MAN/COMPUTER COMMUNICATION: AN OVERVIEW

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MAN/COMPUTER COMMUNICATION: AN OVERVIEW

INTRODUCTION

I have often felt that social psychologists will one day have a field day in analysing the development of man's relationship to the computer. Whether one regards the computer as a partner or a tool, a colleague or a slave (or a master!), there is no doubt that the simile that likens a computer to a person stimulates interesting and relevant analyses of the man/computer relationship. The importance of the analogy is that the computer is the first tool that impinges actively on the domain of man's mind (it is possible to regard books as precursors of the computer in this respect – as tools that operate at the level of the mind – Popper's 'Three Worlds' model clarifies this rôle of books and may be extended to include the computer).

For example, the peculiar nature of the batch processing environment which early computer hardware unreliability and costs forced us to create becomes very apparent if we think of a 'colleague' in a similar environment. The communications barriers that exist around a batch processing computer *do* have analogies in human-to-human communication. There are obvious similarities to communicating through written correspondence passing through the delays of the postal system. Such extensive delays are clearly already in themselves not conducive to an effective 'dialogue'. However, the barriers we created in this situation went far beyond such delays. One would not expect any but a small population of enthusiastic and experienced devotees to integrate effectively into any organisation in which communications already in an artificial and stilted language had to be routed through various irrelevant and unreadable intermediate forms; replies were received after indeterminate intervals ranging from hours to days; the majority of those belated replies indicated that the messages not precisely correct in all aspects had been imperiously rejected!

Such a way of using computers will seem very quaint to future generations – it seems very funny already (except to those still using it!). With the advent of low-cost minicomputers, graphic colour terminals, and real-time operating systems, close man/computer interaction has become possible. However, close interaction does not automatically mean that there is effective communication. You and I may interact in any of a number of ways, shout and swear in any of a number of languages, but there may be very little communication indeed! To realise the potential that computer systems now offer in terms of close man/computer *interaction* and turn it into close man/computer *communication*, a partnership, a symbiosis, requires much effort on the part of the computer community, far more than we ever realised when interactive access first began to become available. We are still largely amateurs in programming effective man/computer communication and our interactive systems of today will look as quaint in ten years' time as do the batch processing systems of yesterday.

THE COMMERCIAL SIGNIFICANCE OF HUMAN TECHNOLOGY

We are in an era where great improvements in man/computer communication can take place on a cost-effective basis. The obvious question to ask is what can we do with such improvements? There are as many answers to this question as there are viewpoints on life and society, some concerned with the advancement of knowledge, others with the improvement of society, artistic endeavour, etc, but I shall interpret the question in this paper only in financial terms. What does improved man/computer communication mean commercially?

There are two prime effects to be considered:

- Firstly, the impact on total sales volume
- Secondly, the impact on differential sales, i e, competetiveness.

In terms of total sales volume the computer industry has already become an accelerating treadmill in which the continuing fall in costs of computers and systems software is forcing a rate of expansion in applications far greater than the actual rate of expansion of sales in financial terms. To achieve this massive overall expansion we have to both increase the penetration of existing markets and also continually open up new markets. The size of the new markets required to give continuing scope for expansion under these circumstances forces us out of specialist applications into the semi-professional and consumer markets. In the next decade it is the office and office-like environments that provide the scope for expansion, and in the following decade it will be be the home and home-like environments (for later decades only the more far-out science fiction literature provides any reasonable projections!).

In these new environments we cannot expect to find specialist staff with computer knowledge or training – we cannot expect the person to adapt to the idiosyncracies of the computer – we cannot expect sympathy or tolerance for the artificial barriers to communication that have existed around our venerable computers. At the ever-increasing rate at which we must install systems we do not have time for elaborate training programs, even to write elaborate user manuals – they will not be read. We need systems that are simple to use, self-explanatory, natural, and so on – this is where interaction must turn into communication and where it will pay off.

The argument for the significance of improved man/computer communication in terms of market penetration and total sales volume is a telling one, but like all projections into new territory it is complex and uncertain in detail and open to a range of criticism (including that from those who see no virtue in expansion anyway!). However, the argument for the major commercial importance of man/computer communication in terms of competetiveness is extremely straightforward and obvious. In the past decade we have solved hardware problems to an embarrassing degree – computers are cheap and reliable, ridiculously so – who cares whether a microprocessor chip costs only $10 or only $100? Primary storage costs have dropped to an extent that hobbyists criticise microprocessors that can support only 64K bytes of memory – the 1M-byte semiconductor store for the hobby market is already with us. And so on for backing stores, display terminals etc. I turn to *Byte* and *Interface Age* for my data on 100M-byte Winchester disk drives and colour graphic terminals at prices to suit the hobbyist and small business user!

