Lecture Notes in
Artificial Intelligence 617
Subseries of Lecture Notes in Computer Science

V. Mařík O. Štěpánková
R. Trappl (Eds.)

Advanced Topics in Artificial Intelligence

International Summer School
Prague, Czechoslovakia, July 1992
Proceedings

Springer-Verlag

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Springer-Verlag
Berlin Heidelberg New York
London Paris Tokyo
Hong Kong Barcelona
Budapest

Series Editor

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CR Subject Classification (1991): I.2, K.3, J.4, J.6

ISBN 3-540-55681-8 Springer-Verlag Berlin Heidelberg New York
ISBN 0-387-55681-8 Springer-Verlag New York Berlin Heidelberg

Printed in Germany

Typesetting: Camera ready by author/editor
Printing and binding: Druckhaus Beltz, Hemsbach/Bergstr.
45/3140-543210 - Printed on acid-free paper

Lecture Notes in Artificial Intelligence 617

Subseries of Lecture Notes in Computer Science
Edited by J. Siekmann

Lecture Notes in Computer Science
Edited by G. Goos and J. Hartmanis

Foreword

This volume contains the texts of 26 lectures and contributions to the program of the International Summer School *Advanced Topics in Artificial Intelligence* held in Prague, Czechoslovakia, July 6 – 17, 1992.

The International Summer School was jointly organized by the Austrian Research Institute for Artificial Intelligence, Vienna, Austria, by the Faculty of Electrical Engineering, Czech Technical University, Prague, Czechoslovakia, by the Department of Medical Cybernetics and AI, University of Vienna, Austria, and by the Technical University of Brno, Czechoslovakia, under the sponsorship of the European Coordinating Committee for Artificial Intelligence (ECCAI) and with significant support from EC Project TEMPUS No. 1191 TAIC. We gratefully acknowledge the help of all the cooperating institutions mentioned above. We would like to express our special appreciation to Dr. Pavel Brázdil, coordinator of the TEMPUS Project, for his admirable understanding and support in many respects.

The International Summer School *Advanced Topics in Artificial Intelligence* is intended for (postgraduate) students, researchers and all those who want to learn about recent progress in both theoretical and applied AI. We hope that this event will also help to satisfy the needs for information within the expanding AI community in the post--communist countries.

We would like to give our cordial thanks to many people who have encouraged us and helped, namely those co-operating with us in the Advisory Board: Prof. Ivan Bratko (University of Ljubljana, Slovenia), Dr. Pavel Brázdil (University of Porto, Portugal), Prof. Nicholas V. Findler (Arizona State University), Dr. Eva Hajičová (Charles University, Prague), Prof. George J. Klir (State University of New York), Prof. Yves Kodratoff (University Paris-Sud), Prof. Robert Kowalski (Imperial College, London), Dr. Igor Mozetič (Austrian Research Institute for AI, Vienna) and Dr. Sam W. Steel (University of Essex, UK).

We are highly indebted to all the contributors for preparing their texts carefully and in time.

We gratefully acknowledge the substantial and critical role of all the members of the Organizing Committee and the Secretariat consisting of Dr. Lenka Lhotská, Ludmila Kolářová, Jitka Ešpandrová, Marie Měřičková, Isabella Ghobrial-Willmann and Mag. Gerda Helscher.

Last but not least we wish to thank Springer-Verlag for its excellent cooperation in preparing this publication.

Prague, Vienna, May 1992 V. Mařík, O. Štěpánková, R. Trappl

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AI: Introduction, Paradigms, Applications (including CBR), Impacts, Visions

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AI is one of the fastest growing scientific and technical disciplines in history. In this chapter, it is attempted to show why by giving an overview about definitions of AI, areas of research, basic paradigms, applications with special emphasis on the new case-based reasoning (CBR) systems, impacts, and visions. An extensive list of references enables to delve deeper in areas of special interest.

