Božidar Kliček
Faculty of Organization and Informatics
Varaždin
E-mail:bklicek@barok.foi.hr

UDC: 007.52
Original Scientific Paper

Survey of the State and Future Trends of Intelligent Systems

I would not want to be part of any nation that didn't lead in this area.

F. Hayes-Roth

This paper presents an attempt to formalize objective macro model of the field of artificial intelligence (AI). We show that creation of this model is justified, and with the aid of information from World Wide Web it is possible now. With this aim in view, we propose a research method. To obtain a macro model of the artificial intelligence field, we made a survey of research groups in the world, including companies, applications, organizations as well as a general assessment of the state of AI technology. The survey is intended to show some benefits. Intelligent systems are becoming very useful and are starting to achieve many of the projected past promises. Important documents on future trends and roles of intelligent systems have been recently published, as well as interesting surveys in the field. We have assessed several methodologies of research of the state of the art in this field and identified their promises and limitations. Considering the present state of AI technology, research projects, important documents and trends in traditional information technologies, we have made a preliminary model of intelligent systems and their future surveys. In the era of second generation knowledge-based systems and growing complexity of the AI field, we believe that it is necessary to include macro model of AI in all scientific researches and application projects.

Keywords: artificial intelligence, information technology, intelligent systems, strategic directions, forecasting, knowledge based systems, state of the art, macro model of AI.

1. Introduction

Definition: *Artificial intelligence (AI) is part of computer science concerned with designing of intelligent computer systems. Intelligent computer systems are systems that exhibit the characteristic frequently associated with intelligence in human behavior* [12].

Artificial intelligence was glorified during the last ten years, then accused due to failing and underestimated, and now it is coming back with a vengeance and a lot of real expectations [13]. Six stages of development of artificial intelligence are given in the table 1.

Our work is focused on the latest of these six stages. Competitiveness of all human organizations depends increasingly on capacities for information analysis, decision

making, flexible design and manufacturing [2]. Anticipating such challenges, information technology is starting to overcome limitations of insufficient data, lack of computational power, or inadequate control mechanisms in today organizations. It has been shown that many critical limitations of information technologies can be overcome by adding intelligence to ongoing or newly designed systems. Artificial intelligence becomes essential part of information technology and many human organizations.

This paper addresses the needs for survey of the field important for the researchers, strategic decision-makers and practitioners. This article intends to identify relevant research projects, developments and present state of AI.

Table 1. *Phases of development of artificial intelligence* [13]

Phase	Phase descriptions
I	Aristotle's logic was the first formalization of human thinking but two milleniums were necessary for the development of the first ideas of intelligent machines (the Turing test). They both established the fundamentals of human-like thinking and its possible automation.
II	AI started in 1956 in Dartmouth, establishing artificial intelligence as a scientific field.
III	AI realized its first useful projects with real applications of intelligent systems (70's).
IV	From the beginning of 80's to the end of 80's, the first successes provoked many projects, promising important role of artificial intelligence in computer technology.
V	From the end of the 80's to the beginning of 90's, AI projects failed to realize promised goals, and were criticized for inefficiency. AI was overshadowed by other 'traditional' computer technologies. Many said: 'AI is dead'.
VI	AI restarted in the middle of 90's. It began to demonstrate efficient applications, with large payoffs but with no broad applications. Unlike other information technologies that have had exponential growth, artificial intelligent has had only linear growth. But promises and needs for AI are now very high again - the era of the turning of scientific research into technology is beginning for AI. AI is expected to be very important for citizens of the developed countries.

This paper offers both a synthesis and upgrade of previous researches of the field. Although present work of other researchers, referenced from [1] to [10], has doubtless high value, it also has certain limitations. The limitations are consequences of both limitations in various research areas and restricted applications. Generally, those papers are both descriptive and prescriptive, with comparative analysis, case analysis, brainstorming and group consultations, made by the most influential and experienced scientists in the field. Classifications and statistic methods are made on rather narrow topics and certain cases only. The research area was forced to be limited because of the limited sources and the limited amount of information available.

This work has emphasized the need, abilities and methodology frameworks for more comprehensive and objective research of the field. We would like to stress the significant importance in the synthesis of three major research categories:

1. Deep understanding of the field by leading knowledge-based system scientists.
2. Analytic, synthetic and statistical methods based on vast amounts of data and information.
3. System approach to understand evolution of sub fields of AI and the interaction between them and their environment, mainly with other information technologies.

Our survey could not include all the categories in details, but it has shown that it will be possible in near future to provide such surveys on constant and system basis. The fundamental benefits come from availability of information. Results of our limited research are:

1. Comparison and synthesis of previous surveys.
2. Clear summary of the state of the art.
3. Quantitative results of relevancy of the fields.
4. Databases of cases for further research.
5. Understanding the importance of future surveys and their methodologies of research.
6. Creation of preliminary meta model of the field of AI.

Our approach is based on the ability to search, understand, synthesize, handle and provide easy access to very large amounts of data, mainly connected to the World Wide Web. However, present methodologies are not able to process huge amounts of textual and graphical files on World Wide Web sites in an intelligent way and that was our main disadvantage. The usual content of scientific information is very hard to analyze and structure - it needs much hard work of well informed scientists (that was the other disadvantage). With the aid of artificial intelligence tools, we can develop vehicles for research of it's own capability - the data mining of texts. The search and consumer access techniques we propose, however, will become most useful for rapidly displaying results.

