INSTITUTE FOR THEOLOGICAL ENCOUNTER WITH SCIENCE AND TECHNOLOGY

BULLETIN

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Today there is more interest in the faith/science arena than ever. At least so it seems. The number of new books on aspects of faith/science, creation/evolution and so forth floods the market. The direction of that interest extends from developing a theology built on the current scientific principles to a theology which essentially places little value on scientific thought -- the opposite banks of the current theological river.

ITEST is still unique because we are trying first of all to encourage scientists and theologians to be very, very good in their chosen profession and to learn as much as they possibly can about the other "partner" in the dialogue. We are interested in more than their current professional understanding. This basically concerns only an intellectual approach. But that is merely the beginning. We are really interested in the growing love of each of our members for each other and especially for the love of Christ. It is not enough to be in love with a science or with a theology. We are literally the Body of Christ and we equally literally bring the science, the discipline, into God. Do we think about this? What are we doing about it?

ITEST is not primarily interested in just the "doctrine" of either "culture." While the "doctrine" of science and the "doctrine" of theology are really interesting and important, both are merely means to an end. The end is the joining of our being to the being of the Lord. As St. Paul says in Colossians, "in his body lives the fullness of divinity." We are members of that body. We are called to be "a chosen race, a royal priesthood, a consecrated nation, a people set apart to sing the praises of God." In the Lord we in science and/or theology can sing most magnificently of the glories of creation and more of the God who made everything. Who can sing of the glories of the human brain better than a neuroscientist; who better praise our connection to each other than the geneticist and the anthropologist; who can sing of the beauty of the skies better than the astronomer; who can sing of the Trinity better a theologian? One answer: anyone who is truly in love with the Lord. This is the heart of our apostolate. I will write more on this aspect of the faith/science apostolate in the near future. Have a blessed summer.

Robert Brungs, S.J.

The ITEST Bulletin: Publisher, Robert Brungs, S.J.; Editor, S. Marianne Postiglione, RSM

ITEST Offices: Director, Robert Brungs, S.J.
Director of Communications, S. Marianne Postiglione, RSM
3601 Lindell Boulevard
St. Louis, Missouri 63108 USA

ISSN 1073-5976 (314)-977-2703; FAX (314)-977-7211 e-mail: postigm@slu.edu Website: http://ITEST.slu.edu

ANNOUNCEMENTS

1. Please send in your registration as early as possible for the September 26-28, 2003 workshop, *Globalization in the 21st Century: Christian Challenges.* This topic continues to evoke great interest not only from governmental agencies who deal with the underlying economic, technological and political implications, but also from church and community groups concerned with the moral and socio/cultural issues in every country touched by the globalization phenomenon. Is globalization a blessing or a curse? Whether it is or is not a blessing, we are involved with studying this "process" and how it may result in ongoing growth for humankind. Conversely, will it or could it result in the dissipation of already existing human and natural resources? What, then, is the responsibility of developed countries to emerging developing countries? Economically, politically, technologically, socially, theologically? Are we our brothers and sisters keepers or are we empowerers? Will globalization be used to "keep them down on the farm?" These are some of the questions this workshop will explore, research and address.

If you have not yet received registration materials (invitation brochure) to the workshop, and you are planning to attend, please contact us as soon as possible via e-mail or phone (postigm@slu.edu or 314-977-2703). We have several openings for this weekend, but space is limited.

2. All dues-paid members should have received the latest ITEST publication, the edited and bound proceedings, *Advances in Neuroscience: Social, Moral, Philosophical and Theological Implications. (230 pp.)* If you paid dues for 2002 and 2003 and did not receive a book, please contact the ITEST office staff and we will send you a copy. Those who are on the mailing list only (i.e., are not dues-paid members) and who wish to purchase a copy, may also contact the ITEST offices. Price is $19.95 (postage and handling included) for non-members and $15.95 for ITEST members.

3. Check our web site at http://ITEST.slu.edu. Click on ITEST publications then on *Publications of the New Millennium*, to view our books of Proceedings from workshops on *Christianity and the Human Body (2000), Genetics and Nutrition (2001) and the latest, Advances in Neuroscience (2002)* All books from the 90's and the new millennium are listed on the web site. However, since most of these books are still available in print, they do not appear in their entirety on the web. We list the cover with the title, introduction, table of contents and foreword for each book. That information is usually sufficient for anyone researching a certain topic and looking for a suitable book to purchase.

4. We have set a tentative date of early 2004 for the appearance on the ITEST web site of an updated and revised version of *Readings in Faith and Science*. Originally published in 1997 as a spiral-bound book for campus ministry discussion groups on faith/science issues, the "web" book has been expanded to approximately 300 pages with articles by various authors under the general categories of faith/science and science, technology and theology. Titles include, environment and the believer, reproductive biologies, the Christian notion of freedom, spirituality of the scientist, evolution and the Bible, Christianity and modern science, animal research, reproductive technologies, stem cell research, and others. This book will be available free of charge on the ITEST web site. We will let you know as soon as it is "live." It can will be able to be downloaded free of charge for anyone who wants any of it.

5. Many of our members receive the *ITEST BULLETIN* via e-mail. It is important that you let us know when your e-mail address changes or perhaps is cancelled. Also, this is a plea to clean out your mail box. Often we receive a message that the bulletin is not deliverable because the mail box is full.

6. The ITEST Board settled on a topic for the Fall, 2004 weekend workshop, *Artificial Intelligence, Computers and Virtual Reality*. The last time ITEST visited this topic was in 1984, really at the beginning of widespread computer use. The Board of Directors decided that this area of technology which pervades almost every area of life certainly merits a revisit. We will let you know as soon as the faculty, dates and location are confirmed. We are thinking of five (maybe four) essayists for this meeting.

7. We are also tentatively thinking of scheduling a meeting on *Relativity Theory* for the year 2005. That year is the hundredth anniversary of the original work on Special Relativity. Rarely has a theory had an effect so contrary to the theory itself. The "everything's relative" notion so prevalent today stands in stark contrast to the constant speed of light and the many invariances of the field. It is the feeling of the Board of Directors now that such a meeting would be valuable. Nothing, however, has yet been settled for 2005. Your reaction to *Relativity* as a topic will be appreciated. We need your input on matters such as these. We're also thinking of Science and the Law for 2006, but this is still only tentative. We last had a meeting on *Patenting* (an aspect of the broader topic) in 1996.

RICHARD CUSACK (1925-2003)

With all the deaths that ITEST has experienced in the past four months, one name may be known to most of the members -- that of Dick Cusack. Not only was Dick the father of Susie, John, Joan, Ann and Bill, he was the husband of Nancy -- possibly the centerpiece of the family. Dick and Nancy were a couple who can be described by the biblical "two-in-one-flesh."

One day back in the very early 80s I received a phone call from a TV producer in Chicago, wondering if we were contemplating doing some TV work. It was Dick acting on information he had received from some of the Lay Initiatives people -- Ed Marciniak and a few other ITEST members -- in Chicago. They knew that we were in the initial stages of perhaps planning to do a video on genetics and its ramifications. Thus began a long and solid friendship.

It was Dick who produced and directed the two videos that ITEST did in the 1980s, *Lights Breaking*: *A Journey Down the Byways of Genetic Engineering* in 1985 and *Decision* in 1987. *Lights Breaking* won awards at the New York Film Festival, the San Francisco Film Festival and the John Muir Medical Film Festival (best of category in Genetics) and "Best film of 1986" in Booklist Non-print Reviewers Choice.

Dick's last appearance at an ITEST meeting occurred in 1999 at our 30-Something Anniversary Celebration at Loyola University in Chicago. He presented a well-received paper on Biogenetics and the Media. It is printed in the *Genome: Plant, Animal, Human*. I would recommend a re-reading of it. Dick had a way of keeping his finger on the pulse of the culture.

Dick was a good friend and a loyal one. He was also a very creative and thoughtful person. I can still remember him in *Eight Men Out*, a movie about the 1919 White Sox throwing the World Series. In that movie he played the role of the judge of the Chicago trial of the White Sox. At one point Buck Weaver (John Cusack) noisily objected to being on trial. Dick, as judge, ordered him to be quiet and sit down -- and he finally obeyed. Dick noted wryly that that was the first time John ever obeyed him.

