Multi-Agent Distributed Artificial Intelligent Systems Challenges and Issues

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Abstract—**Distributed Artificial intelligence (AI) is an emergent and growing field in AI research. It's a branch of AI in computer science that study and develop intelligent machines and software that mimic human thought and cognitive processes to achieve their goals and solve problems. This work aims to explores the different approaches implore in science and engineering of making intelligent machines. This involves increasing knowledge representation and reasoning of agent by implementing concept of Multi-agent into intelligent machines. In addition it focuses on the challenges and issues confronting the development of next generation software systems, especially when considering large scale distributed application.**

Keywords-***Artificial Intelligence; Expert Systems; Multi-Agent Systems; Distributed Artificial Intelligence; Agent Architecture; Knowledge Representation; Co-design; Software Agent; Agent Technologies.***

I. INTRODUCTION

Artificial Intelligence AI is changing our society. AI and agent systems have been closely related over the last thirty years. Intelligent agents and multi-agent systems represent the next big step in the development of next generation software systems, especially when considering large scale distributed applications [1,2]. Its application in distributed environments, such as the Internet, electronic commerce, mobile communications, wireless devices, distributed computing, and so on is increasing and is becoming an element of high added value and economic potential, both industrial and research. These technologies are changing constantly as a result of the large research and technical effort being undertaken in both universities and businesses [3].

AI is the mimicking of human thought and cognitive processes to solve complex problems automatically in many of today's novel applications [4].

Research in AI aims to develop systems that emulate the intellectual and interaction abilities of a human being [5], while Distributed Artificial Intelligence is the science of distributing, coordinating and predicting the performance of tasks, goals or decisions in a multiple agent environment [6]. A paradigm in current use for the development of Distributed Artificial Intelligence is based on the notion of multi-agent systems.

A multi-agent system is formed by a number of interacting intelligent systems called agents, and can be implemented as a software program, as a dedicated computer, or as a robot [7]. Intelligent agents in a multi-agent system interact among each other to organize their structure, assign tasks, and interchange knowledge.

The agents are software programs that are capable of autonomous, flexible, purposeful and reasoning action in pursuit of one or more goals. They are designed to take timely action in response to external stimuli from their environment on behalf of a human. When multiple agents are being used together in a system, individual agents are expected to interact together as appropriate to achieve the goals of the overall system also called autonomous agents, assistants, droids, intelligent agents, software agents.

DAI, which started as a branch of artificial intelligence about twenty-five years ago has grown into an independent research discipline representing the confluence of ideas from artificial intelligence, economics, psychology, sociology, operations research and organizational theory. It is meant to model the communication, knowledge and decision making processes to sustain societies of computational agents or amalgamation of people and computers.

II. MULTI-AGENT AND DISTRIBUTED INTELLIGENT SYSTEMS

Multi-agent systems are becoming more relevant to artificial intelligence [71]. Distributed intelligent systems are built with cooperative agents [8]. The agent concept evolves from objects. It is a combination of object orientation and artificial intelligence (AI). Many researchers tried to give a definition for the term agent: Maes [9] defines agents as computational systems that inhabit some complex dynamic environment, sense and act autonomously in this environment, and by doing so realize a set of goals or tasks for which they are designed. Wooldridge and Jennings [10] define agents as hardware based or (more usually) software-based computer systems that possess the following properties: .

- Autonomy: agents operate without the direct intervention of humans or others and have some kind of control over their actions and internal state;
- Social ability: agents interact with other agents (and possibly humans) via some kind of agent communication language;

- Reactivity: agents perceive their environment, (which may be the physical world, a user via a graphical user interface, a collection of other agents, or perhaps all of these combined), and respond in a timely fashion to changes that occur in it;
- Pro-activeness: agents do not simply act in response to their environment. They are able to exhibit goal directed behavior by taking the initiative.

In this context, an agent is a software component running in distributed environments and capable of performing independent actions to process requests from other agents, or from external applications. The handling of these requests will often require making new requests of other agents in the system. An agent perceives its environment through sensors and acts upon that environment through actuators to maximize progress towards its goals, as shown in figure 1. It receives input from its environment and through a repertoire of actions available to it, reacts to it in order to modify it.

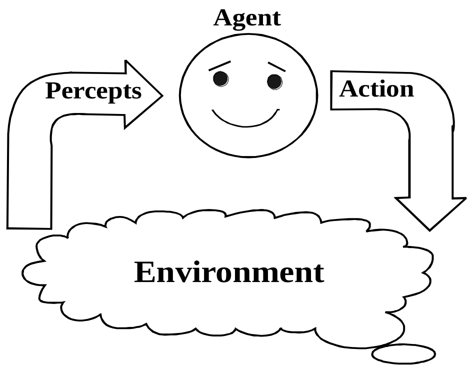

Figure 1. Agent interacting with its environment

In computer science an agent is a software that assists users and acts in performing computer-related tasks. Figure 2 below show a rational agent and figure 3 shows a goal based agent respectively [11,12,13,14,15].