2. AI surveys

We will present an analysis of the latest surveys, describe the methods used and provide a review of obtained results (see table 2). Table 2 shows the most important references and issues connected with the field of artificial intelligence during the last five years. Sort of work and methodologies of surveys have been obtained by the analysis of the text of references. The scope of the surveys was also assessed by analysis, while the influence of specific references was assessed considering the citation of the references, obtained status of the work (government official document, or document of some influential organization), and the way of financing the research.

The significant report [1] presents results of a 1994 meeting, organized by AAAI (American Association for Artificial Intelligence) with the purpose of assisting the ARPA (Advanced Researches Project Agency) in defining agendas for foundational AI research.

This absorbing article describes AI research areas where fundamental scientific advances could enable intelligent systems to meet American national needs. Four families of intelligent systems that demonstrate the excitement of such systems and their potential payoff are intelligent simulations, intelligent information resources, intelligent project coaches and robot teams. The report identified reliable research areas: learning, information elicitation, and automatic adaptation; coordination of perception, planning, and acting; coordination and collaboration; perception; human-computer communication in multiple modalities; content-based retrieval; and reasoning and representation.

The most important goal of the AI was identified as "to build large intelligent systems, integrating multiple capabilities of the technology." Basic research in AI will, in the long run, contribute to both scientific knowledge and technological bases for a wide variety of applications. Authors expect that it will enable search of large bodies of data for relevant information; help users to evaluate the effects of complex courses of action; and work with users to develop, share, and effectively use knowledge about complex systems and processes. It will make it possible to build a wide range of application systems that can assist decision making in adapting and reacting appropriately to rapidly changing world situations.

The second intriguing account "The Role of Intelligent Systems in the National Information Infrastructure" [2] article was completed in a workshop that was organized by the AI and cosponsored by the Information Technology and Organizations Program of the National Science Foundation. This workshop increased awareness among the artificial intelligence (AI) community of opportunities presented by the National Information Infrastructure (NII) activities and identified key contributions of research in AI to the NII.

The authors believe that National Information Infrastructure (NII) will have profound effects on the life of every citizen (of the USA). AI techniques can play a central role in the development of a useful and usable National Information Infrastructure because it offers the best alternative for addressing three key challenges:

1. AI technology can help to make computers easier to use.
2. AI representations and techniques can support the development of a flexible infrastructure.
3. AI techniques can assist in the development of more powerful software tools and environments to support all stages of a project's life cycle.

The results of previous research and applications development place the field of AI in a position to make enormous contributions to the NII and the National Challenge applications. Full realization of these promises requires a concerted attack on several fundamental scientific problems. This paper recommends several basic research initiatives in AI, each having high potential for large payback to the NII project: speech and image processing; knowledge representation structures, plausible reasoning algorithms and large-scale ontologies; machine-learning and planning methods; research on software agent architecture; development of computational

models of collaboration.

Table 2. *Comparison of surveys on artificial intelligence and its fields. The table characterizes the most influential surveys, the methodologies they used, the scope and the assessment of expected or obtained influence to the AI field*

References	Issue	Type of work	Methodology	Scope	Influence
1, 2, 3	Prediction of future development	strategic report	survey group work	broad area	very high
7	Critic of the field	review	subjective survey	middle	middle to high
15	Challenges for AI	short review of abilities	subjective case analysis	small	middle
4	IAAI conferences	review	statistic case analysis	middle	middle
6	Influence of periodicals	review	statistics	small	small
8	State of KBS	estimation of state	strict objective analysis	middle	middle to high
14	Future directions in KBS	estimation of state	short subjective review	small	middle
9, 10	State of KBS in Japan	survey	analysis observation comparative analysis	middle	middle
16	Fuzzy logic and AI	estimation of state	short subjective review	small	small
17	Genetic algorithms	estimation of state	short subjective review	small	small
18	Neural networks	estimation of state	short subjective review	small	small
5	Neural networks in business	survey of application	statistical analysis	small	small
20	Machine learning	estimation of state	short subjective review	small	small

An article from Feigenbaum, et al. [10], presents results of a 1992 study of knowledge-based systems research and applications in Japan. The Japan Technology Evaluation Center selected a team of representatives from research institutions and industries to investigate the state of knowledge based systems technology in Japan and compare it to the state of knowledge based systems technology in the USA [9]. They made comparisons on the applications, tools, researches in universities, industries and the major projects involved.

F. Hayes-Roth and N. Jacobstein [7] present a survey of technology, successes, and failures of knowledge based systems. From the viewpoint of methodology, the survey presents excellent objective and comprehensive research in the area of knowledge based systems and assessed all key issues of KBS technology. They presented essential characteristics of knowledge based systems: values; industrial and commercial applications; trends in applications and experience; components and

architecture; and failures and troubles in application. Their research findings of the state of knowledge based systems technology up to 1994 were:

1. Knowledge based systems had become a relevant and permanent technology in industry.
2. Key success of KBS systems was integration with other information technologies.
3. The entire world economy had become influenced and impacted by knowledge based systems.

The research identified successes and failures of KBS technology, and stated short-term and long-term goals.

