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APPLIED ARTIFICIAL INTELLIGENCE: AN EMERGING TECHNOLOGY OF WIDESPREAD USE

ADOLFO GUZMAN ARENAS

CENTRO DE INVESTIGACION Y DE ESTUDIOS AVANZADOS DEL IPN

DEPARTAMENTO DE INGENIERIA ELECTRICA

APARTADO POSTAL: 14-740, MEXICO 14, D.F.
TEL. 754-02-00 EXT. 141; TELEX: 017-72-826 PPTME
AVE. INSTITUTO POLITECNICO NACIONAL 2508
ZACATENCO, 07000 MEXICO, D.F.

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natural resources in high altitude color pictures, helping in forecasting yield and crop production; others are found inside "robots" that see, manipulate and plan.

In AAI, the different fields of AI: learning, planning, development of expert systems, vision, pattern recognition, robotics, game playing, induction, and others, are systematically used in a variety of complex situations where a "straight forward" programming approach will not yield significant results. These and similar techniques are being (and will continue to be) employed inside computer programs to improve the performance and usefulness of computers, to widen their application, to render them "more intelligent". Not in the distant future, but beginning now, Japan is engaged in an ambitious plan around Computer Science and microelectronics, involving data banks, fast machines and --most fruitful of all, I think-- Applied Artificial Intelligence, to help them to make more intelligent machines that sort mail, answer questions in natural language, become a "live" repository of information, recognize faces, find the similarity or likelihood of shapes (silhouettes, faces, hills), and so on.

The First Revolution was (cf. Alvin Toeffler) the Agricultural Revolution, which converted nomad tribes into sedentary settlements. The Second Revolution, the Industrial Revolution, amplified the power of the muscles of men, by use of vapor and electricity instead. Now, the Third Revolution (the third wave) is the Informatics Revolution, which increases his brain's power by using computers and AAI in applications that greatly expand the possibilities of deduction, reasoning and storage/handling of vast amounts of information.

The paper discusses actual uses of AAI, and predicts probable applications in the immediate future. Special consideration is given to problems of developing countries, and Mexico is used as example.

ORGANIZATION OF PAPER. This paper claims that *Applied Artificial Intelligence is helping and will continue to help to solve important technological problems in our society*; therefore AAI should be considered as an emerging technology, whose developments are likely to be of great social, economic, and even evolutionary impact.

To substantiate this claim, the paper is organized as follows: (a) what is "Applied Artificial Intelligence"; (b) what are [some] actual relevant/important problems of our society; (c) how is AAI helping to solve them; (d) in what form and where it is likely that AAI will be soon of additional use (extrapolations and predictions); (e) some recommendations (especially to the Engineering Academies) regarding AAI.

WHAT IS "APPLIED ARTIFICIAL INTELLIGENCE"? Artificial Intelligence is the part of computer science concerned with designing intelligent computer systems, that is, systems that exhibit the characteristics we associate with intelligence in human behavior -understanding language, learning, reasoning, solving problems and so on [1]. I have added the adjective "applied", not with the intention to create another title, but *in order to emphasize the role of AI in the solution of some real problem.* Seen from the other end --that of the problem to be solved-- it often occurs that, if the problem is complex, a variety of software tools and mathematical methods are used (are tried, at least) in search of a solution. Thus, in the solution of a complicated real problem (for instance, "to design an assistant for an Architect"), in addition to bona fide AI components, there appear pieces of code (portions of software) dealing with linear programming, man-machine communication ("friendly interface", or Ergonomics), data base navigation, etc. These fields may be considered not within AI. Nevertheless, since they were used (in the hypothetical case) to solve a complex real-world problem, the structured collection-interaction of code/software/data will probably exhibit "intelligent" behavior (since, most likely, human beings will agree with such qualifier when a complicated problem is solved). Thus I choose to extend a little the meaning of "Artificial Intelligence" to encompass such additional methods, as well as the particular way they are juxtaposed and used, yielding in this manner "Applied Artificial Intelligence".