1. Introduction

Artificial Intelligence is one of the fastest growing scientific and technical disciplines in history, from its beginning in 1956, when John McCarthy coined the term for a conference at Dartmouth College:

- At present, billions of US$ are spent for AI research and development in international companies. Millions of Dollars of tax payers' money are invested in AI research. During the last years, Japan and England each invested about 300 million US$, Germany 200 million DM, and the European Community spent in its ESPRIT program already more than 200 million US$.
- Worldwide 15–20.000 scientists and developers are working in the AI area.
- More than 200 AI software companies have been established.
- A rapidly increasing number of books and journals devoted to AI is published each year.
- All big universities in the world are offering educational or postgraduate programs in Artificial Intelligence.
- Many research institutes besides many university departments have been founded: In Germany, the German Research Center for AI in Saarbruecken and Kaiserslautern (DFKI), the Research Institute for Applied Knowledge

Processing (FAW) in Ulm, the Bavarian Research Center for Knowledge Based Systems (FORWISS) with labs in Nuremberg, Munich, and Passau, the GMD Research Center in Sankt Augustin, in Austria the Austrian Research Institute for Artificial Intelligence and the Christian Doppler Laboratory for Expert Systems in Vienna, the Research Institute for Symbolic Computation in Linz–Hagenberg, the Istituto di Richerce Scientifico Technologico (IRST) in Trento, Italy, the Turing Institute in Glasgow, to mention only a few larger European research institutes.

The major reason for this success is the fact that products stemming from AI research and development have found their way into the market place: expert systems which contain part of the domain knowledge and reasoning capabilities of (the world's best) experts, natural language systems, which help retrieving information from large data bases or providing raw translations of texts, and robots. In the United States alone more than 3.000 different expert systems have been deployed as of yet. More recent areas like machine learning or neural networks and new combinations of AI methods like case-based reasoning systems are entering the market.

When realistically extrapolating the development of speed and memory capacity of computers (see Fig. 1),

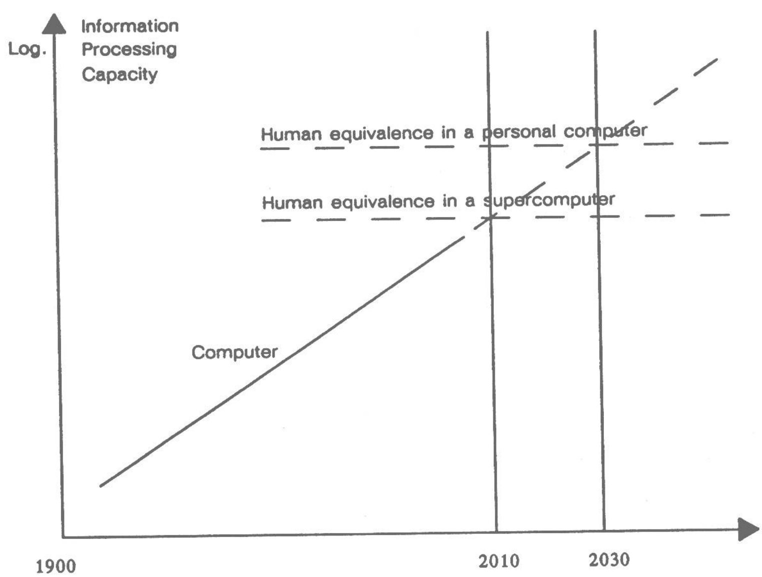

Fig. 1: Development of Information Processing Capacity (adapted from Moravec [59])

their information processing capacity will be par the one of man, around 2010 on supercomputers. Since the processing power of supercomputers is on the average available on personal computers only twenty years later, thus 2030, this capacity can be made easily available.

While this fact does not mean that by this time AI will have developed so far as to cope with human beings in their intelligence, the availability of the processing power poses a big challenge. -

This very bright view of the situation of AI shall not hide the fact that on several occasions, in history, scientific disciplines have not become successfull in the long run and just have been outplaced. One may consider the alchemists who promised to produce gold, some scientists saw similarities between AI and the promises of the alchemists [27]. And we only have to look around to see that many institutes and institutions which together employed very likely more than 1000 researchers were recently closed or "abgewickelt" - all those concerned with Marxism-Leninism.

It depends on what we promise and what we achieve, and especially on the difference between both. In the cases mentioned above, by far more was promised than could be delivered. (Remark: Institutions which promise a reward after death are usually better off, though the general decline of their influence, at least in Western Europe, cannot be overlooked).

This book shall give you an overview about Artificial Intelligence, shall introduce you more deeply into important research areas and thus enable you to apply state-of-the-art methods to your specific problems. By doing research on your own, you will retain a view to what is possible how and where.