The report "Strategic Directions in Artificial Intelligence" [3] presents the results of the "Strategic Directions in Computing Research AI Working Group," held at the MIT Laboratory for Computer Science in 1996. They report a short definition of the field and it's sub-fields, such as: knowledge representation and articulation; learning and adaptation; deliberation, planning and acting; speech and language processing; image understanding and synthesis; manipulation and locomotion; autonomous agents and robots; multi-agent systems; cognitive modeling; and mathematical foundations. Contributions of AI to computing and science were shown to be the pursuing of integration, building robots, modeling rationality, supporting collaboration, enhancing communication, obtaining knowledge and deepening basic foundations.

They stated that AI research makes numerous, large and growing contributions to computing research and to the evolving social and industrial information infrastructure. The most interesting findings are the following:

- Contributions come through study of deep scientific issues, while others come from practical applications. Continuous progress requires pursuing both types of contributions. Both approaches are strongly interdependent.
- AI has needs that intersect with all areas of computing research, in advancing knowledge and techniques on these shared problems.

Wong, et. al. [4], used a statistic approach to analyze neural network applications in business. The applications were classified in accordance with several criteria. They also examined historical trends and potential areas of research. They showed that neural network concepts and applications should be integrated with other existing technologies, as developed advanced AI technologies.

Cheng, et al. [6], evaluated journals assessing the breadth, consistency, trends, and intensity of recognition. They applied statistical, scoring and classification methods to identify four top tiers of expert systems related journals: elite, important, major, and notable. They addressed several notable problems to establish a common appreciation of the artificial intelligence field:

- How is the field structured?
- What research methodologies are used?

- What are the leading research institutions?
- What are the leading journals for publishing research and for keeping readers informed?

H. Shrobe [4] discussed the goals and focuses of the IAAI (The Innovative Applications of Artificial Intelligence Conference) 1990 conference. Innovative application is one area in which AI technology had enabled solutions for problems not previously amenable to computational solutions. The applications presented to the conference were very diverse, not only those applied to governmental institutions. The conference had three periods: first, where AI tried to show its applicability; second, where the focus was on integration with other technologies; and third, where the focus was on problems and domains, and appropriate matching of the problem characteristics to the available technology. Today this technology is in a consolidation phase, where it allows routine applications. The conference members liked to emphasize the need for integration of research activities and application domains.

F. Hayes-Roth [7] attempted to mirror the entire AI community, and thus tried to provide corresponding feedback and self-assessment. The author addresses common problems of AI that do not fit in standard approaches common to other sciences. Contrary to other sciences that use so-called "analytical" piece-by-piece method, the AI approach is more of a "synthetical method", of holistically looking at the system as an aggregate. Such an approach does not allow combining different module independently into complex applications and various contexts. First he discusses some of the proven AI techniques, divides them into four classes of representation, inference, control and problem-solving architectures. The greatest successes using his "synthetical approach" were achieved in the following areas: recognition, interpretation, and understanding; gesture, expression, and communication; analysis and prescription; planning and scheduling; integrated behavior. Usual AI successful application has had narrow scope, focused objectives, stability of environment, a high degree of automation and repetition-tasks that solve, but are concentrated on small projects, and so need a lot of custom work by talented professionals. To address future goals of AI, typical AI systems should have those critical ingredients: multifaceted intelligence, cooperation, affordability and manageability. Such new strategies and approaches to AI research, including holistic approaches, should have new measures of progress as well as potential key milestones.

The limitations of previous survey are visible in the Table 2. Where the surveys have broader scope of the research [1,2,3], the methods were more subjective - survey or group work. When they applied more objective methods, [5, 6, 8, 9, 10] the scope of the research was small or middle. We would like to emphasize big research expenses, because the research teams were big [1, 2, 3, 8], and the important issues were connected with traveling expences [9, 10].

Future research will certainly need better information sources. Complexity of AI missions will become several orders of magnitude higher than any present technology [1,2]. Research and industry will have to understand, follow and predict all important trends. We will especially need more extensive articles related to technology with the

following characteristics:

1. Several articles stressed the importance of the fusion of AI with traditional information technology [2, 3, 4, 8]. Our view is that we also need a serious analysis of structural relations between those two technologies.
2. Research of topics should be done on broad research like [1, 2, 3], in strict formal ways like [8], with usability of statistical methods [5, 6], global comparative analysis [10], and trends shown like in [5, 8]. An ideal source of information could be Internet.
3. Explanation and predictions should be done by a group of experts, like in [1, 2, 3]; they should base their decision on explanation and summary as in point 2.
4. Generation of new ideas could not be prescribed: both individual contributions and group work is appropriate [1, 2, 3, 7, 15].

As the contribution to future survey of the field, our work is directed towards emphasizing the ability to obtain more broader view of the field, previously seen in the works of Feigenbaum, Reddy, Hayes-Roth, etc. Previous researches were based on micro approaches mainly - they developed methods and techniques. The lack of much broader view caused discrepancy between the researches and practical application, and that was one of the reasons caused general crisis of the field of AI in the phase V (Table 1). Today they emphasize the trends of integration of the AI field with other information technology, the integration of the sub fields, specially application and theoretic work [4, 21]. In that case, our final goal - the macro model of the AI field, should help to obtain more efficient and well thought-out researches, lower the expenses, enlarge and fasten the process of application, and with a feedback improvement of all the field. Our approach is based mainly on the availability and extensiveness of information on Internet, and with the aid of this sort of information, it is possible to obtain very comprehensive survey with the aid of new more objective methodologies.