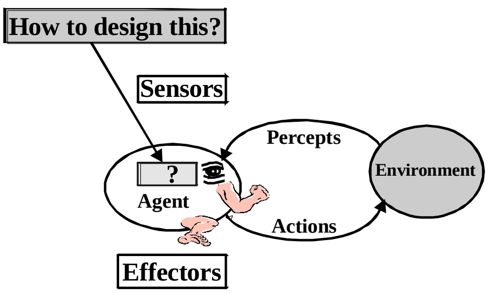

Figure 2. A Rational Agent

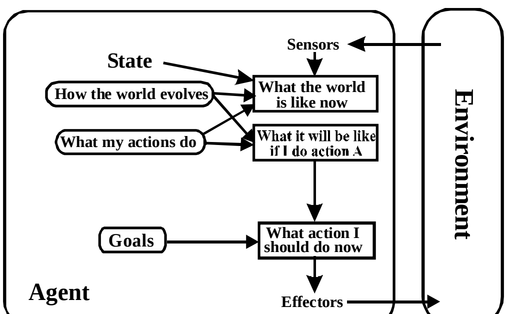

TABLE I. AGENT MODE OF PERCEPTION

	Different Types of Agent Mode of Perception		
	Environment /Agent	***Sensor***	***Actuator***
1.	Human Agent[a]	Eyes, Ear etc	Legs, Hand, Mouth
2.	Robotic Agent	Cameras, IR range finder	Motor
3.	Software Agent	Key strokes, File contents	Displays to screen, write files

A. Agent Architecture

Two levels of agent exist when a number of agent are to work together for a common goal; An architecture of system of agents that will determine how they work together and which does not need to be concerned with how individual agents fulfill their sub-missions; and the architecture of each individual agent, which determine its inner workings.

The architecture of one software agent will permit interactions among most of the following components (depending on the agent's goals): perceptor, effectors, communication channels, a state model, a model-based reasoner, a planner/scheduler, a reactive execution monitor, its reflexes (which enable the agent to react immediately to changes in its environment that it can't wait on the planner to deal with), and its goals. The perceptors, effectors, and communication channels also enable interaction with the agent's outside world. Figure 4 below shows an Agents Architecture and figure 5 shows agent technologies [13,14].

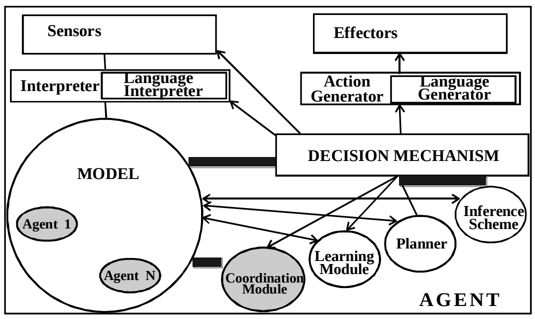

Figure 4. An Agent Architecture (shaded modules represent components particular to agents in MAS)

B. Agent Technologies

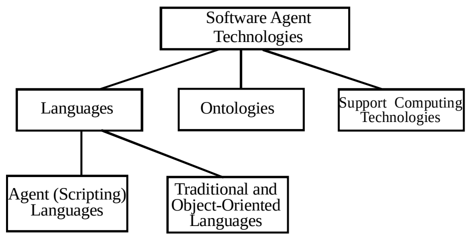

Figure 5: Some Technologies for Developing Software Agent Applications.

III. Review Of Related Work

Early work in AI focused on using cognitive and biological models to simulate and explain human information processing skills, on "logical" systems that perform common-sense and expert reasoning, and on robots that perceive and interact with their environment [15]. A criterion for intelligence is that an intelligent computer program should be able to deal with the real world. But since the world as a whole is too complex to simulate in a computer, we can build a simplified, "toy" version of it, and see how well an AI program can deal with it [16].

In the 1990s and early 21st century, AI achieved its greatest successes. It is used for logistics, data mining, medical diagnosis and many other areas throughout the technology industry[12]. The success was due to several factors: the increasing computational power of computers, a greater emphasis on solving specific sub-problems, the creation of new ties between AI and other fields working on similar problems, and a new commitment by researchers to solid mathematical methods and rigorous scientific standards [17]

A new architecture called DENIS – a Dynamic Embedded Notice-board Information System which relies heavily upon a distributed human system in workplace was designed to provide a simple means by which autonomous intelligent agents can cooperate and coordinate their actions in order to enhance the reliability and effectiveness of a real-time distributed control system. The key to the thinking in this new approach is to model how humans work together, and to implement it in a distributed architecture. However, the main issue raised is that human flexibility depends on their ability to reason logically and also in terms of time [18].

