information is conveyed in analogic form by turning a crank or moving a joystick, or some other hand/eye coordination task, using read-out with precision adequate for the machining process.

Using a dynamic visual display of the entire working area of the machine tool including the workpiece, the fixturing, the cutting tool and its position, the skilled craftsman can directly input the desired tool motions to 'machine' the workpiece in the display. Such a system, which may be described as 'Part Programming by doing', would represent a sharp contrast to the main historical tendency towards Symbolic Part Programming. It would require no knowledge of convential part programming languages, because the necessity to describe symbolically the desired tool motions would be eliminated. This is achieved by providing a system whereby the information regarding a cut is conveyed in a manner closely resembling the conceptual process of the skilled machinist. Thus it would be necessary to maintain and enhance the skill and ability of a range of people who would work in parallel with the system.

Significant research has been carried out in these fields,[33] yet in spite of its obvious advantages it has not been received with any enthusiasm by large corporations or, indeed, funding bodies. That this is so would appear to be an entirely political judgement rather than a technological one.

In the field of intellectual work, Rosenbrock has questioned the underlying assumptions of the manner in which we are developing computer aided systems. He charges, firstly, that the present techniques fail to exploit the opportunity which interactive computing can offer. The computer and the human mind have quite different but complementary abilities. The computer excels in analysis and numerical computation. The human mind excels in pattern recognition, the assessment of complicated situations and the intuitive leap to new solutions. Rosenbrock objects to the 'Automated Manual' type of system since it represents, as he says, 'a loss of nerve, a loss of belief in human abilities, and a further unthinking application of the doctrine of the Division of Labour'.[34,35]

As in the case of turning described above, Rosenbrock sees two paths open in respect of design. The first is to accept the skill and knowledge of the designers and attempt to give them improved techniques and improved facilities for exercising their knowledge and skill. Such a system would demand a truly interactive use of computers in a way that allows the different capabilities of the computer and the human mind to be used to the full.

The alternative to this, he suggests, is to 'subdivide and codify the design process, incorporating the knowledge of the existing designers so that it is reduced to a sequence of simple choices'.[36] This, he points out, would lead to a deskilling such that the job can be done by a person with less training and less experience. Rosenbrock has demonstrated the first human enhancing alternative by developing a CAD system with graphic output to develop displays from which the designer can assess stability, speed of response, sensitivity to disturbances and other properties of the system.

If, having looked at the displays, the performance of the system is not satisfactory, the displays will suggest how it may be improved. In this respect the displays carry on the long tradition of early pencil and paper methods but of course they bring with them much greater computing power. Thus, as with the lathe and the skilled turner, so also with the VDU and the designer, possibilities exist of a symbiotic relationship between the worker and the equipment. In both cases, tacit knowledge and experience is accepted as valid and is enhanced and developed.

In Rosenbrock's case it was necessary to examine the underlying mathematical techniques involved in control systems design.[37] The outcome of his work does demonstrate in embryo that there other alternatives if we are prepared to explore them, and he has suggested that we are at a critical moment when we may close off options which are now open to us.

It will be clear from the foregoing that these alternatives, both in the field of manual and intellectual work, require urgent discussion and research, given the widespread concern at the deskilling and other multiplier effects of conventional 'machine-centred' systems. It is significant that in recent years the major Trade Unions worldwide have shifted from a rather simplistic technological optimism to a growing sense that a re-examination of the underlying assumptions of such technologies is now overdue. The major International Body for Metal Workers has recently published a report in seven languages discussing, on the one hand, job creation possibilities worldwide and, on the other, linking these possibilities to the use of 'human-centred', skill-enhancing, new forms of manufacturing technology.[38] More recently, several of these concerns have been brought together in a highly significant ESPRIT Project. The objective is to design what will be the world's first human centred computer integrated manufacturing system. The project involves nine partners in three EEC countries. Danish teams will research and ultimately design a CAD system. Partners in Germany will produce the CAP and the British partners, the CAM (with the Greater London Enterprise Board (GLEB) acting as prime contractor and coordinator of the project). It was accepted from the outset that science and technology are not neutral but rather that they embody assumptions of the society which has given rise to them. Furthermore, that it is mistaken to assume that there is only one form of science and technology. In the case of manufacturing technology, this might be regarded as 'American Technology'. One should regard science and technology as aspects of culture, and just as culture produces different music, different literature and different language, why should there not be different forms of technology? In this case the object is to design a manufacturing technology which will reflect European cultural, social and political aspirations. Many of the European expectations tend to exist more in the rhetoric than in the reality. Even at a rhetorical level, the idea of designing a system which embodies concerns such as motivation, the dignity of the individual, the enhancement of skill, a respect for quality and support for those organisational forms which diffuse decision making as widely as possible. The project[39] has now been supported by the EEC to a level of £3.8M over three years. One of the objectives throughout will be to ensure that the qualitative or subjective judgements of the worker will be treated as valid scientific knowledge and the worker will dominate the machine rather than the other way round. The systems design will be such as to build upon and enhance the skill, ingenuity and tacit knowledge of the worker. It will reflect the European reality of highly skilled workers and small to medium sized companies.