In the next chapter we will illustrate our ideas on a previous report of a survey we have completed.

3. Subject and methods of research

The subject of our research was a system of artificial intelligence technology, and environment of technology is simplified as information technology. The systems consists of the following entities:

- national and international organizations that contain artificial intelligence and intelligent systems
- foundation for stimulation of development and research of the AI field
- companies involved in application of artificial intelligence
- research and development groups, laboratories and institutes

- research, development and application projects
- artificial intelligence market
- researchers
- AI methodology and technology (methods, techniques, development methodologies)
- AI products
- education
- publications (scientific and practical magazines)
- cases of application
- interaction with the environment (information technologies).

World Wide Web is the system providing all the information on the entities.

We can not claim that the analysis of the artificial intelligence systems is optimal, even more, it can reflect the versatility and inconsistency of present classifications and models, both scientific and application. (There exists big versatility of classification in the literature, given by organizations, in researches, overlapping of the sub fields, in organization of scientific conferences, etc. Every classification is done for some purpose, and that is probably the main reason for the existence of such a versatility. Thus creation of the systematic classification and strict definition of the terms becomes one of the most important tasks in the whole field..)

In the system we identify some samples (elements, cases, etc.) connected to certain entities. By the analysis of textual contents of the WWW pages, we can identify the attributes of the samples. Different WWW pages are focused on some kinds of attributes of the entities, so we should analyze and combine information of the entities from different sources. We gather the attributes, making union of the sets. Based on the comparison, we can reject some attributes as unimportant, and group them as similar, making clusters of attributes. After obtaining the acceptable sets of attributes and their values, we make description of all the cases. Many of mentioned procedures are related to the methods of subjective classification [23].

In the following text, the method for the collecting the information through the Internet. Web pages could be defined as a set of nodes, links between the nodes, and set of text in every node (content of the node). By the analysis of the content, some cases are identified. Cases are related to the entities of AI technology. Every entity is described with one or more databases. Cases are characterized with attributes. During the survey, many inconsistencies, characterizations and classifications were found in the contents of the WWW.

Process of searching the nodes is described with a simple mathematical model. World Wide Web is described as a touple $[N, L, C]$, composed of the set of nodes N, set of links L, and textual content C. WWW represent a search space, where process of obtaining more samples of some entity is provided, attempting to obtain quality description of cases with the aid of their attributes.

Textual content entities E are described, then specific cases S, according to the set of attributes A, and their values from the set V. Set of nodes is described as a touple

[*E, S, A, V*].

Process of searching began through the generic node (in our case it was node AAAI). Generic node is marked as n_1. Through the connections l_1 and l_2 new nodes n_2 and n_3 are identified. Through the node n_3 and connection l_3 node n_4 is identified. In addition to the node n_1 (generic node), and nodes directly or indirectly connected to the node n_1, the existence of the node that do not have any connection to those nodes is also possible. Some of the nodes is n_5. Finding of those nodes is obtained by the intuition of the researchers or with the aid of software browsers.

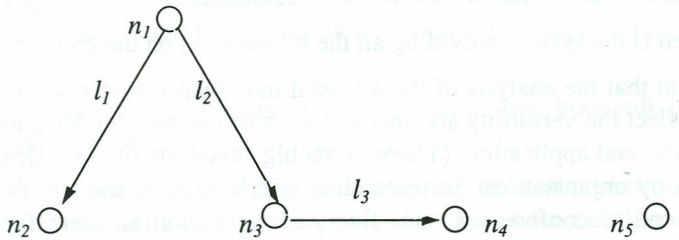

Figure 1. *Techniques for searching the nodes*

Techniques for analyzing the contents of nodes are shown in figure 2. The nodes contain text. Through the analysis of nodes the values for some cases connected to the particular entities are taken (Figure 1.). E.g., through the analysis of content c_1 of node n_1 some information for entities e_1 and e_2 are taken. For entity e_1 the cases $S_1 = \{s_1, ..., s_n\}$ are identified, and through the analysis the other node n_2 information for the $S_2 = \{s_l, ..., s_m\}$ are taken. At the end, for entity e_1, set of cases is taken like a union of all the sets of cases found by the analysis of particular nodes.

$$S = \bigcup_{i=1}^{m} S_i$$

Every node is described by attributes and their values. E.g., for case s_1, an entity e_1 is described through the set of attributes A_1, containing particular attributes $a_1, ..., a_n$. Analyzing some other source of information, from some other node, for case s_1 some set of attributes A_2 is taken. Final set of nodes A, describing particular class of cases S of entity e_1, is taken through the union from n sources of information.

Set A is taken:

$$A = \bigcup_{j=1}^{n} A_j$$

Set A is not necessarily appropriate for describing the set of case. The set A is limited to the set A', some subset of starting set A, or

$$A' \subset A.$$

For each case s, of some entity e, some description of the set of attributes A' and

their values V is taken. In this way database is being created, enabling application of some statistical techniques, classification and data mining. Some problems are identified, connected with the incomplete, ambiguous, doubtful, and redundant data, and their fusion. The other problem is connected with many inconsistent classifications. It is possible that some deficiencies of the classifications have also reflected on survey.