Dick was an uncomplicated man on the important levels in life, but quite complicated on others. He saw trends in the culture clearly and was helpful in that regard to ITEST. He will be (he is) missed. For his work in the Church, Dick will be remembered. He will be remembered for his pro bono work for many causes -- many at significant cost to himself. God be with you, Dick.

[In the Fall of 2004, ITEST will present a Workshop on Computers, Artificial Intelligence and Virtual Reality. By then it will have been a full 20 years since we broached the beginning of our treatment of this technological advance. We were merely at the beginning of the this revolution 20 years. To prepare ourselves for the upcoming workshop, we are reprinting three of the papers from the workshop in 1984. As you can tell from the material, it is out-of-date, but still important for us to know. We hope that the Workshop on Computers, etc. next year will provide both for an updating of the material presented twenty years ago and a grounding (and point of departure) in the thinking of the Church about these technological leaps forward. Here we present the papers of Doctors Rocky Martino, Joop Schopman and Father (Doctor) Joseph Koterski, S.J.]

ARTIFICIAL INTELLIGENCE

Dr. R. L. Martino
Chairman of the Board
XRT, Incorporated

Philosophic Considerations

Artificial Intelligence is a term that is easy to discuss but hard to define. Normally it is applied to the concept of reasoning not performed within a human brain. However, even that simplistic concept opens further avenues for examination, especially the one that includes the electronic digital computer. The computer is different from all previous machines or inventions of man. The computer is the first machine that is an adjunct of man's intellect, as opposed to all other inventions which simply augment physical strength.

The computer is a product of man's brain that functions according to preset command logic in much the same pattern followed by the brain; i.e., man has created the computer in the image of his brain. There is nothing artificial about the logic performed by the computer if it slavishly follows the logical patterns of the creator of the program. The program is really an extension of the brain of the programmer and, as such, the program is not artificial. However, since the program functions outside the physical brain, it can be considered as artificial intelligence.

There has always been an interest in the concept of reason, and the power of reasoning as the major distinction between man and animal. The interjection of the computer has added to these philosophic considerations. Indeed, because of the capability of the computer to perform very complicated calculations faster than man, some very sophisticated reasoning and heuristic programs and systems have been created. This has sparked greater insight and challenge into the quest for intelligence outside the brain.

Computer programs work on rules in the program. The computer can branch to other procedures based on the results of a series of logical steps. These logical steps can even be set to be self modifying, essentially evolving in capability. It is theoretically possible to program a set of rules for right and wrong. This program could even be set to modify itself based on "situations" it encounters. Hence, such a program would appear to function as a "conscience".

Some psychologists even believe that conscience is programmed into us from childhood. But one thing must be remembered. Programming is a mechanistic approach that handles logic, data, and calculations upon data. Computers work as directed by programs; and programs have no concept of "other", and no concept that cannot be reduced to measureable or quantitative values.

Logic in the computer is entirely quantified. While much can be quantified, the notions of love, beauty, poetic expression, and true conscience can never be programmed no matter how sophisticated we ever become in the programming of artificial intelligence into our machines.

For a moment let us become ultra extreme in our thinking. Let us assume that we can capture the logic, thoughts, and memories of a live brain in a machine. Is that artificial intelligence? No!

That's a life-support system, or a copy. If the "duplicate" brain functions, it must function within a machine, and that machine, like all others, can only function in a logical pattern on quantitative data. With artificial intelligence and with computer science, as with all other branches of knowledge and science, there is no "philosopher's stone."

This paper will not concern itself further with these or any other philosophic questions. Rather, it will concentrate on the means of creating an artificial intelligence capability within and without the computer.

The Nature of Intelligence

The concept of intelligence embodies the ability to analyze diverse situations, to search the memory for data concerning them, and to connect the retrieved data in order to reach conclusions associated with a specific need. This entire process is normally directed to a specific purpose or objective, unless it is mere day dreaming. The process can go on and on until a final result is reached, or the process is abandoned.

For example, assume we meet someone on the street. We search our memory to connect the visual impression of the person, find the name, and say, "Hello, ... "; or we cannot recall the name, and say, "I'm embarrassed, but I know you and cannot remember your name."

As another example, consider a musical tune that you might hear. This may recall the first time you heard it; or the most recent. From there you might recall people you were with. This can lead to memories of concerts you have attended; then on to dinners after a concert; then to foods you like; and on and on!

But you still can't dredge the name of the tune from your memory. But maybe you weren't even trying, and your mind was just set "on idle" recapturing memories with no purpose at all.

Intelligence, then, consists of:

- memories, or facts, catalogued in many ways
- keys to those memories
- retrieval capability
- correlation

The level of intelligence is associated with the speed of retrieval, the breadth of retrieval with related keys, and the breadth of the correlation capability.

Learning is the process whereby we catalogue our memories and establish the correlations between them. We add to learning from experience, from facts we receive from others, and from our reasoning. Reasoning is the process of establishing newer correlations based on the ones we have, or based on the facts or memories we acquire.

For example, mud is formed when we mix water and dirt. Water is a liquid. We may learn as a fact that vinegar is a liquid; and that vinegar is mostly water. Hence we might deduce that vinegar and dirt will mix together to form mud. We know this mud is different, but the result will be a part of dirt, called mud. With this knowledge, we might experiment and find that mud made with vinegar has an acrid smell, while mud made with water does not. Hence, this set of facts is stored in our memories.

However, if we had used vinegar before, then we would know of its smell, and either deduce that vinegar mud would smell, or look for that property when the experiment is performed. In other words, we would correlate the properties of liquid and smell associated with vinegar to deduce that mixing dirt and vinegar would produce an acrid smelling mud. We would confirm this fact with an experiment or not, or we might ask someone.

The human cognitive process is based on experience, direct and indirect. This experience is catalogued and indexed by our brains. However, not all learning is based strictly on experience. Learning can be associated with facts transferred to the learner, or can be deduced from other facts. For example, a person can be taught to use a parachute. The parachutist need not jump without a parachute to know that this is dangerous. The parachutist can also be told to carry a spare chute without ever experiencing a malfunction of the primary chute.

Knowledge or experience, then, in a cognitive process, can be acquired from direct involvement (experience), transfer of knowledge from another person (or database), or by deductive reasoning based on facts within the database.

In the human sense, genius is linked to the speed of retrieval, to the breadth of the retrieval indices, and to the breadth of the correlation capability. In the computer, there is no limit to the breadth of retrieval or correlation, with the speed of retrieval determined strictly as a function of the speed of the machine and the complexity of the key-indices-structure of the relational database.

The human brain is unsurpassed in its ability to store and retrieve data; but the computer can calculate faster. At this time, the computer must be ranked as a virtual imbecile next to the human brain. But that current truism must be examined in the light of current and projected developments in artificial intelligence.

Artificial Intelligence Defined:

For purposes of this paper, artificial intelligence is defined as systematic learning and application of that learning, in a mechanistic, non-human, or computer environment.

The "intelligence" of a computer is associated with:

- storage of data into a data base
- organization of the data base into structures that include
  - volumes and subvolumes
  - files
  - records
  - fields or items of data
- key structures to retrieve the data
  - major and alternate keys for volumes, files, and records
  - relational keys connecting volumes and files
- the logic of the program
  - decision patterns
  - branching
  - pattern recognition
  - data retrieval - single, multiple, or relational key

Because the computer works in absolute precision, artificial intelligence is directed towards the ultimate in precision of logic, of decision pattern, and the weighting of facts in a decision. All decisions, whether made by man or by machine, are associated with the extraction or retrieval of data, the correlation of that data by a set of rules, and the conclusions reached by weighing the possible paths through the data connectors.

Current State-of-the-Art

Going beyond the theory and the philosophy, there are a number of sophisticated artificial intelligence systems in operation and under development at this time.