2. Definitions of AI

There is no unique definition of AI upon which all AI researchers would agree. Several years ago Negrotti [62] presented to the participants of a general AI conference a questionnaire in which they were asked to give a definition of AI. He received 180 replies and most of these replies differed. By using statistical methods, he could boil down those replies to three different main ones which, slightly modified by me, even now represent very well the different aspects under which AI research is seen:

1. AI is the science and technique to make computers smart, i.e., to make computers perform tasks which normally require human intelligence.

2. The aim of AI is to better understand model human intelligence.

By definition 1 AI is not interested in how the human mind works, but in making computers solve problems at least as good as human beings can (and in the long run, hopefully even better). Only the performance is important. This is the technical solution. Definition 2 is the psychological way of seeing AI: In human history, the most complicated technical equipment was always used as a model of the human mind, be it hydraulic models by Descartes or complex clockwork. Statistical and mathematical methods have been used to functionally represent some mental processes. It is therefore not far-fetched to expect that AI programs could help make us understand cognition better. In the meantime, the so-called "computational paradigm" plays an important role in psychological research.

Some people assume that both definitions lead to the same results, i.e. a convergence is expected. However, there are some counter-examples in technology: Since inventors considered evolution to lead to good examples for the solution of technical problems, in the last century the flight of birds was carefully watched and mimicked by people who tried to build airplanes. However, they were unsuccessful. Only when inventors looked for different means, not developed in millions of years by evolution, it became possible for man to build airplanes which did no longer move their wings, and at present we can fly by far faster than any bird does.

Back to the still missing third definition:

3. The aim of AI is to build machines which behave intelligently by moving and acting in a partially unknown changing environment having sensors and effectors.

This definition was chosen by people who did not believe that it would be possible to model intelligence independent from the driving forces which made, in the long way of evolution, animals and man intelligent, namely the need to survive, i.e. to drink, to eat, and to reproduce. As long as computer programs would rest in a computer somewhere in the corner of a room with no information about the outside world than that fed into it by a wire, intelligence really could not be studied. Recently, this definition has again attracted high attention (see Chapter 4 of this paper).

From the many more definitions of AI - Dicken and Newquist [25] alone list 16 definitions given in AI books and articles - I will cite one more because it should guide us when doing our research and development. It is part of a definition given by Winston and Prendergast [99]:

4. An aim of Artificial Intelligence is to make machines more useful.

3. Areas of Research

There are many distinct ways of dividing AI into subfields, as can be seen from the different textbooks. The simplest way is to look at what we would consider as necessary prerequisites for intelligent behaviour, be it in man or in a machine.

First of all, the intelligent being must know something about a problem, a domain or the world as such. This knowledge will have to be represented in some way, thus we have

1. Knowledge Representation

   It will not suffice that this knowledge is just idling around; in order to solve problems, to plan ahead, etc., this knowledge will have to be combined in a way that makes (hopefully) sense:

2. Reasoning, Search, Planning.

   Somehow, this knowledge must have come into this intelligent being (while possible in a computer, "downloading" is not (yet?) feasible with humans). Furthermore, we would deny the attribute "intelligent" to a person or a machine who/which always repeats its mistakes. So an important topic – some AI researchers consider this *the* topic – is

3. Learning.

   Now we have the basis. Men as intelligent beings are social beings, they love to communicate, so they have to develop

4. Natural Language Processing

   which we want to exhibit also in machines, not only to study language, but also to use communication with them. E.g. when we work with robots, it would be most useful if they would communicate in a natural language, so if a log is accidentally falling down, we could understand them when they shout to each other.

   Our intelligent being already can hear, but not yet see, therefore next point:

5. Vision.

   It cannot yet move around and actively change the environment. That's studied in

6. Robotics.

   In order to model the above-mentioned aspects of intelligence, special

7. Languages and Tools

   were developed.

Several of these topics are covered extensively in this book. In order to get a more detailed general overview of AI, there exist several older albeit still good introductory text books on AI, e.g. Winston [98], Bonnet [12], Charniak and McDermott [19], Fischler and Firschein [30], Michie and Johnston [57], the latter is less technical, but also with great ideas. Good new textbooks have been written by Partridge [66]; Partridge and Hussain [67], Turban [95]. An interesting, colourful AI introduction is Kurzweil [46], very stimulating and thought provoking Minsky [58]. A good introduction for many years was the Handbook of AI [4], [5], [6], [20], but of the now four volumes, three were published already in 1981 and 1982, so it cannot any longer convey the state-of-the-art.