On the other hand, a collection of "advanced methods" (from AI or not) which has not yet been able to solve some "hard" problem, can not [yet] be considered AAI.

The boundary of AAI is fuzzy. The boundaries between ordinary computer science and AI, and between AI and AAI, are fuzzy, and not very essential to the purposes of this paper. Because it normally occurs that, *after a solution is found*, a problem yesterday considered complex and profound is today seen as simple or straightforward. *Familiarity breeds contempt.* Thus, some techniques that once belonged to AAI are now not considered there.

This needs not bother us. Quite the contrary, AI may be considered both as:

(a) the "edge of the knife", always dealing with new techniques and unsolved problems that wait for the creation of not-yet-discovered methods; always interested in the solution of complex problems; and as

(b) a generator of new branches of computer science, connected to AI, to Programming Technology, to Mathematics. Examples are: logic and databases; robotics; expert systems; symbol manipulation; pattern recognition.

Topics Belonging to AAI

In one parragraph for each, I try to enumerate some of the subjects that can be considered part of AAI, stating the reason for their inclusion.

Knowledge representation. The study of formalisms and data structures for the representation of knowledge to be used for natural language understanding, problem solving, scene understanding, expert systems, etc. [4]. The knowledge of the system about the application domain is explicitly viewed as a separate entity or *knowledge base* rather than appearing only implicitly as part of the coding of the program [2]. The representation of knowledge usually takes one of the following forms:

(a) network representations, based on direct graphs;

(b) predicate calculus representations, based on the standard syntax of symbolic logic;

(c) procedural representations using procedures written in a high level programming language;

(d) using *frames* [10] as stereotyped repositories of knowledge with "slots" or qualified variables.

Expert systems (to be discussed later; see Table "Some Existing Expert Systems') used heavily a *knowledge base*, to be manipulated by a separate, clearly identifiable control strategy (see "Control Structures" below).

Control structures. AI programs are often quite large and are made up of many modules each carrying out a certain kind of subtask. These subtasks must be intelligently sequenced to perform the whole task properly. It is the purpose of the control structure of an AI system to apply the knowledge stored in the *knowledge base* to successfully solve the problem at hand.

The control structures most often in use are: (a) hierarchical, when there is a specific call from one routine to another [control is transferred into it] by another, when needed; this includes recursion and backtracking (a search for a solution is carried in some order, taking notice in a "list of alternatives" of possible new directions to be explored later; if not found in one direction, another direction or alternative is tried, until success is achieved or the list of alternatives becomes depleted); (b) heterarchical, either data-directed or event-driven; (c) pattern-invoked procedure calls; (d) message passing [9] , as in communicating coroutines. In a heterarchical control structure, a routine is not "explicitly" called by another. There is even a heterarchical computer [7,8] that processes pure Lisp in parallel. Control structures are widely used in expert systems.

Learning and inductive inference. A program "learns" if its performance improves under repeated instances of the same input, due to modification of the program, of its knowledge base, or of its parameters during each execution. Also, by inductive inference is meant "the formation of general rules which can then be used by methods of deductive inference" [4]. Examples of successful learning programs are Samuel's checkers player, and Hacker, a program that acquires skill as it works [14].

Planning and problem solving. It is the study of methods of constructing programs that constuct plans to be used -possibly with modifications- in later problem solving activities. Included in this topic is *heuristic search* [how to search large problem spaces guided by some knowledge about the problem, but where that knowledge is insufficient to guarantee that no false paths will be searched. In this regard, *backtracking* (q.v.) is useful] and game playing (chess, checkers, poker, etc. -used to study problem solving in a competitive environment).

Mighty Bee, a program written by Hans Berliner of Carnegie-Mellon University, defeated the world backgammon champion in 1979. The current world champion among chess programs is Belle, developed at Bell Labs. It has a chess rating of 2160 ("expert" rating).