System software shows a similar trend – we have our multi-tasking, device-independent operating systems in PROMs and our BASIC, FORTRAN, COBOL and PASCAL compilers for our micro-based systems. Nothing is perfect – there is scope for substantial improvement both incrementally and by revolutionary new thinking – but it is amply good enough for a range of applications and markets at least two orders of magnitude greater than

we have so far penetrated.

If hardware and software are in such good shape and so freely available then manufacturers must look elsewhere both for their competetive edge and for their added value. What are now the key determinants of relative effectiveness of different systems? *Ease of applications programming* and *ease of use* now loom largest as commercial variables in determining the most attractive system to purchase. The supplier who is able to provide packages that do precisely the task that is required and does it in a 'user-friendly' fashion will win orders from those whose 'machine-technology' rides roughshod over any faint resemblance to 'human technology'. Systems offering simple and natural user communication and control together with help when required and without condescension will be bought in preference to those that put the user through a mental wringer. When no applications package is available it is the system whose programming support is user-friendly that will win out – interactive operating systems, editors, debugging tools, etc, all have at least a great 'human factors' component as technical component in their design.

It is *these* considerations that are leading the major computer manufacturers to swing so much research and product development funding into human factors research. We need a 'peopleware' technology tomorrow that is as well-founded as the 'hardware' and 'software' technologies of today. Figure 1 summarises the current state of the art in terms of how the three computer technologies rate in terms of utility (does it do the job required?), availability (can we get it?), cost (at reasonable expense?), and reliability (will it go on doing the job?).

	Utility	Availability	Cost	Reliability
Hardware	Does job	Readily available	Low and decreasing	High and increasing
Software	Variable - restricts applications	Variable - choose configuration for software	Variable - low for operating systems and standard languages	Variable - high for operating systems and standard languages
Peopleware	Poor - man/computer barrier rather than interface - can be lowered	Chance - if you get the right craftsman - can be taught	? - no proper market yet - coming - can be low	? - too little experience - can be good

Figure 1: Three computer technologies

WHERE ARE WE AND WHERE ARE WE GOING?

This volume provides a detailed state of the art report on the key factors in man/computer communications. In the remainder of this paper I shall attempt to provide just a context, an overview of the major factors that underlie current developments and some feeling for the reasons why certain developments are of critical importance during the next few years.

Forecasts may be of two distinct types: *predictive*, in which one attempts to project current trends and develop required technologies; and *normative*, in which one attempts to impose future trends and develop required technologies. These two aspects are complementary and both are important in practical applications. Purely predictive forecasting is extrapolation from essentially noisy data and hence subject to cumulative error. It also has the danger that when things are going badly because a technology is lacking, then the only prediction can be that they will get worse! Purely normative forecasting is interpolation between the present situation and future goals and thus less subject to random variation (provided the goals are actually accepted!). It has the dangers of setting unrealistic targets or of routing effort to less rewarding objectives.

I mention both aspects of forecasting because I feel we should always read 'What next?' not only as predictive but also as normative; what *should* come next, as well as what may. As system designers there is a strong normative component to our actions – we are setting standards in each new system delivered. For some time yet, most users will be having their *first experience* of man/computer communication through the systems we are now developing. Even the few 'experienced' users may still be sufficiently resistant to the brain-washing of past systems to react favourably to improved man/computer communication.

Thus there is a real need to take continual cognisance of the normative rôle of our work. Some of the technology we need is subject to technical limitations of display rates, costs, computational power, etc, but much of it is in the knowledge-limited areas. *Knowledge only* is the limitation in so many aspects of man/computer interaction – the current hardware technologies are adequate for many tasks in which our current lack of success is due solely to our lack of knowledge of how to use them. Speech recognition is clearly in this category – electronic signal processing capabilities go way beyond what is needed at the lower level, computer data storage capacities are much greater than those needed at higher levels, and, more speculatively, I believe that current computational power is adequate to cope with co-ordinating the necessary 'knowledge-base'. However, we do not yet know enough about either the problem or the techniques required in its solution.