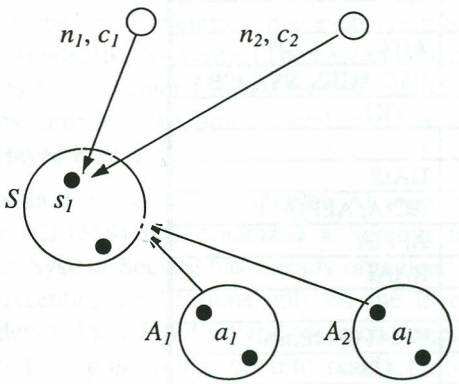

Figure 2. *Description of samples.*

4. Survey of the state of research in AI

We have provided a preliminary investigation based mainly on resources on World Wide Web sites. The other sources were AI periodicals (AI Magazine, IEEE Intelligent Expert Systems, ACM Communications, Decision Support Systems, Expert systems, Knowledge Based Systems etc.). We have also identified several key WWW sites (AAAI, IEEE, ACM, ECCAI), containing numerous links to other sites. Those sites were analyzed, and obtained information were saved in databases. We identified problems of characterization of entities (for example how to recognize that company X, with described activities, was significant in certain product classes and not significant in another, mentioned class). Databases were then processed with classical statistic and data mining tools. Some important findings are quoted bellow.

Assessment of AI researches in developed countries

We identified 28 national AI societies and 380 research groups. (The term "research group" is related to an institute, laboratory or formal R&D group, organized on permanent basis with significant staff, projects and previous results.)

The leading AI country is the USA having 29,2% of all research groups. Some other developed countries do not lag far behind (Germany has 48 groups or 12,6 %, Australia 35 or 9,2%, Italy also 35 or 9,2%, UK 29 or 7,6%, Netherlands 23 or 6%).

The USA leads in quality, advancement and results of researches. Unique evaluation of each research group is necessary! Some of the data given in the table are necessarily incomplete.

Table 3. *National AI research groups and national societies, identified by survey*

Country	AI groups	National AI society
USA	111	AAAI
Germany	48	GI/KI
Australia	35	-
Italy	35	AIIA
UK	29	BSC-SGES, SSA ISB
Netherlands	23	NVKI
Canada	16	-
Denmark	16	DAIS
Spain	13	ACIA, AEPIA
Portugal	12	APPIA
Russia	7	RAAI
Japan	5	-
Belgium	4	BAAI (Dortmant)
Slovenia	4	SLAIS
Switzerland	4	SGAICO
Sweden	3	SAIS
Austria	2	OGAI
France	2	AFIA, AFCET, ARC
Israel	2	IAAI
Bulgaria	1	BAIA
Czech Republic	1	CSKI
Finland	1	FAIS
Mexico	1	-
Norway	1	NAIS
Slovakia	1	SSKI SAV
Taiwan	1	TAAI
Ukraine	1	-
Yugoslavia	1	YUGAI
Greece	-	EETN
Hungary	-	NJSZT
Ireland	-	AIAI (Dortmant)
Latvia	-	LANO
Lithuania	-	LIKS-AIS
TOTAL	**380**	

There is an interesting indication of absence of some strong national organizations or connections between national research groups. Strong national filed is attempting to make also strong organization of the activities on national level. The troubles in

organizing AI activities in some countries perhaps make certain dilemmas or difficulties in instituting AI research. France has a special position: AI is divided into several strong national organizations. Japan has been developing special AI areas: fuzzy logic, chaos theory and neural networks. The Japanese AI field, however, suffered from the consequences of Fifth generation failure. Some national organizations are even asking for help to create and identify their own AI groups. Some AI organizations are dormant, like in Ireland and Belgium. Some European countries still do not have sufficient modern equipment to communicate well with others. Some small countries, however, are more flexible, showing greater success in specific fields, like Slovenia. (The case of Slovenia is showing an opportunity of small countries to be included in the race of national competitiveness the AI field, which somehow broadens the fundamental motto of our article conveyed by the citation of the F. Hayes-Roth.)

Croatia does not have a specific AI organization; However, the Croatian System Society (CROSS) has organized a Section for Intelligent Systems in 1997. The Croatian System Society has already organized three symposia on Intelligent Systems [13], presenting applications only on the level of prototypes. There is no specific group devoted to AI, but several research projects exist. There are several applications of AI, but no application is yet remarkably visible in the field.

Interest for the sub fields

We analyzed 57 magazines dedicated to AI (Appendix I), or those have significant impact on AI. Each periodical indicates considerable interest for an established sub-field of AI. In determining the categories, we classified all magazines and obtained frequencies that are some significant indicators of the AI sub-fields. The results are shown in table 4.

Table 4. *Number of periodicals - an indicator of relevancy of AI sub-fields*

	Number of periodicals	
Applications of Artificial Intelligence	14	24,6%
AI General	10	17,5%
Neural Networks	8	14,0%
Cognitive Science	7	12,2%
KBS	3	5,3%
Pattern Recognition	3	5,3%
Computational Aspects	2	3,5%
Cybernetics	2	3,5%
Artificial Life	1	1,7%
Data Mining	1	1,7%
Evolutionary Computation	1	1,7%
Fuzzy Logic	1	1,7%
Machine Learning	1	1,7%
Reasoning	1	1,7%
Robotics	1	1,7%
Uncertainty	1	1,7%

Profiles of AI companies

We have identified, characterized and analyzed 77 important companies involved in AI technology. We made an analysis of European companies, mainly helping to provide additional structured information. Activities of these companies have been analyzed and grouped into 20 categories (Table 5).