Natural language processing. This branch of AI is walking towards maturity; it is divided into (a) natural language understanding (how to design procedures to understand natural -written- language intelligently, to decipher its meaning, as opposed to handling the sentences as meaningless symbol strings), where we cite Winograd's SHRLDU; (b) speech understanding, when accoustic waveforms are used as input; the outstanding system in this area is Hearsay-II [5], which uses pattern-invoked control structures (q.v.); (c) speech synthesis or sentence generation, which provides a voice to the computer.

Expert systems. Most of the practical results of AI projects can be attributed to the design and use of *expert systems*, problem-solving computer programs that can reach a level of performance comparable to that of a human expert in some specialized problem domain. See table "Some Existing Expert Systems". Such systems typically provide formats or languages for representing both procedural knowledge and declarative knowledge, control structures (q.v.) for manipulating this knowledge, and user interfaces. As we see, there are expert systems in medicine, in science, in engineering, and in education. Most of the existing expert systems interact with the user and help him to find the solution to a problem in its domain of expertise. Thus, they are often called "computer-aided-methods", for instance, computer-aided-manufacturing, computer-aided-diagnosis, etc.

Vision. Under this term I group here these closely related subjects:

* Pattern Recognition: the analysis, description, identification, classification and extraction of patterns in data [not necessarily picture data; it may be for instance, the analysis of the human electrocárdiogram searching for results of medical interest].

* Vision: design of programs that process, categorize and understand visual information.

* Image Processing: techniques for the manipulation and analysis of pictures by computers. For instance, reading typewritten text by the computer.

* Remote sensing: a branch of *Scene analysis* (the description of pictures in terms of parts, properties and relationships) that studies pictures of the earth surface taken by airplanes and satellites. This branch is finding wide use [6,11] in earth sciences, meteorology, environmental studies, crop prediction, natural resources inventory.

TABLE " SOME EXISTING EXPERT SYSTEMS "

SYSTEM	EXPERTISE
AQ11	Diagnosis of plant diseases
Caduceus	Medical diagnosis (unrelated diseases)
Casnet	Medical consulting (glaucoma)
Dendral	Hypothesizing molecular structure from mass spectrograms
Dipmeter Advisor	Oil exploration
EL	Analysis of electrical circuits
Internist	Medical consulting (internal medicine)
KMS	Medical consulting
Macsyma	Mathematical formula manipulation
MDX	Medical consulting
Molgen	Planning DNA experiments
Mycin	Medical consulting (infectious diseases)
Prospector	Mineral exploration
Puff	Medical consulting (lung diseases)
R1	Computer configuration

(Table adapted from [2]).

<u>Simulation and modeling</u>. A model is an image or abstraction of a system or object, used to gain experimental insight; simulation is the process of computerizing and using a model for its intended purpose.

A model depicts only those aspects of the modeled object [of the "real world"] as need to be studied; a model is *validated* against reality, checking its (simulated) behavior against that observed in the real world. Many AI systems, notably those which learn, use an internal model of the problem at hand, which then refine, adjust and validate.

Robotics. The design of machines that interact with their environment by moving around it (Exploration robots - the machine moves about in its environment, "senses" and perceives it, avoids crashing into obstacles, falling into ditches, etc.) and/or manipulating it (Manipulation robots - the machine manipulates its environment or objects in it, using both sensors and effectors), and do this in what could be considered an intelligent manner.

This field is clearly in an industrial production state, although much additional work remains to be done. Japan is the leading country in Robotics; see tables "Number of Industrial Robots Installed by Country" and "Robot Production in Japan" [3]. Since the Royal Swedish Academy of Engineering Sciences is presenting later today a dissertation on Robotics/Automated Production, I shall not ellaborate further on these most important disciplines.

TABLE " NUMBER OF INDUSTRIAL ROBOTS INSTALLED BY COUNTRY "
(1981)

COUNTRY	NUMBER OF UNITS	COUNTRY	NUMBER OF UNITS
Japan	67,345	Switzerland	8,050
United States	4,100*	Czechoslovakia	531
West Germany	11,400	United Kingdom	371
U.S.S.R.	3,000*	France, Sweden	not available

* simple units are not included in the U.S. numbers.
** estimate.