At XRT we are working with the National Board of Medical Examiners on a Computer-Based Examination process -- CBX -- that will be used to test medical licensees on their knowledge of medicine. The system will present a situation, and the examinees will be allowed to request tests, prescribe medication and therapies, and make decisions on both the location and type of care required. The CBX system will assimilate this data and develop the progression of the illness or condition to a conclusion. In the future, systems of this nature could be used for diagnosis and semi-automatic treatment in the absence of a physician.

In addition, at XRT, during the past ten years we have had under development a system for creating computer systems by filling in the answers to prompted questions. Within a short period of time, this system will allow complete free-form expression, thus shortening the time span from request to result. Furthermore, this system substantially reduces the training requirement for systems engineering and virtually eliminates the need for detailed programming at the application level.

Other systems are MYCIN, a program that diagnoses meningitis; CATS-1, a diesel locomotive repair system; PUFF, a system for diagnosing pulmonary diseases; and R-1, a system used by Digital Equipment Corporation to configure its VAX computers. In addition, a language called LISP (for List Processing) has been in existence since 1958. LISP manipulates symbolic logic parameters, resulting in programs that can call other LISP programs, modify databases, and modify themselves or other programs.

To illustrate the nature of this mechanistic approach, let us consider a more detailed example.

> There is a wood fire. Heat and light are given off by the fire. Heat on the skin may cause pain, and too much heat will cause a great deal of pain, or a burn. Hence, putting a finger into a wood fire will cause a pain as the finger burns. Water does not burn. Putting the finger into water and then putting it into the fire will provide protection for a short period of time until the water evaporates, and then the finger will burn. Steel is a strong material. Putting the finger into a steel glove will provide a great deal of protection for the finger, but when the steel gets red and white hot, the finger will burn even when removed from the fire. Asbestos is a soft material without the strength of steel. Putting the finger into a glove of asbestos will keep the finger from burning while it is in the fire and afterward.

For this example, we need a set of facts. These are:

- a wood fire can give off excessive heat
- excessive heat burns
- water removes heat by evaporation
- steel is a good conductor of heat
- steel retains its heat when removed from a fire until the heat dissipates into the surrounding air, or some other medium
- asbestos is a bad conductor of heat

These facts can be stored under various headings such as heat conductors, heat retainers, burning, pain, material strength, fire, etc. The organization in our minds can be apparently random, but in a computer must be precise. The keys for storing the data must be fully designed, and the rules for arriving at a decision must be pre-established.

In this example, we can set up a truth, or decision table, to illustrate the logic. All decision tables consist of four elements; viz, the condition stub, the action stub, the condition entries, and the action entries. This is shown in Figure 1, and the decision table associated with our example is in Figure 2.

Figure 1. The Structure of the Decision Table.

	STUB	RULES
CONDITIONS	CONDITION STUB	CONDITION ENTRIES
ACTIONS	ACTION STUB	ACTION ENTRIES

Figs. 2 and 3 will be situated at the end of this article.

An examination of Figure 2 will illustrate both the logic and the completeness of the decision table approach. The number of rules is always equal to the value of 2 raised to the power of the number of conditions. Hence, once the conditions are set, the number of rules is immediately known. The value factors in each entry location can be filled by logic, retrieval, or by experiment. And once the entries are filled, the data can be stored with keys connected to the example, the conditions, the rules, or the combination of conditions.

This example can be simplified and generalized to handle all situations without regard to the specifics of the insulator as shown in Figure 3.

In writing a program to handle this situation, there would be a need to create the database, establish the keys, set the data retrieval rules, enter the data, and establish the procedures for the entry of data.

Carrying this example a step forward, let us set up a volume in the data base called "Heat", and within this volume two files labelled "Conductors" and "Heaters".

The file labelled "Conductors" will consist of individual records containing information, or data fields, on the Material, the Heat Transfer Coefficient, the Cost, the Machineability, and so on. The file labelled "Heaters" will consist of individual records with data fields on the Source of the Heat, the Amount of Heat, the fumes, the light, the combustibles, etc.

Then, if we have a wood fire and an asbestos glove, we search both files according to the rules as given in Figure 3. In this case, then, there is no burn. Extending the example, the system can be applied to any material once we establish the data for it as a combustible or as an insulator. In fact, we could begin a systematic study of all materials in the universe, cataloguing them by these parameters, and finally arrive at an ultimate solution of the best known protection against fire. Once the factors of garment fabrication and cost are added, the model is more complete with regard to this problem. Further modification can be made by extending the model to other parts of the body, to plants and materials, and so on.

This rather trivial example illustrates both the simplicity and the complexity of the problem and its solution. In a concise statement, artificial intelligence can be programmed by implementing a multi-key variable size relational data base with the ability to search for new data and combinations of data.

Variations of this approach can be used to develop a heuristic approach to the discovery of chemicals linked to cancer cures; to moves in a chess game; to a machine that can read documents; to a program that writes poetry; or to a machine that thinks in boolean logic, extracting premises, conclusions, and facts from books, text, speech, or other programs.

As previously stated, the human cognitive process is based on experience which is directly lived, or indirectly learned by knowledge transfer or by deduction; and all this data is catalogued and indexed by our brains. Human genius is linked to the speed of retrieval, to the breadth of the retrieval indices, and to the breadth of the correlation capability; while in the computer, there is no limit to the breadth of retrieval or correlation, with the speed of retrieval determined strictly as a function of the speed of the machine and the complexity of the key-indices-structure of the relational database. By today's standards, only rudimentary models can be developed because the correlation capability of the computer is still in its infancy with regard to self-correcting or evolutionary type of programs directed to "intelligent" functions. Still, even this rudimentary ability can be put to significant and immediate use .

The Application of Artificial Intelligence

Rudimentary forms of artificial intelligence exist now, and have existed from the advent of the first computer. In fact, simple models predate the electronic computer. To some extent, any analog device is a form of artificial intelligence. The common speedometer, the slide rule, and the thermostat are ones that come quickly to mind. In the more complex computer-communications-electronic environment of the future, we will see rather far reaching developments take place. These will include such examples as automatic idiomatic language translation; symbolic mathematical logic manipulation such as integration, network solutions, circuit design, and diagnosis of faults; program correction and enhancement; speech analysis and synthesis; medical diagnosis and curative intervention; education and examination for students at all levels of study from kindergarden to graduate school, and even postgraduate; and to just about everything that involves cognitive learning, retrieval, and correlation, so long as we can set the rules. And, as Shakespeare has Hamlet say, "Ay, there's the rub!" If we don't know the rules, can we write the program? Not unless we can write a program to search for rules, try them out, and assume they are correct when they produce a result known to be correct.

The real problem here is to walk before running. We have to first create models in a single discipline before we start exploring multi-disciplinary procedures. The larger the domain encompassed by a system, the larger the number of rules and correlations, leading to potential confusion within the model if the logic is intractable either to the programmer or to the system. Before setting some guidelines for the future, an assessment will be presented on the current state-of-the-art in Artificial Intelligence.

The most significant feature of most of these systems is their implementation on mini- and micro-computers. This will lead to major impetus in future applications. In fact, the emerging countries can have as significant an impact as the highly industrialized since no large economic or industrial base is required to become a force in this field. The requirements are only skilled and knowledgeable people, a resource independent of the size, industrial, or economic might of any nation.

The major drawback is the ultimate and exact precision required by the computer. In these systems, there is no room for approximation or error in logic, even if there is massive flexibility in coping with input error and compensating for bad data.

One final example will be used that illustrates this ability to cope with error. This example further illustrates a learning curve capability.

Assume that we must find the square root of a number. For instance, we want the square root of 100. Let us assume the answer is 20. When we divide 100 by 20, we get 5 as the answer. Let us then take the average of 20 and 5, or 12.5, as our next guess. When we divide this into 100 we get 8. The mean of 8 and 12.5 is 10.25. We divide this into 100, and get 9.7560975. The average of this and 10.25 is 10.003048. We could keep going and would get 10 as the square root of 100 to any accuracy we desire. Now let us look at the model. The procedure is to pick a number and divide. Then to take a new number by using the result and the trial value. We picked a mean. We could pick a weighted mean, or whatever we want to use to test our rules. We could, if we wish, extend this concept to cube roots, quartic roots, or roots of any value. (Better ways are used for finding such roots, but the example is valid and illustrates the concept.)