The most frequent activities are expert and intelligent systems (near 30% of all companies have each activity), then in data mining and neural networks (19,5 and 15,6% respectively), then in genetic algorithms, fuzzy systems, CBR, knowledge based systems, robotics and Prolog (from near 12 to 8% each).

We expect that there is and will be a large scale integration of different techniques in intelligent systems applications. Companies have to integrate the abilities of producing different modules of software. (Integration of different companies, strong in some area is also possible. Buying modules too.) We made a cluster analysis to see the presence of some remarkable integration of different AI activities in some companies. The used methodology was K-Means, with binary variables (described presence or absence of some characteristics), and Euclidean distance.

We also have some rather interesting unique cases (producing lonely clusters): Ascent Technology Inc. (expert systems, machine learning, probabilistic reasoning, database mining, genetic algorithms, computer vision, natural language understanding), DFKI from Germany (agents, constraint technology, data mining, natural language processing, Prolog), Integral Solutions from United Kingdom (PopLog, data mining, knowledge based systems, neural networks, agents) and Bolesian from Holland (neural networks, CBR, fuzzy systems, constraint technology). It follows cluster with 5 cases (Hugin Expert A/S, Ingenia, Interface Computer, IQSoft and Prolog IA), generally having the presence of expert systems, but another technologies as well, like Prolog or fuzzy systems. Cluster 5 has 11 cases (Brainware, Electronic Brains Australia, Neurotec, NovaCast, PMSI, Recognition Systems, Unica and Warmoes&VanDamme) with combination of expert systems, genetic algorithms and neural networks. Then there follows cluster 1 with 18 cases, and cluster 2 with 39 cases.

Cluster 1 has the presence of case base reasoning, decision making, expert systems and real time technologies. Cluster 2 is general intelligent systems. The most usual are strictly specialized companies with a smaller number of activities. Only a few companies apparently have complex activities. The most obvious, but still middle scale, is a combination of three techniques: expert systems, genetic algorithms and neural networks (cluster 5), which resulted from some of the most obvious activities (table 5).

Model of penetration of AI

Several authors mentioned the linear growth of AI technologies, compared to other information technologies that follow an exponential growth. Unfortunately, there was no analysis approved the Easingwood's model of penetration [25] applied to AI. According to Easingwood's equation, the cumulative number of entities, that excepted

an innovation in time t, is Nt. (Parameters are: m - potential of the market, p - coefficient of extreme influence, q - coefficient of internal efficiency).

$$N_t = N_{t-1} + p(m-N_{t-1}) + q\, N_{t-1}^{\delta}\,(m-N_{t-1})/m \quad (1)$$

Table 5. *Presence of some remarkable activities of AI companies*

Topic	Presence of activity (%)
Intelligent systems	29,9
Expert Systems	29,9
Data Mining	19,5
Neural Networks	15,6
Genetic Algorithms	11,7
Fuzzy Systems	10,4
CBR	10,4
Knowledge Based Systems	9,1
Robotics	7,8
Prolog	7,8
Constraint Technology	6,5
Agents	6,5
Natural Language Processing	5,2
Mathematical Programming	2,6
WWW	1,3
Safety-Critical Systems	1,3
Real-Time Intelligent Systems	1,3
PopLog	1,3
Neuro-Fuzzy Systems	1,3
Lisp	1,3

According to Easingwood [25], AI has typical linear growth for the beginning of technology. We will be witnessing the full growth of AI for some decades or more. (Indeed, the rise curve is not completely linear. According to table 1, there was a fall in the fifth phase.) As mentioned in several articles, the influence of traditional technologies on artificial intelligence was very high - the rise of AI should thus be understood from the strong connection to information technologies. The Easingwood model will probable be inappropriate, especially due to the nature of certain parameters, as well as being dependent on the changeable ways of communication. The finding, illustrating this is mentioned below, indicating penetration of the field of AI in publications. The crisis of the AI field is well illustrated in Fig. 3. (The years 1992 to 1995 are not representative because they lack of the collected bibliography.)

Investment in AI technology

This is a case study of impact of AI on ARPA. It manages and directs selected basic and applied research and development projects for DoD, and pursues research and technology where risks and payoffs are both very high but where success may provide

dramatic advances for traditional military roles and missions and dual-use applications.

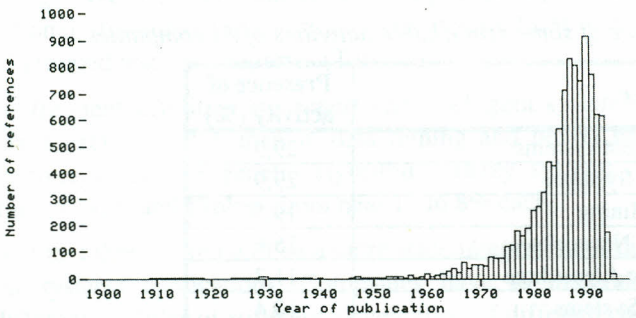

Figure 3. *Penetration of the field of Artificial Intelligent, assessment of the state according to distribution of publication dates to the 1995 [24].*

DARPA started as the main catalyst of AI efforts in the USA. (The main payoff of major DARPA investments in AI was obtained in basically one major field application - a system called DART that planned the logistic of NATO troops during the Gulf War in 1990-91. That payoff was assessed to be between five to ten billion US Dollars. We also analyzed the budget of DARPA, and assessed the role of AI in specific projects and summarized overall costs [12].