A book which is an (expensive) must is the "Encyclopedia of Artificial Intelligence" in 2 volumes, the second edition of which was published in 1992 [80].

But be warned: Not all material was updated, e.g. the entry "AI Literature" strangely ends in 1986!

4. Basic Paradigms

While in the late Eighties, some researchers announced that symbolic AI, called by them charmingly "GOFAI" ("Good Old-Fashioned AI") would soon be replaced by their neural networks (which I don't believe), in '90/'91 the slogan was "fuzzy kills neuro" (see remark above) which may be replaced in '92/'93 by "case kills fuzzy" (remark ditto). Paradigms shift, but usually the useful aspects remain and hopefully are integrated into synergistically working systems. Since Minsky supposes that several hundred different programs are working in our brains, there is still room for many paradigms left.

What are the most important paradigms in present-day AI?

1. Symbolic AI:
"Physical Symbol System Hypothesis": a physical symbol system has the necessary and sufficient means for general intelligent action (Newell and Simon, 1965 in [65]), i.e. a reasoning process operating on a symbolic internal model. Most chapters of this book are prepared by proponents of this paradigm.

There are two discernible strands among the scientists, who base their research on this paradigm, namely
1.1 Neats, who see AI as primarily based on logic, and
1.2 Scruffies, who mainly write programs to try out their hypotheses and see if they work.
Please do not ignore – as is done by some opponents against this paradigm – that the logic used is not necessarily classical (see e.g. fuzzy logic), nor that its systems are only rule-based (see e.g. CBR systems).

2. Sub-symbolic AI, Connectionism, Neural Networks:
More or less synonyms for the idea that AI should be based on multilayer networks of computational elements (units) which bear very vague similarities to "live" neurons, and weighted links. Developed in the late Eighties, Neural Networks have in several instances already proved their high qualities as trainable statistical pattern recognizers. For more details see the two other chapters with this subject (Dorffner, Havel).

Remark: It would be interesting to investigate if agnostics tend more to symbolic and religious/philosophical minded persons to the sub-symbolic paradigm.

3. Nouvelle AI, Fundamentalist AI, Moboticism:
Two arguments led to the development of this most recent paradigm:
1. In the symbolic paradigm, and to a large extent also in the subsymbolic one, symbols/weight-structure are related to the "world" only through the definitions of the programmer (no "physical grounding").

2. Language, expert knowledge, reasoning, are very recent capabilities in the time span of evolution. It took evolution millions of years to develop systems with the ability to move around in a dynamic environment, and survive by sensing and interacting.

Assumption: "Mobility, acute vision and the ability to carry out survival-related tasks in a dynamic environment provide the necessary basis of true intelligence" [16].

Three aspects of this paradigm [52]:
1. Emergent functionality, resulting from an intensive interaction of the system with its dynamic environment. One of the results is that you cannot tell the system how to achieve a goal.
2. Task level decomposition: Decomposition of intelligence into individual behaviour generating modules, whose coexistence and cooperation let more complex behaviour emerge. No global internal model. Key observation: The world is its own best model. The trick is to sense it appropriately and often enough [15].
3. Reasoning methods, which operate on representations close to raw sensor data, e.g. analogical representations.

This paradigm is tested and developed further by physically building systems, i.e. robots. They are based on the so-called "subsumption architecture": a series of incremental layers, each connecting perception to action. The physical realization is a network of finite state machines, augmented with timing elements.

For more details on this paradigm see [52, 56, 16]. It is interesting to note that most of the work in Nouvelle AI does not make use of Neural Networks.

Remark: The reason why I presented this paradigm more extensively is that
1. it seems not to be represented by any author in this book, and
2. in my opinion it will considerably influence AI research in the future.

5. Applications

5.1. General

From the inception of AI, already the pioneers considered it necessary not to develop esoteric systems, but theories which would eventually be realized in programs which then could be tested on "real" problems, i.e. applied. When, in the late Fifties, Newell and Simon made their now somehow frivolous-looking predictions about the accomplishments of AI during the next ten years, they used testable questions:
1. A digital computer would become world champion in chess.
2. A digital computer would find an important mathematical theorem and prove it.