It is held that such a 'human-centred' approach could be applied more widely to system design work undertaken by the Greater London Enterprise Board in a number of projects that are likewise based on a human centred approach.[40] Work is proceeding on an Expert Medical system in which the object is to diffuse knowledge outwards into general practice and the community. The database will be so structured as to render visible the assumptions to the general practitioner rather than to concentrate knowledge in the hands of a small élite of consultants. Thus it is hoped it will be possible to democratise decision making, sharing it between the general practitioner and the consultant. More particularly the presentation of the data in the surgery is such as to provide both the patient and the medical practitioner with a range of different treatment options. This, firstly, avoids the major defect in western scientific methodology; 'the notion of the one best way'. Also it enforces a dialogue between the medical practitioner and the patient, thus providing a framework in which this relationship can be more democratised. Likewise, an interactive video disc project at GLEB seeks to build upon the knowledge and culture of ethnic minorities, rather than providing them with a series of 'commands'. It is hoped that such work on Expert Systems will be ultimately integrated into manufacturing systems since, of course in the best sense, a skilled worker on the shop floor is as much an expert as is a medical practitioner or a lawyer. In designing such systems no attempt is made to reduce the knowledge of the practitioner to a totally rule-based system. It is accepted that there are the facts of the domain and that these provide the basis for a rule based 'core', (see Figure 1), but that surrounding this there is tacit knowledge, heuristics, fuzzy reasoning, intuition, imagination, and that these cannot or should not be reduced to a rule base. Thus the systems are designed to create a dialectical interaction between the rule-based core and the rest. In designing such systems an attempt is made to concentrate on that part of the cybernetic loop which is knowledge and wisdom based rather than on the data and information end, (see Figure 2). Thus we are concerned with minimising noise in the system and enhancing signal.

5 CONCLUSIONS

This work is as yet at an early stage. It is however hoped that projects of this kind will begin to bring about paradigmatic shifts in our concepts of how systems can be designed in future, and that they will provide an environment in which such systems can be carried out in practice. It is our view that the problems and contradictions of the existing systems are now so great that the search for alternatives is a matter of considerable urgency and that 'human-centred' systems provide one interesting starting point.

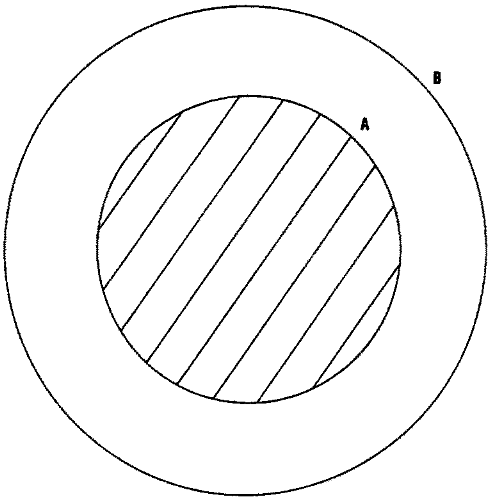

Figure 1 A Facts of domain
B Expertise including tacit knowledge

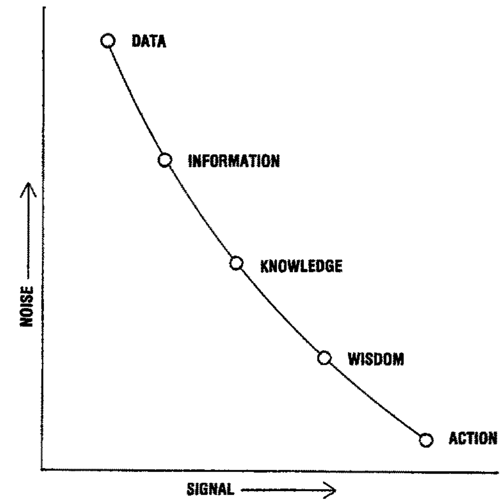

Figure 2

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