Source: Japan's Newest Technology, Robot Gijitsu Hyakka, p. 16., cited in [3].

TABLE " ROBOT PRODUCTION IN JAPAN "

YEAR	UNITS	CUMULATIVE UNITS
1968	200	200
1970	1,700	2,300
1972	1,700	5,300
1974	4,200	12,000
1976	7,200	23,600
1978	10,100	42,300
1980	19,900	76,700
1981	24,000	100,700

Source: Japan Industrial Robot Association. Cited in [3].

Symbolic and Algebraic Manipulation. Algorithms and systems which deal with the manipulation of mathematical expressions or formulas in their natural, symbolic form rather than just the manipulation of numbers.

Macsyma is the expert system in this rather specialized field, facilitating derivation of mathematical formulas that were tedious and error-prone for human mathematicians/physicists.

Topics not Belonging to AAI

Some examples follow of what should not be considered AAI. These are applications where the computer is mainly used as a computing (calculating) artifact [for instance, engineering formulas, or payroll calculations] or as a classical information retrieval system ["tell me the amount of money in bank account # 3315"]. Also, techniques where data is moved around with little change, from one file to another -such as many of Cobol programs.

It is not intended to belittle the importance of these topics. They are useful and well known, but they just do not belong (generally) to the "edge of the knife" mentioned in the introduction.

IMPORTANT/RELEVANT PROBLEMS OF OUR SOCIETY

Although not exhaustively, I try here to list some problems that now affect significantly our society, our economic development, our industry or our way of life. I classify them into those of developed nations and those of interest to developing countries, albeit some are all-pervasive.

An important technology (such as AAI) should be capable of helping to solve several of them. Not all the problems listed here are, at present, being attacked by AAI methods. When AAI has been successful in their solution, I add a note in parenthesis, in italics.

Problems of developed nations. (*In italics, some solutions offered by AAI*).

* The arms race. (*Large, distributed databanks begin to be used intelligently, keeping track of enemy deployment of missiles, etc*).

  - Placement of foreign missiles in our own land (for instance, in European territory).

- Convincing the enemy not to attack first. (*Simulations of attacks, battles, etc.*)
- To keep conflicts and wars as local as possible. Not to escalate.

* To diminish fuel consumption.

- To replace transportation by electrical and wireless communication.
  - remote purchasing
  - electronic funds transfer (*digital signature*)
  - descentralized services (payment of debts, infractions, etc.) (*electronic mail*)
  - establishment of suburban branches of offices (*computer networks*)
  - office at home (*computer networks, teleprocessing; distributed processing*)
  - *access to remote data banks*
- To communicate better.
  - *access to remote data banks*
  - cellular radio
- To produce better cars and transports (*Robotics; automated factories*) (*microprocessors inside cars*)

* To diminish/avoid high costs of labor. Who must do the "dirty work"?

- *Robotics/factory automation.*
- *Office automation.*

* How to spend free time.

- video games (*intelligent games; chess; checkers*).
- cable-tv.

* Obesity control.

<u>Problems of developing countries</u>. (*In italics, some solutions offered by AAI*).

* Hunger. To produce enough food.

- Technical assistant in the use of water, fertilizers, etc. (*expert systems*).

- Production of better varieties of corn, wheat, etc. (*banks of germoplasm*).

- Techniques for storage and control of harvested crops/products. (*AAI control of electricity/cooling produced by wind, sun, etc.*).

* Better medical attention.

- Diagnosis, clinic use.

  - *Expert systems for medicine/diagnosis*
  - *Electrocardiogram interpretation by computer*
  - *Diagnosis of poisons*
  - *See other expert systems in corresponding table*

- National system for individual medical records (*distributed data bases*) [15].

* Illiteracy/education.