At a more mundane level I will make the same comment about interactive dialogue with the non-professional user at a computer terminal. What we most often see is unimaginative, sloppily designed, often appalling in human factors terms – why? Main answers:

- The users do not know enough to complain
- We *do not know enough about dialogue in the general case* to have the background to deal with the man/computer one.

For many linguists the listener seems an embarrassment rather than a necessary part of dynamics of language. That he may actually interrupt and reply – that a conversation may itself have organic unity and purpose – these aspects seem relegated to the study of rhetoric and are anathema to much of the present scholarship of language.

Thus, each user of an interactive system to whom we demonstrate what *can* be done and send back dissatisfied and complaining about the systems *he* is forced to use; each linguist we persuade to take an interest in man/computer dialogue; and so on – all of these are part of our normative role in improving man/computer communication. It is easy to adopt the passive predictive rôle and gear one's work to the natural inertia of the world, technological or otherwise, but a major component of progress must always

be a quest for what is better, what is appropriate, what is right. We have to engineer systems within our limitations and would be foolish to attempt otherwise, but those limitations must be subject to continual questions, testing and open criticism.

Perhaps these comments seem so obvious that an example is necessary. Computer-based instruction was over-sold a decade ago. The computer was going to bring new freedom into education by individualised instruction, tailoring it to the personal needs of the student. And where was the knowledge of these needs to come from? Through a few characters per second link to a student laboriously typing capital letters at a teleprinter terminal. Would we have promised the educational advance of the millenium if it had been offered to link *our* students to *us* in the same way? Are we surprised not to have achieved it? Do some of the statements about helping students to understand their errors now not seem subject to rather obvious information-theoretic limitations?

The same thing is happening today – put all your information into a database and clearly all your problems can be solved; forecasts, resource allocation, management information and automated control of all kinds must surely follow. In another decade we may look back wryly and note that if you put all your information in a database then you have just that – all your information in a database. Information is not knowledge, and even knowledge is not necessarily power – we have a long way to go.

THE MAN/COMPUTER SITUATION

Figure 2 shows the basic man/technology situation. I have deliberately chosen this ancient symbolism rather than the usual inter-connected boxes because it is rather more

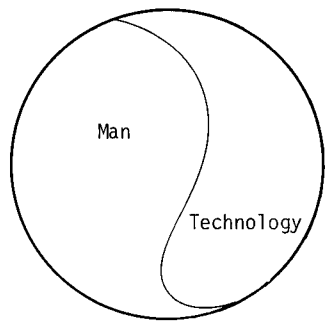

Figure 2: Man and technology - the basic situation

suggestive of our real objectives. The tools of man are essentially part of man himself – they have long extended our muscles and our senses – with the computer we may extend our information storage and processing capabilities – ultimately we may extend our *minds*.

The central division in Figure 2 is initially a *barrier* dividing us from our technologies. Progress consists of making that barrier more and more permeable at appropriate points – flow of control from man to technology – flow of information from technology to man (those who claim that the flows are tending the other way point to a very real danger – what permeation *you* feel is appropriate varies, for example, with whether your social status is the governor or the governed!).

It is perhaps more realistic to draw Figure 2 as Figure 3, at least pre-computer. What

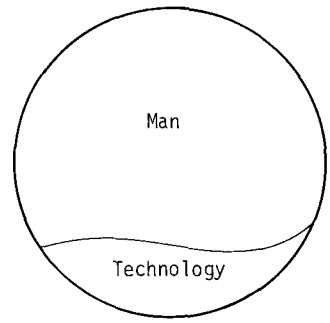

Figure 3: Man and technology - pre-computer

seems plausible is that Figure 2 is now becoming a more realistic picture as we add the computer to the technologies available. It is the first technology that presents the possibility of a *partnership* where *both* parties can comprehend and respect the full capabilities of each other. However, *neither* side of the division has yet achieved that level of understanding of the other.

As shown in Figure 4 we can think of the man/technology partnership facing its common environment together. Such a system has the potential for greater comprehension and control of the environment than either of its parts alone. The term '*intelligence amplifier*' has been coined for the rôle of technology in this situation. However, the potential and its realisation are quite distinct – we can provide many examples already of the computer an an '*ignorance amplifier*' – the potential is equally high!