This apparently simple example is profound in showing an iterative and heuristic approach to artificial intelligence where the rules compensate for initial data whether valid or not, and allow us to vary the means of finding whatever result we want.

The Future

The current explosion in microcomputer use, in the office, the lab, the school, and the home will have an accelerating effect on these developments. More and more people will direct their intellects to the use of machines to expand their intellects. Before the decade is out, machines and robots that "think" will be commonplace, and inexpensive. Languages will exist to make reasoning and the application of reasoning simpler and available to more people at all levels of experience and education.

Some of the developments of artificial intelligence for the future are somewhat mind boggling. In medicine, we will have machines that will help the crippled walk, the blind to see, the deaf to hear, and the dumb to talk. Speech translation will be immediate from any language to any other language, both aurally, and visually. Systems will parse speech and documents for key words, style changes, ideas, rules, and even determine whether Marlowe wrote any of Shakespeare's works. In education, machines will teach, examine, diagnose and correct learning disabilities, and substantially accelerate worldwide literacy and higher level education. The office will provide instant linkage to all parts of an enterprise, with voice, visual, and data transmission. The home computer will control dust, keep schedules, adjust to illness, and vacation; keep the books, paying bills, taxes, and even fighting with other systems over errors in charges.

Our way of life will be dramatically changed, and improved. In agronomy, productivity will increase as machines become more common in the control of planting, harvesting, and irrigation cycles. Weather modification for local requirements will be commonplace as long-range weather forecasting becomes more exact. Science will progress even more rapidly with shorter time intervals between correlations of diverse data in many fields.

In the arts, machines will duplicate the old masters, turning out masterpieces in a few minutes. Can you imagine a machine studying a Norman Rockwell painting, and then producing three dimensional figures, or newer painting using the same artistic pattern. Working with such a system, the artist of tomorrow could put together a montage of photographs, sketches, or specifications, and have the system create the final work of art in any medium, following the style of any old master, or creating a new one.

Of greatest wonder will be the machines that make machines, repair machines, and reprogram them all. Programming systems will self-modify, and create new systems.

Life for man will be one that offers the fullest range of both help and full expression. Our structures will change dramatically as cottage industries rise for those who will use and service these new systems. All nations of the earth will benefit since no large-scale industrial base will be required to participate.

Is this a Utopian dream, or a true picture of what is coming as we combine computer, communications, and electronics to develop an artificial intelligence capability, and then apply it to our lives and environment? Let us examine in a little detail just one of the examples mentioned -- making the crippled walk.

A mechanism can be strapped on the body of a normal person to record all the muscle and skeletal movements as that person walks, runs, sits, stands, and does all the things that a physically able person performs. Each set of such movements can be stored in a "program." That same person, or a crippled, or paraplegic person, could then be fitted with an apparatus that will control movement according to commands given by voice, by signal, or by muscle flexing. Someday, perhaps, signals could even be given from a sensor implanted in the skull to interpret brain originated commands.

Any of the projected examples can be divided into system segments of this nature showing the components, their linkages, and the data bases they use.

But even such advanced systems will be only artificial intelligence at work. The true intelligence of man, while apparently slower than that of the machine, will be wider ranging in perception, intuition, and creativity. No matter how advanced these systems become, their intelligence will be less than that of man.

Epilogue

It seems ironic that as we approach the golden age of man because of his ingenuity, we are also approaching man's possible extinction because of his belligerance. Perhaps the computer-communications-electronicsrevolution in which we are living will provide so much benefit that self-interest by everyone will prevail against the stupidity of self-destruction.

While machines will think, and artificial intelligence will be almost commonplace, reasoning will remain the province of the human. Feelings, conscience, and the concept of "other" must remain with the soul; and no machine can ever duplicate or copy the soul of man. Man is still the master since man has a free will, but the machine depends upon a program, and must always live within the limits of that program. Man, and only man, can set his own limits.

Figure 2. The Decision Logic for the Finger and Fire Example.

Each columnm is a rule, or represents a number of rules. Since there are six conditions, there are a total of 64 rules based on 2 raised to the sixth power. Every condition that is blank or contains a dash (-), denotes a Y or N as having no effect. Each (-) represents two rules. Hence Column or Rule #1 with 5 dashes, represents 32 rules; #2 with 4, 16 rules; #4 and #5, with no dashes, only one rule, and so on. As a result, the example can be completely checked with regard to logic based on having all 64 combinations checked and validated. In the general case, where n is the number of conditions, the number of rules is 2 raised to the power of n.

CONDITIONS						RULES		
RULE #	1	2	3	4	5	6	7	ELSE
# OF RULES	32	16	2	1	1	4	4	4=64 RULES
Is there a fire	N	Y	Y	Y	Y	Y	Y	Y
Is a finger in the fire	-	N	Y	Y	Y	Y	Y	Y
Was finger dipped in water 1st	-	-	N	Y	Y	-	-	-
Has water evaporated from finger	-	-	-	N	Y	-	-	-
Is there a steel glove	-	-	N	N	N	Y	N	Y
Is there an asbestos glove	-	-	N	N	N	N	Y	Y
ACTIONS								
Finger will not burn	X	X					X	X
Finger will burn now			X		X			
Finger will burn soon				X		X		
Finger will continue to burn on removal from fire						X		

Figure 3. The Generalized Case for the Burn Example

Total = 64	32	1	1	2	2	2	8	2	2	4	4	4
Is the part of the body exposed to enough heat to burn	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Is the body protected with an ablative heat shield	-	Y	Y	Y	Y	Y	Y	N	N	N	N	N
Will the body part be in the heat after all evaporation	-	Y	Y	Y	Y	Y	N	-	-	-	-	-
Is the body part protected by an insulator	-	Y	Y	Y	N	N	-	Y	Y	Y	N	N
Will insulator retain enough heat to create a burn when body is removed from heat source	-	Y	Y	N	-	-	-	Y	Y	N	-	-
Is body part protected by "unknown" material	-	Y	N	-	Y	N	-	Y	N	-	Y	N

Body will receive burn			X			X			X			X
There will be no burn	X			X			X			X		
More knowledge needed		X			X			X			X	

ARTIFICIAL INTELLIGENCE: THE EMERGENCE OF A NEW SCIENCE

Dr. Joop Schopman

Doctor Joop Schopman was born in Arnhem in 1937. He received a doctorate in Physics at the Municipal University in Amsterdam in 1971. He worked as a research scientist at the F.O.M. laboratory for Atomic and Molecular Physics in Amsterdam and later at the Institut de Chemie at the University of Liege, Belgium. Still later Dr. Schopman was appointed to the Central Interfaculty of the State University of Utrecht, where he specialized in the history and philosophy of science. Most recently he has been at the University of Innsbruck, Austria where he has founded a group on theology and science.

PROLOGUE

According to the sociological criteria Artificial Intelligence (A.I.) has taken its place amongst the sciences. It has its own scientific community. Since 1964 the *Society for the Study of Artificial Intelligence and Simulation of Behaviour* (AISB) has been in existence and has now grown to about 600 members. In 1965 an international meeting was held in Edinburgh as the first of a series of workshops. The Proceedings, edited by N.L. Collins and D. Michie under the title *Machine Intelligence*, were landmarks in the development of the field. A series of international conferences started in 1969 as the *International Joint Conference on Artificial Intelligence* (IJCAI). The community had its own journal *Artificial Intelligence* since 1970. And finally, in 1982 the third and last volume of *The Handbook of Artificial Intelligence* was published under the redaction of Paul Cohen and Edward Feigenbaum.

As in all new disciplines, it took quite a while before A.I. got external recognition. One could say that the first to recognize the field politically was the Japanese government. Its 1981 decision to develop a fifth generation of computers gave A.I. a political status. Quite a few governments realized then that the results of A.I. research could have an enormous impact on their economies which had already had difficult times.[1] All this may not convince every one that A.I. has a scientific value. Let us therefore consider A.I. more closely.