DARPA will invest 8,4 - 10,4% of its overall budget into AI! (DARPA has been the main promoter of AI for many years, since its inception.) Many other information technologies are not that important to DARPA as AI - since they are not considered technologies "where risk and payoff are both very high and where success may provide dramatic military advances".

Table 6. *Investment of DARPA to AI technologies*

I s s u e	Expenses
DARPA overall budget for fiscal year 1998	2204.4 mil $
Project ST-11 Intelligent systems & software - budget for year 1998	105.5 mil $
Other project that have involved AI*	80-123 mil $
Overall investment of DARPA in AI in year 1998	185,5 - 228,5 mil $ 8,4 - 10,4 %

*Projects CCS-02, NGI-01, ST-22, ST-23, ST-24, ST-25, ST-26, TT-04, TT-06, TT-10, EIC-03, EE-21, EE-27, EE-37, EE-53, MT-05, CCC-01and CCC-02 involved the costs related to AI in range of 10-20%. It was estimated after an analysis of content of the projects.

5. Conclusions

We expect that artificial intelligent will become very influential branch of information technology with many promising government, industrial and commercial applications. The prospects for artificial intelligence are excellent and it will have long term impacts on human society as well as on improving the prosperity of nations and organizations that will recognize its significance and provide funding for AI research and development activities.

This paper addresses today's scientific focus on the deepening and broadening of specific application areas of artificial intelligence, including their integration. On the research and development side we want to apply as many basic scientific foundations as possible to make artificial intelligence even more successful and more efficient. Understanding these twin processes is a precondition for full achievements in this field.

Problems of our research, as stated in this article, are:

1. Finding all the relevant information on AI. Our search seems to be incomplete so far, but is already providing some indicators as well as some relations and trends.
2. Problems of characterization (classification, definition of terms, taxonomy, etc.).
3. Processing huge amounts of data as required by an effective intelligence tool, that can help search, browse and structure many involved and complex scientific texts.

We make model for better understanding of the filed of artificial intelligence and fundamentals for understanding the interrelationship between its sub fields. As a contribution to broadly applied subjective survey of the field, our contribution comes from objective, statistical and classification models. So we show some interesting indicators:

1. analyzing the strength of sub fields, companies, researchers and laboratories from information in databases
2. cluster analysis, indicating integration trends
3. trends, analyzing temporal data
4. indication of interdependencies of entities.

During our research we developed a better understanding of the scientific aspects and technology of artificial intelligence. We also proposed a new approach for a cheaper method for researching the field, based mainly on the processing of data on the Web as well as organizing these data on both CD-ROMs and Web-Sites for broad based accessibility and usefulness. This can be achieved through the continued consultant and devoted AI system activities which have been proposed or being under way.

We intend to develop the World Wide Web site that will constantly track and evaluate progress in this field, as well as provide an appropriate bases for researchers, practitioners and extended applications. Our current research has helped us to understand how to make such information more usable.

References:

1. Grosz, B. and Davis, R. 1994. A Report to ARPA on Twenty First Century Intelligent Systems. AI Magazine 15 (3): 10-20.
2. Weld, D. S. ed. 1995. The Role of Intelligent Systems in the National Information Infrastructure. AI Magazine 16 (3): 45-64.
3. Doyle, J. and Dean, T. 1997. Strategic Directions in Artificial Intelligence. AI Magazine 18 (1), 87-101.
4. Shrobe, H. 1996. The IAAI Conference: Past and Future. AI Magazine 17 (4): 15-20.
5. Wong, B. K.; Bodnowich, T. A.; Selvi, Y. 1997. Neural Network Applications in Business: A Review and Analysis of the Literature (1988-95). Decision Support Systems 19: 310-320.
6. Cheng, C. H.; Holsapple, C. W.; Lee, A. The Impact of Periodicals on Expert Systems Research. IEEE Expert 9 (6): 7-14.
7. Hayes-Roth, F. 1997. Artificial Intelligence: What Works and What Doesn't? AI Magazine 18 (2): 99-113.
8. Hayes-Roth, F. and Jacobstein, N. 1994. The State of Knowledge-Based Systems. Communications of the ACM 37 (3): 26-39.
9. JTEC Panel. 1994. Knowledge-based systems in Japan. Communications of the ACM 37 (1): 17-20.
10. Feigenbaum, E. A.; Friedland, P. E.; Johnson, B. B.; Nii, H. P.; Schorr, H.; Shrobe, H.; Engelmore, R. S. 1994. Knowledge-Based Systems Research and Applications in Japan. AI Magazine 15(2): 29-43.
11. Barr, A. and Feigenbaum, E. A. 1981. The Handbook of Artificial Intelligence. William Kaufman, Los Altos.
12. http://www.arpa.mil/documents/98_budget.html
13. Klicek, B. 1997. Metodologije na znanju temeljenih sustava. U J. Božičević (urednik): Inteligentni sustavi, Društvo za sustave, Zagreb, str. 95-106.
14. Swartout, B. 1996. Future Directions in Knowledge Based Systems, ACM Computing Surveys 28,
15. Reddy, R. 1995. Grand challenges in AI. AI Magazine, Volume 27, No. 3 (Sept. 1995), 301-303.