Figure 5 illustrates the points made previously about the current state of man/computer communication. What it does demonstrate clearly is the current asymmetry in information flow – man to computer is weak, slow in data rate, inaccurate and unnatural – computer to man is (or can be!) strong, fast, precise and well matched to our data-input systems. Text preparation, colour graphics and speech synthesis are low-cost technologies – we still have plenty of ground to cover in the 'knowledge-systems' to control these technologies but that is Carnapian in its incremental steady progress. Handwriting, pictures and speech as computer inputs are still research projects rather than technologies, and so far behind our requirements that a Kuhnian 'paradigm-shift' seems necessary before progress can be made.

The direction of hope here is illustrated in Figure 6. The processes of man/man communication that we wish to extend to the computer seem dependent on some assumption that those communicating share much of their internal world models – not in a Jungian sense (although a metaphor of a 'racial memory' is a good one), but at least as related

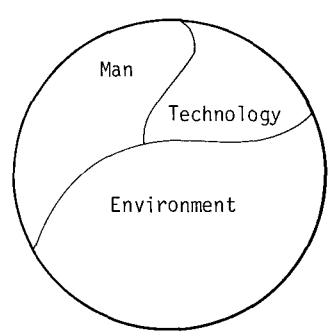

Figure 4: Man, technology and environment

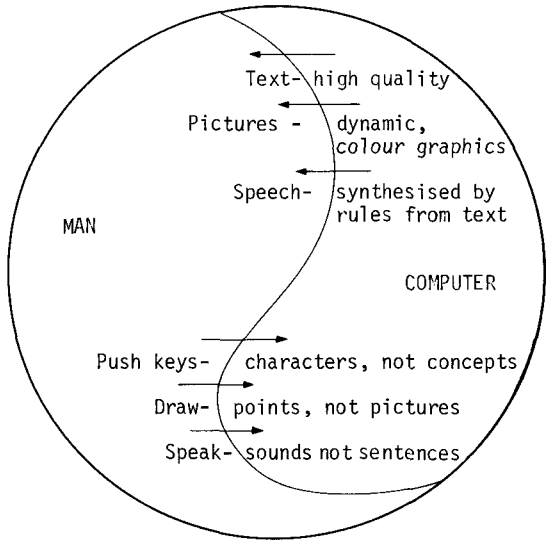

Figure 5: The current state of man/computer communication

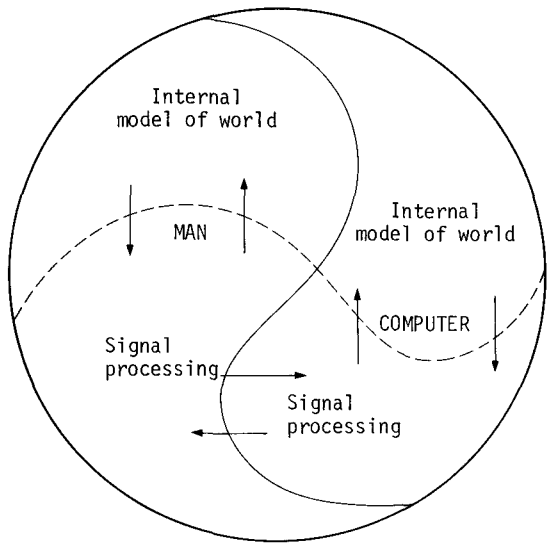

Figure 6: The role of world-models in man/computer communication

domains of knowledge. The source of this communicatability is difficult to analyse rigorously. Post-Humean philosophy seems to have arrived at an acceptance of his definitive argument that we cannot justify our acquisition of knowledge. We may derive what consolation (or inspiration) we like from Kant's transcendental arguments (we do it because we do it — probably programmable in LSIP but not in FORTRAN!) and agree with Wittgenstein that:

> "If anyone said that information about the past could not convince him that something would happen in the future, I should not understand him."

Equally, the debates in linguistics as to *why* we share a common language (given that many of us do not!), and *how* we can communicate with one another at all (and what that means anyway), are still hot-beds of argument and speculation. We come from a common genetic stock in a common, relatively stable, physical environment — perhaps that is

sufficient constraint to pull our minds into some degree of synchronisation. As a science the study of ourselves is severely restricted by our limited range of examples of intelligent systems evolving in a common environment.