- To teach many students economically (*Secondary school by tv; computer-assisted instruction; microcomputers; networks or heterarchies [8] of microcomputers*).

- Education for technicians/engineers.

  - Education in software technology (*computer-aided instruction*) [16]
  - Teaching a foreign language (*spelling programs*)
  - Laboratory facilities/experimental training (*computer-controlled laboratory experiments*)
  - Continuous education (for people already in the working force) (*computer-aided design/manufacturing*) (*simulation; modeling*)
  - Use of specialized tools (*expert systems; geographic data bases; VisiCalc*)
  - Troubleshooting (*expert systems such as HACKER; troubleshooting by computer*)

- To find the right person for the right job (*skill databanks*).

- To find existing technologies for a particular task or problem (*Technologies databank*) [17].

* Corruption. To curtail corruption; ways to enforce existing laws. To device corruption-resistant public officers/government policies.

* External debt. To pay all the money we borrowed.

* Better use of our resources [18].

  - To produce enough jobs for all those low-skill people. (*Danger: do not introduce carelessly people-displacing disciplines, such as Robotics or Office Automation*) [19].

  - Prospection and management of natural resources. (*Remote sensing; picture processing; national and regional geographic data banks; expert systems such as Prospector*).

* Increasing productivity.

  - Increment the amount of added-value to the products (through instruction of workers, use of better techno logies, avoiding imports of some products or parts, etc).

  - Improve quality of produced goods.

  - Fight inflation (a Mexican worker works half a day in order to buy one kilogram of meat) [20].

PREDICTED NEAR-FUTURE USES OF AAI (5 YEARS)

Based in current AAI applications towards relevant actual problems, as depicted in the preceding section, an attempt is now made to extrapolate its use, as well as to hint to new applications of AI.

AAI BRANCH	APPLICATIONS TO PROBLEMS IN DEVELOPED COUNTRIES	APPLICATIONS TO PROBLEMS IN DEVELOPING COUNTRIES
AAI in general	In January 1982 the Japanese government announced that it will spend US $ 45 million over the next three years to begin research on "fifth-generation" computers, a new family of machines designed especially for AI applications. The effort includes both computer hardware design and advanced computer programs. The effort does not finish here; it will continue, with additional monies, during ten	

AAI BRANCH	APPLICATIONS TO PROBLEMS IN DEVELOPED COUNTRIES	APPLICATIONS TO PROBLEMS IN DEVELOPING COUNTRIES
	years, requiring at least US $ 450 million.	
Knowledge Representation		- Of continued use inside expert systems. - Major break-through if sucessfully applied to semantic representation of concpets in, let us say, English [cf. OWL project for natural language].
Control Structures	Increased use is expected of heterarchical software, of distributed databases, of asynchronous process, daemons, actors [9] , etc. To be used mainly inside expert systems and Robotics software. Standarization of virtual devices/programs (WRITE INTO a process) such as those used by Tandem computers, to provide for smooth/friendly interfaces.	Distributed processing and distributed database enquires will make large medical/national databanks possible.
Learning and inductive inference	Of some use in office automation and electronic mail. Setting up "daemons" to make follow-ups.	
Planning and problem solving	[Videogames] . Better computer-playing programs; chess, go. (Amusement; how to spend free time).	
Natural language understanding	Rather good performance of programs to understand natural sentences in narrow fields of applications. Combined with character recognition, the computer will "read" book and documents, understand	