I. ARTIFICIAL INTELLIGENCE, ITS SCOPE AND SOME OF ITS HISTORY

As in all young sciences -- still immature in the eyes of the established disciplines -- there is a lot of discussion about how to define the field. This is a relevant fact because the title A.I. covers quite a variety of intellectual endeavours and it is not surprising that each one prefers to define the field from his or her own scope. As a working definition we could use: A.I. is the study of intelligence by means of computers.

The idea of simulating human (intelligent) behavior by machines pre-dates the existence of any computer; the construction of sophisticated mechanical robots in the 17th and 18th century exemplifies that. But even the start of what is now called A.I. took place before any usable computer was available. As early as 1936 Alan Turing claimed that there was a machine that could be built that would be a sort of "universal machine." He said it could do every possible computation. By extension, it could carry out any operation that any other information machine could do, whether it was an abacus or an animal's brain. This was possible, he said, because this ultimate machine could simply take for its instructions a complete description of the machine to be imitated.[2] Before he started to realize his ideas (1946) there was quite an effort going on in the USA to actually build computers. The appearance of computers promoted the analogy between computers and the human brain. Work was done in this direction by the neurophysiologists Warren McCullock and Gray Walter, the physicist Donald MacKay, the psychiatrist W. Ross Ashby and the mathematicians Walter Pitts and John von Neumann.[3] Ashby even tried to build "a self-organizing system," which he called a "homeostat." It's a cluster of four units, each unit able to emit direct current output to the others and to receive theirs in turn. Since definite values were assigned to various governing devices in the units, the homeostat would begin to exhibit definite patterns of behavior relative to the settings of those governing devices, always seeking to stabilize itself.

Ashby extended this principle to living organisms, suggesting that their adaptive, learned behavior could be expressed as a system that organizes itself to seek stability.

He pointed out that his own aim and the aim of a person who designs "a new giant calculating machine" might both be described as trying to design a mechanical brain. But the latter wants a specific task performed, preferably better than a human can do it and not necessarily by methods humans might use, while Ashby's aim "is simply to copy the living brain. In particular, if the living brain fails in certain characteristic ways, then I want my artificial brain to fail too, for such a failure would be valid evidence that the model was a true copy" (1952) .

Here Ashby articulated the distinction that would subsequently define two major branches of artificial intelligence: one aimed at producing intelligent behavior regardless of how it was accomplished, and the other aimed at modeling intelligent processes found in nature, particularly human ones. That division was to turn out to be less distinct than researchers in the 1950s imagined".[4]

Slowly more people got involved, helped by the increased technical possibilities of the computer. For example John McCarthy heard von Neumann speak at the Hixon Conference (1949) and Oliver Selfridge (MIT) started a group to discuss A.I. in connection with pattern recognition. His talk at the Rand Corporation (1954) put Allen Newell and Herbert Simon on the A.I. track. At that time both were working there on organizational problems.

But more important than the quantitative growth was the change of attention, the different course. The comparison between brain and computer structure was left alone (and only quite recently taken up again (George Hinton, CMU). The emphasis was shifted to the writing of programs (and construction of hardware) to get the computer to behave in ways which resemble some human behavior. The Darmouth Conference in the summer of 1956 might be considered to have been the turning point and the start of the actual A.I. work. For that occasion the field was dubbed by one of the organizers, John McCarthy, as *Artificial Intelligence*. One of the remarkable events of that conference was the presentation by Newell and Simon of a program called the "Logical Theory Machine" which could prove theorems of the *Principia Mathematica* by Whitehead and Russell.

Next to this type of problem, a lot of attention was paid to games, not to the now popular war games, but to intellectual games which are clearly rule-governed: checkers and chess. Checkers, the rules of which are simple, was the first problem to be successfully attacked by Arthur Samuel. Playing chess proved to be much harder. Although the game is a neat problem, a few rules regulate the movements of some six different pieces, nevertheless, it seems a real intellectual game. As the computer scientists soon found out, the number of possible moves is so large that the game can not be calculated completely. So, the computer must, so to speak, imitate the human approach: develop a strategy, i.e., it had to calculate a limited number of steps which look most promising -- in advance. This is an interesting development. It shows that even a neat, not very complicated situation such as occurs in chess, cannot be solved exactly. Only a reasonable approximation can be obtained. An appropriate strategy has to be developed because there is no general solution, only particular ones, adapted to the situation: i.e., external knowledge is needed (the so called "knowledge of the world"). The same proved to be the case with Problem solving. Initially one tried to develop a General Problem Solver. No chance!

But what resulted from this were methods, tools (like heuristics, search) which proved also to be very useful for other types of problems. But there were even more surprises to come. It turned out to be the case that the so called intellectual tasks like chess, logical reasoning are not the hardest to solve. Ordinary abilities like language, human vision, and human action are more challenging. With hindsight one can explain this. Those human capabilities are the results of a long evolutionary process, and thereby much more built in. They happen so to speak, unconsciously and are therefore much harder to formulate explicitly, if at all.

Those developments had an enormous impact on the A.I. ideology. Originally, the computer was seen as the model of human mind and some people still hold this point of view. Simon told me that what can be done by cells, can be done by Integrated Circuits (I.C.'s). But the above mentioned developments made a lot of researchers much more modest. They see A.I. and the tools it developed as tools for solving the problems in their own field, e.g., linguistics. It is a metaphor, several people told me, and we use it as far as it goes. The change became manifest in the appearance of a new name, "Cognitive Science." A journal called by that name started in 1977. Where Artificial Intelligence is often a part of Computer Science (as it is at Stanford and CMU), Cognitive science seems to cover the cooperation between Linguistics, Psychology, Philosophy and Computer Science.

One might conclude from this that the internal development with A.I. made the field no longer a competitor of the human being, but more a tool which can be used to get a better understanding of human intellectual abilities.

II. ARTIFICIAL INTELLIGENCE, THE ACTUAL STATUS

1. Research topics[5]

History, personal interest and (inevitably) commercially useful applications have shaped the domain of research. The main topics are: inference and reasoning; search, planning and problem solving; natural language understanding and speech recognition; vision; representation of knowledge; learning (knowledge acquisition); expert systems and robotics.

Inference and reasoning; we have already met it. It has mainly focussed on mathematical reasoning, theorem proving and deduction. A process which as we remember from our schooldays require quite some intellectual skill. There prove to be many ways which lead to Rome, but to find the shortest (and most elegant) one is not so easy.

Search, planning and problem solving; characteristic for human behavior is that it has goals; that it wants to realize those goals. It therefore needs planning. As indicated in relation to the chess problem, even a simple, rule-governed situation has already too many options to be calculated exactly. One needs a strategy, to search and to evaluate the possibilities at hand, and to decide then which strategy appears to be optimal.

Natural language understanding (spoken language); the dream of automatic translation (from Russian to American) was one of the first efforts, and it proved to be a complete failure. Understanding spoken language proved to be too difficult a task. But even a much simpler (?) problem: the understanding of written language appeared to be very difficult. Several efforts have been made to understand sentences by syntactical analysis. It turned out to be impossible without a simultaneous semantic analysis. Even understanding of utterances concerning a very limited domain of human experience proved to be extremely difficult, because it nearly always presupposes an understanding of (some of) the rest of the world.

Vision; it runs into similar types of problems. In order to see, to recognise, i.e., to be able to attach meaning to the visual input, a large degree of knowledge of what one is seeing is needed. Here top-down and bottom-up approachs change as do fashions. Although there are some industrially applicable devices available as spin off of the A.I. work, they only operate in very simple (artificial) environments.

(N.B. Both language and vision problems appear to be tractable as long as they are restricted, e.g., limited to "block worlds," i.e., to a limited number of neat geometrical objects.)

Representation of knowledge; in particular the last two fields make clear that a "knowledge of the world" is necessary, but how can that knowledge be represented in a computer, so that it can perform the functions as human memory does? How do we do it? Several techniques have been developed, e.g., semantic networks.

Learning (knowledge acquisition); perhaps even more important is how those representative systems can acquire (or delete) knowledge. As you can imagine, this is about the culmination of all difficulties. Relatively less has been done in this area.