I did not digress into this slough of philosophic and linguistic despond for its own sake. It serves to make one important point about Figure 6 that goes back to an elementary aspect of computer programming – *we cannot program that which we do not understand*. A clear illustration of this has been in the syntactic aspect of linguistics. We fumbled with natural language parsers for many years – now post-Thorne and Dewar we set such parsers as undergraduate projects. The moral is very much shown in the motivation for their work – it was to *demonstrate the consistency of a linguistic parsing schema*. Where it was weak or failed (e g, in the conjunctions) was where the linguistic definitions were themselves vague or contradictory. Similarly, today when we argue as to whether a program has produced the correct parsing, it is generally what *is* a 'correct parsing' that is the source of debate – not the correctness of the program.

It is our lack of understanding of both sides of the upper half of Figure 6 which limits man/computer communication at the lower level. We do not understand what constitutes the 'world-model' used by a person. We have only begun to realise the difficulties of constructing adequate models of the world within computers – not miniature, circumscribed, artificial worlds, but the real world that is large, complex and unbounded, consisting of interacting *dynamic* processes, some of which are themselves *intentional*.

Note that Figure 6 does not show the 'environment' of Figure 4. The 'world models' of man and computer can be considered separately from *the* 'world'. It is our common 'hallucination' that is significant, not its source or accuracy. This is significant because it emphasises that much of the 'world' relevant to discourse is not the hard empirical world of the physicist, but rather the constructed, imagined world of artist, novelist and poet – the world of concepts and possibilities that we ourselves fabricate. We can speak of 'unicorns', 'beauty' and 'god', as readily as we speak of 'length', 'atoms' and 'physical dynamics' – perhaps more readily because myth, emotion and faith are buried deeper in human nature than is our veneer of numeracy and measurement. This conceptual structure is of course, Karl Popper's 'third world' of knowledge and civilisation. A world that exists in books, minds and society, but need have no physical counterparts.

'Artificial intelligence' (AI) research has during the past decade become primarily concerned with the questions that arise in considering Figure 6 – how do we structure the 'world model' within the computer – how can man and computer communicate in 'natural language'? Hence the close links of this research area to that of cognitive psychology – the one remaining component is the internal world of the mind of man himself.

The direction of effort means that most work in AI is very much narrower in scope than the title might imply. Intelligent interaction with the world does *not* imply that either the 'intelligence' or the 'world' should be that of man. Surely one dream must be that we can make machines *more* intelligent than ourselves, or with *differing* intelligences from ourselves. But here we are back to the realm of science fiction speculation, for it is not at all clear what this means or, if achieved, that we could either comprehend the achievement or communicate with the resultant machine. Thus, the objectives of research on 'man/machine communication' and that on 'artificial intelligence' are bound to be closely related for both historic and fundamental reasons.

The close relationship between AI research and development and those in man/computer

communication should not blind one to the major differences in objectives, and hence approaches, that exist between the fields. In AI research we are trying to extend the computer's capabilities to their limits. In man/computer communications research we are trying to make the most effective use of the capabilities of *both* men and computers. Often, the *current* capabilities of computers are more than adequate if effectively exploited through proper communication.

A good example of this distinction is the emphasis in man/computer communications research on the *casual user*, i e, someone who is only an infrequent user of, for example, a database. The database itself may be totally adequate for all the requirements of this user, but his problem is lack of expertise in using it. Taking a very black and white view one might say that:

- The AI approach to the problem would be to build a better database system with 'understanding' of the user, his requirements, and natural language communication, i e, put all the load on the computer and make it clever enough to deal with the casual user.

- The classical applied psychology approach would be to develop a training program for casual users that gave them as rapidly and effectively as possible the skills to use the database, i e, put all the load on the person and make him clever enough to cope with the computer.

- The man/computer communication approach would be to determine where the problems lie in the interface between user and computer and design a communication package that helped the person to formulate his requests in a way natural to him but such that they could also be translated directly for the database system.

That is a very bald statement of what is in practice a spectrum of differences, but it demonstrates in essence that there is a specific area of man/computer communications research and development that has an identity separate from either computer or psychological research and development.

A NEW PARADIGM FOR 'PROGRAMMING'

This essay has been an overview setting, a context for the more detailed studies of the state of the art in this report.

Let me finish, however, by suggesting one specific 'paradigm-shift' that I believe could occur in the near future and be very significant for many of the problems discussed.