AAI BRANCH	APPLICATIONS TO PROBLEMS IN DEVELOPED COUNTRIES	APPLICATIONS TO PROBLEMS IN DEVELOPING COUNTRIES
	them (somewhat) and store (some of) their meaning in a knowledge data base, which can later be used to answer meaningful questions. Combined with speech synthesis, machine will "read" aloud books for the blind.	
Speech understanding	Vocabulary to be further enlarged. Machine will be able to ask meaningful questions when in doubt - spoken dialogs.	Restricted applications will begin to appear in some countries to get rid of the expense of the computer terminal.
Speech synthesis	Ability to generate very adequate speech from condensed strings and from phonetic and pseudophonetic alphabets.	
Real-time translation from a natural languate to another	Not very successful in the near future (five years). Massive use of parallel processors.	
Expert systems	More expert systems developed. Expert systems interact.	Some expert systems developed.
In natural resources management	Increased use in natural resources exploration; for crop inventory, forest management; hydraulic resources management [remote sensing experts together with a geographic data base]. Shape classifier using similarity/shape popularity or frequency. Development of an expert in fertilizer use, in water irrigation, and agricultural chores. Continued use for oil and mineral exploration.	Automatic location of new roads [designed from digital terrain models and a geogr. data bank].
In Engineering	Appearance of expert systems that are easy to use,	Use of computer-aided design/computer-aided

AAI BRANCH	APPLICATIONS TO PROBLEMS IN DEVELOPED COUNTRIES	APPLICATIONS TO PROBLEMS IN DEVELOPING COUNTRIES
	friendly and ergonomically well designed for fields such as Electr. Eng., Architecture, Publicity. Diagnosis of faulty computers. Maintenance expert. Design of complex computer chips. Design of pipe layouts for chemical process plants.	manufacturing systems. Use of computer-aided instruction, especially for continuing education (training to people already working).
In Medicine	Experts begin to interact. A way is deviced to incorporate new knowledge [for instance, new drugs] easily into data base.	
In Defense	To produce attack plans on enemy bases; to display on a map answers to questions posed in natural language about enemy positions. To train soldiers.	
In Business	A law expert; a tax expert; an investment adviser; a personal finances adviser.	
Pattern Recognition	Development of industrial vision systems.	Analysis of sounds produced by machines failing or early failing (help for diagnosis).
Vision	Some moving scenes. Successful analysis of scenes "with help", i.e., target is painted purple.	
Image Processing	Use of multi-resolution imagery for analysis of difficult pictures. Further advancement of shape from methods. Use of shape resemblance to improve classification accuracy.	Regional planner expert, using geographic data bases and remote sensing data, as well as past experience.

AAI BRANCH	APPLICATIONS TO PROBLEMS IN DEVELOPED COUNTRIES	APPLICATIONS TO PROBLEMS IN DEVELOPING COUNTRIES
Remote Sensing	Combination of statistical pattern classifier with geographic data banks (historical information) to provide better classification. For natural resources management. Classification on board of the satellite.	
Exploration Robots	Some progress for space and deep-sea exploration.	
Manipulation Robots	Proliferation of robots; they will become less expensive, and more flexible in their use.	Robots will begin to emigrate to some developing nations.

CATALIZERS OF AAI

There are certain disciplines and developments that have a strong and positive influence in the development of AAI. Among these we have:

Microelectronics: With the advent of cheap semiconductor chips and the rapid decline in the cost of computer power, AI scientists are finally in a position to develop commercially useful systems. The design of custom-made chips is further accelerated by existing silicon foundries or bakeries, which use computer output coming from LSI and VLSI design packages.

The advent of microprocessors and personal computers has further intensified the applicability of AI [13] to small projects/problems.

Parallel processing. Since the computers are getting cheap, it makes sense to buy several of them, and to place them to work together on the same problem, as in Hearsay-II [5] . This trend will continue, specially in image processing, where the data are huge. The Z-MOB multi-microprocessor [12] and the AHR Lisp machine [7] are both based in many Z-80 microprocessors collaborating in effective ways.

Distributed processing. Once we have several machines cooperating to solve the same task, Distributed Artificial Intelligence begins to appear. The introduction of distributed computing will aggravate the problems of AI: the need to synchronize, to manage resources; to work even with some members down; to send messages, etc. It also simplifies the task of AI: each machine can handle its own (private, local) data; each machine can be considered as an expert or specialist of some kind, subject to some well defined interaction.