Finally, more directly application oriented areas are:

Expert systems; systems which try to make the knowledge of experts explicit. For example the knowledge of chemical structures and of the way the chemical substances split in mass spectrometers has been used to make this kind of chemical analysis automatic. It also has been applied to several medical fields and oil exploration. It seems to be a commercially promising spin off.

Robotics; here mentioned as a particular field (of application). It depends heavily on the outcome of the other mentioned fields, e.g., vision, but it also has a complete new problem, namely that of *action*, the performance of three dimensional movements, and the coordination of all participating fields. In particular the development of the fifth generation computer, i.e., an intelligent robot will need the support of all mentioned fields.

II.2. DISCIPLINES INVOLVED (and their interaction)

Originally people were involved who can not be described as monodisciplinary. E.g., Turing got interested in biology, von Neumann studied physiology. There were a lot of contacts between information theory, mathematics, management, logic, automatic theory, statistics, psychology, engineering, cybernetics, physiology. Now the participation seems to be limited to computer science, logic, psychology and linguistics (philosophy).

Computer science; that will speak for itself: it provides the "interface" with the computer; how to handle the computer. A.I. is often a subdivision of Computer Science, although the relation is not always harmonious.

Logic; in particular mathematical logic plays an important role in the writing of programs for computers. It is a powerful instrument for the analysis of problems, and for the formalization of theories (e.g., formal semantics). New kinds of logic have been developed to deal with problems particular for A.I., e.g., fuzzy logic.

Linguistics; the Chomskian approach has initiated a whole series of efforts to formalize language. No acceptable theory has been developed so far. For some the computer proves to be a good tool to test the theories which they have developed. For others, the computer will give the final solution, because language is just information processing.

Psychology; like linguistics it does not have an appropriate theoretical basis. For some the computer model provides the desired model, "the computational paradigm." For others, it is still too early to look for a general theory. There is not enough knowledge available.

Philosophy; A.I. advocates have made strong philosophical claims, in particular, in its earlier phase. So, it claims to have solved centuries-old philosophical problems, like the mind-body relation, intentionality. Few philosophers try to understand A.I. and to use it, some others have reacted violently against it: A.I. has nothing to do with intelligence at all. But most philosophers do not even notice its existence (the same is true for the bulk of the other disciplines).

Although it seems to be a project which requires interdisciplinary cooperation, that hardly exists except for some technical projects. Interdisciplinarity exists only in persons, e.g., a linguist who learns to program a computer, or a computer scientist who goes into psychological literature. Even interdisciplinary courses and centres are just an addition of disciplines. Recently Stanford has started a common research project with computer scientists, linguists and logicians.

11.3 GEOGRAPHICAL SITUATION

As described A.I. has its origin in the U.K. and the USA. And it has been restricted to the two countries until quite recently. In Edinburgh, Scotland, Donald Michie succeeded in creating the major center of the U.K., but growing difficulties resulted in a report by Sir James Lightfoot (1973) and in a dispersion of many researchers over other U.K. universities and over the USA as well. Outside the University of Edinburgh, Sussex and Essex became the centers.

In the USA things started with individual people in different places; MIT was the most recognizable point. From there it spread to the Rand Corporation, Newell and Simon moved to Carnegie Mellon (1955). Several people from MIT moved to Stanford, where they started an A.I. section at the Computer Science Department (1963). These three, MIT, CMU and Stanford became the major centers, although in a lot of other places people did similar work (e.g., Maryland, Rutgers University, University of Massachusetts at Amherst, Cornell University). In the last few years A.I. was taken up in Japan and in several European countries. The resistance to enter the field, which might have been caused by the extreme claims of some A.I. researchers, was put aside when the possible economic impact became apparent. But with the exception of the earlier-mentioned fifth generation computer project in Japan -- at the Institute for new generation Computer Technology (ICOT) in Tokyo, there is no major A.I. research center outside the USA.

III. 1. ITS IMPACT: IT WILL BE ENORMOUS

Its social impact; the impact on the productivity of labor will be large, but not revolutionary. It is a continuation of a trend which has been changing our labor pattern since the second World War: automation, micro-electronics, robots, intelligent robots. It will all help to increase our labor productivity considerably, not only the productivity of blue collar workers. For example, by the introduction of micro-electronic devices (o.a. computers) the California Bank of America will make 4000 of its employees redundant in 1984. All the talking about the creation of new labor places is to a large degree just ideology, in the negative sense of the word. When we work, the work will be so more efficient; we will have to work fewer hours (or fewer people will work -- that is our choice). This in itself is not a negative development. I might even dare to say: it is a positive effect. Or better, it can be a positive effect, if we are willing to rethink the position of labour in our life and the distribution of income.

Micro-electronics can have many positive effects, promotion of democracy for example, but it appears to become a threat for our privacy. The same is true of A.I. Intelligent machines can be tools to improve our existence, if.... But there are many signs that the 'if' condition will not be fulfilled, or perhaps only after a catastrophic existence for many people. The tension inside societies will rise very high.

The increase in productivity and the thereby reduced need for labor, and in particular of skilled labor, can have a disastrous effect on the educational motivation of our youth; a trend which can already be seen. This means an enormous burden on our educational systems. Because on the one hand a utilization of the best minds will be needed to keep industry competitive with other economies (otherwise the whole system will collapse) and on the other side it must be able to motivate people, and in particular the youngsters, to exploit their talents in a non-productive way.

Machines were only a threat to the skilled blue collar labor. This micro-electronic intelligent robot will take the place of many white collar workers as well. Now it is the bank employees who are fired, the next ones might be the medical people and teachers. The expert systems and communication networks will do their job better. Will they?

This development will have an enormous impact on the distribution of wealth in the world. Now, labor shifts to lower cost countries. But in the future there will be no lower cost labour force than intelligent machines. So, production can return to the rich industrial countries. Within those countries there are means to force some distribution of wealth, although the traditional unions will have no say-so. But the third world countries do not have the means except war (or by being a threat to the economic system, as is happening at the moment).

III. 2. ITS IDEOLOGICAL IMPACT

Already the term "A.I." or "intelligent robots" gives many people shivers. It is experienced as an impersonal, inescapable threat. There have already been some violent reactions against computers.[6] The computer can become that anonymous entity which pushes one out of his or her job, which controls all one's movements, statements and spendings. In short, it may create an Orwellian *1984*.

The main thread however, might come from the inside -- so to speak -- and not from the computer activities themselves. Darwin had an enormous influence on human thinking about ourselves which can result in the opinion that man is just the next step in evolution: just a monkey with enlarged brain volume. But this reductive opinion is not the only possible one. The performance of A.I. might promote the idea, that a human being is just a piece of mechanics, albeit a very complicated one, i.e., we are just information processors. But again, this is not the only possibility. It was the initial arrogance of A.I. which seemed to promote the reductionist view. Here too the answer should be: let it make true its claims. That is the best way to demonstrate its shortcomings .

In the meantime the A.I. approach might have a tremendous impact, an impact which can hardly be overestimated by the pervasive character of it. (In this respect it can be compared with the profusion of microelectronics in existing techniques). Expert systems can become a real threat,[7] in particular because of the clumsiness of the actual technology. Perhaps this stage is less dangerous because its shortcomings are more obvious.

The tone of this section is pessimistic. That is not because the impact of A.I. has to be negative. As a powerful tool its possibilities are for the best as well as for the worst. It is only that the lesson of history seems to indicate that the negative influence seems to prevail.[8] As long as we allow the development of science and society to be Darwinian,[9] this has to be the case.

IV. SUGGESTIONS

Nuclear technology as a large-scale technology may be thought of as a development which can be stopped, at least for a time, as has happened in several countries at this moment. Yet that will be impossible in the case of a small-scale pervasive technology as A.I. I do not think that it has to be done that way, even if it could be done. What should be done is to promote the positive aspects and to suppress the negative ones as much as possible.

1) As indicated already: decreasing the need for a productive labor-force makes a rethinking of the status of labor and of the distribution of income urgent.