'Programming' is a new term entering our vocabulary since the mid-forties. We have erected and refined a career structure around computers that involves the 'systems analyst', 'programmer' and 'user'. I suggest that the distinction is without a difference, or, at least, that any differences are themselves artefacts that must go because they are increasingly counter-productive. A computer is a universal machine, capable of actualising any definable algorithm. To 'program' a computer is to communicate to it the algorithm in such a way that it can implement it.

By force of habit we have come to regard 'programming' as a very specific human activity whereby we translate the specification of the systems analyst into a computer program that will satisfy the end users. The concept of the *virtual machine* has already

relativised this distinction – for me as a microprogrammer, you as assembler writer are the end user, yet you regard yourself as providing an 'intermediate language' for the writers of several compilers who themselves are providing virtual machines for FORTRAN, COBOL, ALGOL, etc, programmers and so on, through a chain of 'library programs', 'application modules', ultimately getting to the end user who may well be a 'virtual machine' to someone else, e g, a stock-exchange dealer providing a 'service' (a historic term for a virtual machine!) to clients who are themselves institutional investors providing a service to further clients.

At every level of the virtual machine we tend to provide 'options', means whereby an upward flow of control can vary the behaviour of the machine above. We may call them 'status-words', 'instructions', 'parameters', etc, but fundamentally they all have the same function – to vary the operation of the virtual machine from the user level. I suggest that a shift to this broader concept of 'programming' will occur – is already occurring. Psychological studies of programming and debugging are becoming increasingly concerned with the broader context of these activities as human cognitive, problem-solving skills. Database systems that offer 'query-by-example' are giving the end user substantial program control. Much of artificial intelligence research may be seen as essentially developing new means for programming computers. A 'self-organising' system is one which programs itself by interpolating a current state of affairs and a desired state. A 'learning' system is one which programs itself by storing the results of exploratory experience.

It is this more general concept of 'programming' that may break down some of the barriers we have erected in the past that stifle progress now. In particular, for man/computer communication we should be prompted continually to ask, 'What is the communication for – what purpose does it serve?', and attempt to answer that question in these broader programmatic terms. For example, the key problem with a visual display is no longer the technical mechanism for obtaining a picture at low cost, but rather that of *controlling* that mechanism to get not just the *right* picture but one whose construction and change matches our conceptual representation of the structure in the picture. Picture manipulation involves choice and, wherever there is choice, there is a program which has to be induced by interaction. Recent progress in graphic languages, particularly those suited to both picture analysis and picture generation, suggests that the programmatic aspects of interaction must come first. Until we have a language that can enable man and computer to communicate naturally about pictures, we do not have the graphics we need but only the capability to produce drawings.

CONCLUSIONS

Well 'What next?' – clearly the steady incremental but rapid progress that has borne computer technology so far so fast will continue. Next is smaller, faster, cheaper, more reliable and so on. But there are also qualitative changes apparent which must come to fruition before the promises of the technology itself may be realised.

If I speak of 'mutual respect' between man and computer it may seem strange, for what is the computer as seen by the user except a program written by another man. It is indeed understanding of, and mutual respect amongst ourselves, that is needed. The computer can be a vehicle to vent the worst extremes of a 'technical-cognitive' authoritarian view upon others. Equally, it can be the means for the 'emancipation of cognition' through a participatory partnership.

These may seem grandeloquent terms fit for sociologists but not system engineers. However, this dimension of control and emancipation is apparent in even the simplest interface between man and computer. Man must control the computer – the computer must emancipate man (and emancipation is *not* to give unnecessary and undesired choice, quite the contrary). To allow adequate control we must broaden the concept of programming to that of the flow of control up to a hierarchy of virtual machines. Our need for a world-model inside the computer can then be seen as necessary to allow communication in terms and concepts comprehensible to man.

However, all this involves far greater understanding of ourselves, and it is perhaps to the applied psychology of man/computer studies that we must turn to most in asking 'What next?'.... Until I know what it is for *you* to understand me, how can I hope to program a machine to do likewise. As in all dialectial questions the resolution is a synthesis – a combination of philosophical, psychological and linguistic scholarship with electronic and computational technologies, under the pressure of commercial requirements for improved man/computer communication. It is in *that* mixture in *that* crucible that the answer to the question, 'What next?', is currently being formed.