Telecommunications. Packet switching; satellite links; optical fibers; local computer networks; all these have an effect both in distributed processing and in the easiness with which AI can be carried on or applied. If the (local) program at hand lacks some data, it may ask a distant expert program or huge data bank through the network.

THE CASE OF MEXICO: PROPOSED AAI TOPICS TO DEVELOP

If we want to foster the development of AAI in our country, it is important, I think, to focus in some problems or group of problems whose solution is likely to require some AI. We should be problem-oriented, not approach-oriented.

This is being done already in several existing projects; these are good places to promote AAI, since the people are already convinced. *First help the projects that already exist and that have some applications in sight.*

Robotics. Both the Center for Advanced Research (Natl. Polytechn. Inst.) and the Autonomous Metropolitan University have (rather small) projects in mechanical manipulators, computer-controlled. These projects should be enlarged, for instance to encompass vision, and a practical purpose or problem to solve should be given to them.

Pattern Recognition. The Cardiology Institute has developed an electrocardiogram analyzer. I believe also the Medical Center has done similar work. The Institute for Electric Research has analyzed the sounds (and their spectra) of failing or about-to-fail engines (turbines).

Voice/Speech/Natural language. Both the Engineering School-UNAM, the Engineering Institute-UNAM and more recently the Institute for Electric Research have fairly ambitious programs for speech analysis and synthesis. As for natural language, the Sciences School-UNAM had a project to translate between natural written languages.

Remote sensing. Large activity exists in this area. IIMAS at the National University of Mexico (UNAM) developed the first "commercial" remote sensing package, called PR. Detenal-SPP (the Mexican Map Commission) also has its own. The National Hydraulic Plan too. And some others. But all of them need, to my belief, to go out of the "small experiment" status and to enter routine production. It is in this later stage when operational/logistical problems will appear, but I am sure they will be solved.

Picture Processing. There are image processing laboratories at IIMAS-UNAM, Detenal-SPP and the Engineering Institute-UNAM. Detenal is strong in map handling; the Eng. Inst. group in holographic images; IIMAS in hardware. In the Optics and Electronics Institute (INAOE) there are image processing laboratories combining electronics, optics and holography. Also in CICESE (Baja California) there is a laboratory, mainly for remote sensing pictures, I think.

Geographic data bases. Detenal, IIMAS, DDF (the government of the city of Mexico) and perhaps PEMEX (the Mexican Oil Company) have developed systems that combine geographic (two-dimensional) data with alphabetical/numerical data. These tools marry nicely with other efforts for natural resource detection and management and will provide invaluable help to the expert programs yet to be written. The Ministry of Public Works is trying to write one of these experts: to automatically select the best path, slope, altitude, etc., of roads (new roads).

Expert systems. Computer-aided design/computer-aided manufacturing systems begin to appear in Mexico, as imported packages. There is an interesting effort in VITRO (an industrial company) to build a specialized design package. PR and the EKG programs are also expert systems designed in Mexico.

I am sure there are some other programs that can be considered as expert systems, and that were developed "deep inside" the industry or organization that "owns" the problem. For instance, in the Mexican Oil Institute (IMP). But, since I am not acquainted with the problems, I have been unaware of these systems. On the other hand, probably these systems were developed as a collection of procedures, without special awareness of the tools that AI offers.

Additional Topics in AAI to Develop

Looking back at the section "Problems of developing countries", I would like to suggest for Mexico some additional projects related to AAI:

* More expert systems, specially dealing with food production/agriculture/cattle growing; with natural resources prospection/management; with medicine. In this connection a nation-wide medical information system, of use by IMSS, ISSSTE, and others, for keeping medical records and treatments.

* An effort towards computer-aided instruction and the introduction of small computers (or networks of microcomputers) at high schools and

colleges. The idea is not to buy the first thing that appears good or cheap; rather, a "market research" followed by a design phase are needed.

* In addition, the groups (and the country) should make an effort to prepare more people in AI, by sending them to appropriate universities and research groups doing AAI; in addition, graduate programs in AI should be started in Mexico.