2) Education will become more important and will have to shift its attention from preparation for a productive labor-force to the exploration of other human capacities, e.g., artistic. That by no means implies a degeneration of the function of education or a reduction in its level.

3) The development of A.I. will have to be critically followed and required to verify its claims, in order to prevent us from ending up with a reduced reality, in which only that becomes real, which can be handled by A.I. With critical review this research will not result in a degradation of man; rather increased insight will make more and more evident what a unique being man is.

4) In particular, the applications of A.I. have to be evaluated critically. Not only do they influence directly our existence, but for economic (and science funding) reasons their potential will be greatly exaggerated.

5) All the afore-mentioned efforts presuppose a very serious and honest reflection on our own existence. To this the contribution of religion could be essential and on its turn religion will be fertilized by scientific insight.

NOTES

1) An effort was made by Edward Feigenbaum and Pamela McCorduck to draw the attention of the American public and government. They published *The Fifth Generation Computer: A.I. and Japanese Computer Challenge To The World*. Reading, MA: Addison-Wesley, 1983.

2) J. Hilts, *Scientific Temperaments*, N.Y.; Simon and Schuster, 1982, p. 212.
3) John von Neumann, *The Computer And The Brain*, New Haven: Yale Univ. Pr., 1958.
4) P. McCorduck, *Machines Who Think*, San Francisco: Freeman, 1979, p. 83.
5) A very readable account of the performances of A.I. research so far is: M. Boden, *A.I. And Natural Man*, N.Y.: Basic Books, 1977.
6) Hilts, p. 278.
7) J. Weizenbaum, *Computer Power And Human Reasoning*, San Francisco: Freeman, 1976.
8) An additional reason for our suspicion is the fact that nearly all A.I. work is militarily funded, by ARPA.
9) Cfr. G. Boehme, W. van den Daele and W. Krohn, "Alternativen Der Wissenschaft," in: Zeitschrift fur Soziologie, 1 (1972) 312ss.

CERTAIN ESSENTIALLY HUMAN ASPECTS OF INTELLIGNCE

Doctor Joseph Koterski

Dr. Joseph Koterski received his PhD in philosophy from Saint Louis University in 1982. The title of his dissertaion, written under the direction of Dr. James Collins, was "Truth and Freedom in Science according to Karl Jaspers." In 1984, when he presented this paper, he was on the faculty of the Center for Thomistic Studies in Houston, Texas. Doctor Koterski presently teaches philosophy at Fordham University in New York City.

Is thought more a process or a product? The greatest of philosophers have always insisted that it is an activity, rather than a static collection of mental results. It may be the fact of written and printed expressions of our thoughts that leads to the notion that thought is a set of fixed objects similar to its material expressions. Even those patterns of thought which are fixed, our enduring concepts, for example, or our memory of past thoughts, are better regarded as activities of the mind than as mechanical parts that can be shelved or removed from the shelves of the mind to be put back into active circulation at our pleasure. But it is reflection on the incredible innovations in the world of artificial intelligence that lets us see even more deeply why the realist philosophers of all ages have insisted on seeing it as a vital activity rather than, say, as a mechanical production.

Knowledge has no real existence apart from a knower. While verbal, numerical, and other symbolic displays of information can be correlated with meanings intended by a knowing subject and can often be mechanically and electronically manipulated far more quickly and more massively than any person alone could do, these signs are not *per se* the knowledge. Rather, it is the activity of thinking the meaning of these signs that is the knowledge.

My task in this paper then is by no means to disparage the marvels of these recent developments, but to remind ourselves of certain essentially human aspects of intelligence. It is precisely the possibility of correlating meanings with symbols which makes these ventures in artificial intelligence so valuable, but it is also well to recall certain specifically human activities involved: the insights that make concepts possible, the strategic decisions that are made in the course of thinking things through, and the freedom that is an indispensable aspect of human existence. Even though freedom might not be on the tips of the tongues of many philosophers in describing knowledge in the same way that, say, generalizing the many particulars in the one concept by means of a universal term would be, I believe that it is important to note how intrinsically freedom is related, not just to our acting and choosing, but to the very structure of our knowing. This consideration is vital in the theory of knowledge in general, and all the more so in addressing the question of artificial intelligence that is before us today.

THE STRUCTURE OF OBJECTIVE KNOWLEDGE

Let us consider first the structure of objective knowledge -- that is, thought considered as a product of the mind, thought that is the result of our thinking, and then work backwards to the essential structures of human thinking. The public expression given to this thought, whatever its form (oral, written, drawn, printed, electronic) makes it accessible to other minds. Whether this objective knowledge be in the realm of simple information, some fact or some catalogue of facts, or in the realm of propositions, more or less complicated, or even if it be in the form of some elaborate chain of reasoning, suitable to bear the name of rigorous scientific demonstration -- whatever the type, the objective knowledge in question is marked by certain traits.

There is something definite there to be understood and to be grasped in the universal terms called concepts, which are in turn interwoven in judgments. This something definite is something independent of the knower and is expressed in publically accessible fashion. The very existence of concepts, let alone those more complicated structures called judgments, manifests the insight that is peculiarly human: an ability to grasp the general from many particulars. Agents of artificial intelligence exhibit their efficiency by no flash of intuition but by an almost unimaginably speedy manipulation of particulars.

Consider, for example, the way in which computers have mastered a game like backgammon. Their ability to beat any human opponent is proven. While it takes only a few seconds for them to determine their next move on their inevitable march toward victory, it is rather by no insight of strategy that they maneuver their forces; it is by testing all the possible outcomes of every possible move that they make their decision. The speed of the calculation is baffling, but in fact every step in the deliberation is short (and to the human, unbearably repetitious!) and but one of a myriad exactly like it. Interestingly enough, computers have not yet mastered chess. The problem does not seem to be a difficulty in principle but only of practice, for the number of possible moves simply exceeds present capacities of computation, when the computation must move ploddingly through every possible move for the entire rest of the game for each move to be made along the way. By contrast, even the grand masters, who are able to calculate many moves ahead of their present one, do not make such repetitious calculation. Rather, they understand the game in a different way altogether.

TRAITS OF A KNOWER

Besides the fact of certain traits expected in objective knowledge as objective, there are certain claims that can be made about the relation of the knower to what is known. This known "something" is other than the knower. While he may want somehow to change the object or state of affairs in question, he is nonetheless dependent on the object, in the sense that he will only truly know the object, process, or state of affairs when he makes his thought conform to what is. He is dependent on the intelligibility of its structure to learn about it as it really is, even if the whole point of his learning about it is to change it.

THE CASE OF KNOWLEDGE OF A SCIENCE

Especially when we consider something like the thorough knowledge of some science, it becomes clear that science is a larger entity than merely propositional knowledge, however large the set of well-expressed propositions may be. Science as a body of objective knowledge is accessible to any mind whatsoever, provided the individual mind has the necessary training, and is the same for all, in the sense that subjective factors like disposition and volition play no role in causing the validity of the claim. A demonstration is either cogent and compelling, or is not. The truth of a proposition is rooted in the objects known and the thought involved in grasping this truth is capable of being made evident to any mind whatsoever which has had suitable background, has the same data to consider, and has the same attitudes and habits of attentiveness. But any given science is more than the organized system of propositions that such minds would understand.

There is as well within a science the art of discovery that is quite subjective, for this aspect of a discipline uses feelings, intuition, and in general the subjective or nonrational for achieving a rational goal (viz., an insight whose truth can be demonstrated and shown to be founded upon the objects under study). As art of discovery, a given science is subjective, filled with emotions, idiosyncrasies, errors, personal relations, and even theology. How indeed can the randomness of pure subjectivity be the source of the universal necessity of objective truth?