16. Dubois, D.; Prade, H. 1995. What Does Fuzzy Logic Bring to AI? ACM Computing Surveys, 27 (3), 328-330.

17. Forrest, S. 1996. Genetic Algorithms. ACM Computing Surveys, 28 (1), 77-80.

18. Jordan, M. I.; Bishop, C. M. Neural Networks. ACM Computing Surveys, 28 (1), 73-75.

19. Wellman, M. P. 1995. The Economic Approach to Artificial Intelligence. ACM Computing Surveys, 27 (3), 360-362.

20. Dietterich, T. G. 1996. Machine Learning. ACM Computing Surveys, 24 (4).

21. Chandrasekaran, B. 1994. Remarks of a Retiring EIC: AI, Knowledge, and the Quest for Smart Systems. IEEE Expert 9 (6): 2-6.

22. Avison, D. E.; Fitzgerald, G. 1997. Information Systems Development: Methodologies, techniques and Tools. McGraw-Hill, London.

23. Hartigan, J. 1995. Clustering Algorithms. John Wiley, New York.

24. ftp://ftp.cs.umanitoba.ca/pub/bibliographies/Ai.

25. Easingwood, C, et al. A Nonuniform influence innovation diffusion model of new product acceptance. Marketing Science 2, 3 (Summer), 273-295.

APPENDIX I. Magazines dedicated to AI generally and its subfields.

AAAI, Adaptive Behavior, AI in business section, AI in Finance, Applied Artificial Intelligence, Applied Intelligence, Artificial Intelligence and Law, Artificial Intelligence for Engineering Design, Analysis and Manufacturing, then Artificial Intelligence in Engineering, Artificial Intelligence in Medicine, Artificial Intelligence Review, Artificial Intelligence: An International Journal, Artificial Life, Behavioral & Brain Sciences, Canadian AI Magazine, Chicago Journal of Theoretical Computer Science, Cognition, Colibri, Complexity, International Computational Intelligence, Decision Support Systems, Engineering Applications of Artificial Intelligence, Evolutionary Computation, Fuzzy Sets and Systems, IEEE Expert, IEEE Transactions on Neural Networks, IEEE Transactions on Pattern Analysis and Machine Intelligence, IEEE Transactions on Systems, Man and Cybernetics, IFIP TC-12 section (AI), Intelligent System Report, Intelligent Data Analysis - An International Journal, International Journal of Applied Expert Systems, International Journal of Intelligent Engineering Applications, International Journal of Intelligent Systems in Accounting, Finance and Management, International Journal of Neural Systems, International Journal of Pattern Recognition and Artificial Intelligence, International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, Journal of Artificial Intelligence Research (JAIR), Journal of Automated Reasoning, Journal of Experimental and Theoretical Artificial Intelligence (JETAI), Journal of Intelligent Systems, Knowledge-Based Systems, Machine Learning, Minds and Machines, Neural Computation, Neural Networks, Neural Processing Letters, NEUROVE$T Journal, NIPS information, NIPS: Neural Information Processing Systems, Northwest Artificial Intelligence Forum, Pattern Recognition, PC AI Magazine, Psyche, Psycoloquy, Theory and Review in Psychology, THINK.

Received: 1997-08-22

Kliček B. Istraživanje stanja i osnovnih trendova inteligentnih sustava

Sažetak

Ovaj članak prikazuje jedan objektivni pristup formaliziranju makro modela područja umjetne inteligencije. Pokazuje se da je stvaranje takvog modela opravdano, a pomoću informacija s World Wide Weba sada i moguće. U tu je svrhu predložen jedan model. Da bi se ostvario taj makro model umjetne inteligencije, provedeno je istraživanje istraživačkih grupa u svijetu, uključujući kompanije, aplikacije, organizacije, kao i opće prosudbe stanja tehnologije umjetne inteligencije. Namjera je istraživanja da ukaže na neke nove mogućnosti. Inteligentni sustavi postaju vrlo korisni i počinju ostvarivati mnoga prije planirana obećanja. Nedavno su publicirani važni dokukmenti o budućim trendovima i ulogama inteligentnih sustava, kao i zanimljiva pregledna istraživanja na tom području. Napravljena je prosudba nekoliko metodologija istraživanja na tom području, te su identificirane njihove mogućnosti i ograničenja. Razmatrajući postojeće stanje tehnologije umjetne ingeligencije, istraživačkih projekata, važne dokumente i trendove u tradicionalnoj informacijskoj tehnologiji, izradili smo preliminarni model inteligentnih sustava i njihovih budućih istraživanja. U dobi druge generacije sustava temeljenih na znanju i narastajuće kompleksnosti područja umjetne inteligencije, vjerujemo da je nužno uključiti makro model umjetne inteligencije u sva znanstvena istraživanja i projekte primjene.

Ključne riječi: umjetna inteligencija, informacijska tehnologija, inteligentni sustavi, strateški smjerovi, predviđanje, sustavi temeljeni na znanju, stanje područja, makro model umjetne inteligencije.