CONCLUSIONS

* AI is a well-established discipline with important developments of its own.
* Applied AI (AAI) begins to emerge as an important technology of strong and everlasting impact.
* The importance of AAI is likely to increase as the time passes; indeed, it may become the second computer revolution.

RECOMMENDATIONS

These suggestions are addressed to: (a) researchers and participants in groups doing AI; (b) professional organizations encompassing such people, like the National Academies of Engineering; (c) government bodies concerned with AI, computer science, and national development.

AI should be developed near the "real problems". Use the problem oriented approach, not the technique-oriented approach. Nevertheless, do not abandon research in theoretical AI. Do this by moving back and forth between pure and applied work.

Centralized vs decentralized AAI dissemination. I am rather pessimist about the usefulness of centralized places where AI is done. The "National Center for AI research" or something like that (in a small or developing country) is likely to be highly biased towards some techniques (v.gr., use the syntactic or linguistic approach in pattern recognition; avoid the statistical approach), and also away from some real problems. It is better to get AI closer to the real problems. Put some AI in the Oil Research Institute, to get some expert system in oil production or refining; place some additional AI into map-making and geographic information systems, probably inside the Map Commission or National Surveying System. But keep some form of central coordination, for instance, by the National Research Council or the National Academy of Engineering.

To have some kind of "National (or International?) Center for AI

Investigations" can have some advantage if you want to do publicity, or to foster sales/exports of AAI packages to other countries. You may be able then to hide some information, or to keep certain techniques as "secrets". This is probably a good way to do commerce, but not science.

Follow the example of Japan. Japan has created the Institute for New Generation Computer Technology, with Substantial funds from government, and with the active participation of industry and universities. This effort will last for ten years. The goal is to create the "fifth generation computers", relying heavily in AAI and microelectronics. Perhaps other countries or groups of countries (the Latin Americans, the Scandinavians, the Arabic countries, for instance) should do the same.

AAI will change the relation of production means. The relation between means that are used to achieve productions of goods will change, mainly due to AAI. What will it happen to the secretaries? to the un-skilled workers soon to be replaced by robots? To the Mexican wetbacks in the U.S.A.? To the Turk immigrants in Germany? To the Algerians in France? The relation among countries will also change -- I do not know the answers.

APPENDIX. SHORT LIST OF QUESTIONS THAT I WANT TO RISE

* Could it be that I have been developing a complex program to solve an important problem, and that I am not using the tools offered by AI?

* I saw that the (imported) package works well in its place of origin. But, does it apply to my situation? Or I want to buy it just to follow the fashion, or to yield to high sales pitches? Could it be better to build one (locally)?

* How can I transfer the expertise of mine/my department/my company to some computer program? What do I gain? How can it "learn" and accumulate additional knowledge, so as not to become obsolete?

* * *

* Centralized or decentralized impulse/dissemination of AI? Should each (small, medium) country set up a national AI institute? What about Mexico?

* What to do about the fear (of workers) or being displaced by the computer, the robot and AAI? How real is the threat?

* How can we introduce sooner students into the use of computers? What is the adequate view that a student should have of a computer?

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FOOTNOTES

15. For instance, in Mexico it is quite feasible to have unique medical records (of each patient) to be nationwide available, due to IMSS and ISSTE, two social security/medical public institutions of national coverage. The two of them cover most of the Mexican work force.

16. A popular idea in Mexico City is to teach Basic to each secondary school student.

17. Other developing countries that went into the same adventures/ projects, and what happended to them. To learn from/share other similar experiences.

18. Do not export raw materials (only); add value [some manufacturing, some processing] before exportation.

19. It is often the case in developing countries that, due to imitation or high-sales-pitch pressure, solutions are adopted that run contrary to common sense, although no doubt the same solution is valid in the country of the originating technology.

20. Half a day to be able to buy a kilogram of meat! No wonder he has no free-time!