The answer I want to give to this question is not just the affirmation that truth can come from knowing subjects, but that in fact it is the free exercise of our power to choose which guarantees for us the *possibility* of truth. Subjectivity does not assure the fact of truth, but it does provide the possibility of truth, and without subjectivity and its essential aspect, freedom, we never find truly human knowledge, but only some manipulation of symbols that can become the object of a mind's gaze. It has been the bane of modern thought to suppose that there could be a perfect method, a sure-fire defense against error by the persistent application of impersonal method. But this quest for an error-free method of discovery (or, at least, a method that will eventually guarantee the eradication of error if used consistently) has in fact reduced genuine knowing to a shadow of its former self by neglecting one of thought's essential ingredients. To put the matter in another way, the recognition of truth once achieved is impossible without freedom on the part of the knower.

The reason for this insistence on the need for freedom as a necessary condition for appreciating any truth we gain comes from the fact that knowledge, whether objective and publically expressed or quite private, is a modification of the knowing subject in regard to his senses and his mind. For knowledge to be public only means that its form of expression makes it accessible for possession by other minds. Knowledge is not a substance with its own existence, but is a mode of human activity.

THE TEMPORALITY OF KNOWING

As an activity of a knowing subject, knowing is a temporal activity. While there are aspects to our thought which are non-temporal in the strict sense, the activity of having and using these non-temporal and immutable forms of thought is intrinsically temporal. For instance, our conceptual categories, once received or constructed, are stable in character, and their very permanence is what makes them useful in bringing our minds into conformity to reality. Even if these concepts enter or leave our minds, or are changed by our forgetfulness or by intentional revision on our part, they have no intrinsic mutability, and are effective tools of communication between minds because of their stability and identity over time.

Likewise, true judgments have an intelligible structure independent of time and change. But this immutability only holds if the judgment is preserved in its full context, including temporality. If there is a temporal qualifier, the form in which the assertion is expressed must change, at least as regards the verb-tense, to remain truthful. False judgments have a similar structural invariance.

But what is not true about knowledge is that it consists of bits and pieces of trans-temporal fragments which could, say, be fitted together in an expanding collection of fragments that ever increasingly approximate the truth in a given science. The fallacy involved here is the result of assigning knowledge the status of an independent entity, when in fact the appreciation of the meaning of any claim requires the presence of human attention, an intrinsically temporal matter. This temporality is a sign of the freedom indispensable to knowing.

The temporality intrinsic to the knowing subject does not mean the abandonment of the concept of truth. It does not mean the reduction of thought to a psychological flux. But neither does it mean that we must remove ideas to a world apart in order to preserve for them the permanence necessary for knowledge. Instead, time must be seen as the medium in which our intellectual structures are related to one another and to the world. (New ideas, for instance, can force us to reconceptualize certain older ones.) The very timelessness of really cogent assertions, universally valid, depends upon the temporality of the subject who makes the assertions for there to be a possibility for the meaning to be grasped. While the validity of a knowledge-claim is independent of the temporal character of its acquisition, the possibility of appreciating its meaning is dependent on the knowing subject in his or her temporality and freedom.

To put the claim more succinctly, let us grant that the truth, or for that matter, the falsity, of a proposition depends on its conformity or lack of conformity with reality, in such a way that its content is rational and objectively verifiable for any mind at all, given the same background. But because propositions do not have existence independent of minds, it is not enough to say that the truth of a proposition depends on its conformity to reality. Indeed, the assertion of a proposition is a formal, cognitively invariant act of a living mind. And were a human mind able to achieve complete conformity with some object, an absolute truth could be conceived which would be entirely timeless, for then the knower would be completely unreliant on the subjectivity of the knower. But the polar relationship of subject and object in all consciousness entails a temporal measure for even the most objective of knowledge-claims.

THE TEMPERED PRESENCE OF FREE CHOICE IN KNOWING

The temporality which the subjective pole introduces into scientific knowing means a definite, but controlled and tempered, presence of human free choice in all knowing. To make anything the material of objective knowledge entails the choice to abstract certain elements from the ongoing flow. If nothing else, there is a choice to restrict and delimit what one will study and what approach one will take.

Otherwise, the very endlessness of possibility frustrates cognition. Yet this basic level of freedom's entry into knowledge is a controlled entry -- it is not freedom run rampant, or objective knowledge would be hopelessly distorted by arbitrariness. Timeless as the structures of objective knowledge are (the principles of identity and contradiction, the conceptual categories, the use of these categories in propositions expressed in well-formed judgments, etc.), the actual knowing takes place in time, and is the result of real motives, a person's interests and the choices of the will. The timeless meaning is the product of choices made in time. The situation of realizing even what is timelessly true is a temporal situation, and this temporality points to the freedom present in all acts of knowing.

There is no logical escape from the compelling rigor of good reasoning, and no diminution of the universal validity of a demonstrated truth is intended by this explanation. But, on the other hand, there is no denying the often-neglected point that the recognition of universally valid truth requires the free assent of the mind. This freedom is not uncontrolled arbitrariness by which a person can whimsically decide to allow or ignore a conclusion as it suits him. It is rather the freedom by which the knower has made the prior choice to accept a certain set of standards of cogency, rigor and meaning, by which he is now acting as he denominates a particular claim to be a truth universally valid.

The invariants we employ in our cognition have their structure and configuration from reality if our thought is truthful, yet there is constant choice going on, and not just of a trite sort. In a science, for instance, there is endless decision-making, including the hypothetical assumption of certain ideas and theories, the tentative rejection of others, the selection of relevant data, and the dismissal of other data, the selection of a non-contradictory framework for setting up a problem. Even more strategic questions could be included on our list: whether a given difficulty is worth one's trouble, how the problem should be set up, whether direct or indirect means should be employed in the investigation, whether approximations will suffice or whether full rigor and complete exactness should be one's goals from the start, or only worked for later on. The same constant decision-making present in scientific work is present in an analogous way in all speculative cognition (even in neighborly conversation over a back-yard fence!).

The significance of this recognition of the place of free choice in knowing is that the judgments made in knowledge are not acts of intellect alone, mechanically pursuing a logic of cogency along the ruts and grooves of a trail that could very well be streamlined and traversed more quickly by artificial means, but are also the products of the rational will and its power to accept or reject. Freedom I regard as a necessary condition, though by no means, a guarantee, for the realization of truth.

Whether or not the question ever becomes explicit in a decision, a knower interested in the truth about whatever is being considered must show a willingness to subject his thinking to the compelling logic of the discipline in which he is working. This basic decision is an act of self-determination and of freedom on the part of the individual. It comes naturally for most people, but it can become a matter for deliberate decision in someone for whom reflection on his knowing makes the question explicit: by so conforming one's thinking, one is disposing oneself suitably to comprehend the world and its intelligible structures as they are, in all their real *otherness* from the knower.

All the deliberate choices that follow in someone's investigation of a problem seem to be acts of selection from a set of alternatives. But the rationality of these choices follows from a will-to-know -- a deliberate desire to understand as truly and as fully as possible. Not all the alternatives are likely to be right, or even equally plausible. And the full reality and goal of the freedom present here is only to be appreciated with right choice, with selection in accord with truth. But, however mundane the decisions in the ordinary activities of problem-investigation, the entire road to cogent knowledge is informed by the basic motive of the will-to-know and so shares in the freedom of this act.

These remarks then are intended to point to certain essentially human aspects of intelligence. Knowing involves a self-determination in the sense of a will to grasp and hold within oneself a formal apprehension of the objects known. The standard is nonarbitrary, for the measure of truth is the object as the object really is in itself, but the human agent is self-determining by his concern to comprehend the intelligible structure of these objects. Without a willingness to be changed, to be developed by the very process of cognition, a person would be doing imaginative thinking, but not truthful knowing.

The freedom involved in knowing is thus manifest in the receptivity to be changed by what one comes to know as well as by the intense activity of the mind which a person wills in order to achieve the truth. The search for ever more adequate formalization and for conceptual apparatus sufficient to express the intelligible structure of reality is frequently tantamount to a struggle, but a struggle motivated by a love for the truth and a personal disposition of humility, understood as St. Bernard of Clairvaux is wont to understand it, "the loving reverence for the truth."

IN MEMORIAM

Mr. James Blackburn
Mr. Richard Cusack
Fr. Jorge Hoyos, S.J.
Bishop John Sheets, S.J.

We also ask your prayers for ITEST members who are ill. May they feel the restoring hand of the Lord.