The immediate challenge for machine to support commercial application on a broader scale is to make computers to understand commands typed in plain, natural languages e.g English, to read printed or written material and to comprehend it, to understand and obey spoken word, and to communicate verbally [19].

AI researchers tend to look very far ahead, crafting powerful tools to help achieve the daunting tasks of building intelligent systems [20]

In Kurzweilian scenarios of the Technological Singularity, cybernetic brain implants will enable humans to fuse our minds with artificial intelligence. By around the middle of the 21st century, humans will be able to reverse-engineer our brains. Organic robots will begin to scan, digitise and "upload" ourselves into a less perishable substrate. The distinction between biological and nonbiological machines will effectively disappear.

By contrast, mathematician I.J. Good, and most recently Eliezer Yudkowsky and the Singularity Institute for Artificial Intelligence (SIAI), envisage a combination of Moore's law *and* the advent of recursively self-improving software-based minds culminating in an ultra-rapid Intelligence Explosion. [21].

Scientist in Queretaro, according to Mexico report developed a novel Multi-Agent Distributed CONtroller (MAD-CON) system which intends to fulfill the requirements of reconfigurability for the next generation of intelligent machines. The design drives for the system follows a hardware-software co-design approach using a simple and intuitive structure [22,23].

Other work, Open Data as a key factor for Developing Expert System[24] signify that Artificial intelligence contributes to the advancement of government management models, where issues relating to electronic government and open, ensure transparency of data online and public accountability, and citizen participation.

However this research work focuses on Artificial Intelligence, Expert systems and intelligent agents and Multi-Agent System. The rest of the article is structured as follows; section II discusses on Multi-Agents and Distributed Intelligent Systems; section III discusses on Related Research; section IV discusses on Artificial Intelligence Systems; section V discusses on the need of DAI system; section VI discusses on Expert System; section VII discusses on Knowledge Representation; section VIII discusses on co-design of Artificial Intelligent Machine and section IX is conclusion.

IV. Artificial Intelligent Systems

Artificial intelligence has been the subject of tremendous optimism [21] but has also suffered stunning setbacks. Today it has become an essential part of the technology industry and many of the most difficult problems in computer science [22].

AI has been around for about 50 years and while early optimism about matching human reasoning capabilities quickly has not been realized yet, there is a significant and growing set of valuable applications. It hasn't yet mimicked much of the common-sense reasoning of a five-year old child. Nevertheless, it can successfully mimic many expert tasks performed by trained adults and there is probably more artificial intelligence being used in practice in one form or another than most people realize. However, program control is generally not a predefined step-by-step procedure in which order is important. The figure below shows a distributed artificial intelligence system taxonomy [25].

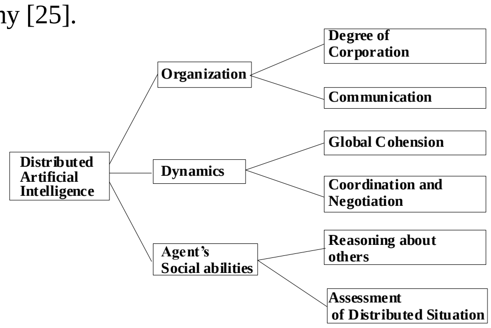

Figure 6:- Distributed Artificial Intelligence System Taxonomy

A. Difficulties in Developing AI Systems.

The major difficulty in developing these systems is extracting the expertise needed to develop the knowledge base. It is difficult to extract an expert knowledge and codify it into a format that can be used in an automated application. The figure below shows the relationship between Multi-Agent System research with the rest of AI and other related fields [25].

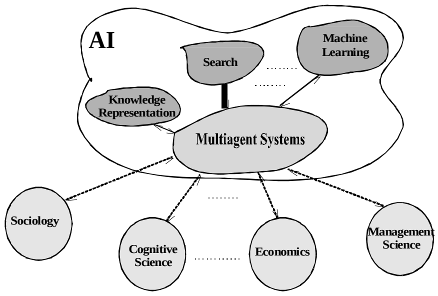

Figure 7. Synergy of Multi-Agent System Research with AI and other related fields.

B. *AI Technologies.*

Artificial Intelligence (AI) is the key technology in many of today's novel applications, ranging from banking systems that detect attempted credit card fraud, to telephone systems that understand speech, to software systems that notice when you're having problems and offer appropriate advice [4].

AI technologies includes; expert systems, natural language processing, robotics, speech understanding, speech (voice) recognition, computer vision and scene recognition, intelligent computer-aided instruction, neural computing, intelligent agents, automatic programming, translation of languages, software agent and summarizing news can all be considered AI technologies. However, the major technologies are expert systems, neural networks, intelligent agents, fuzzy logic, and genetic algorithms. Figure 8 below depicts the technology for designing an agent system.

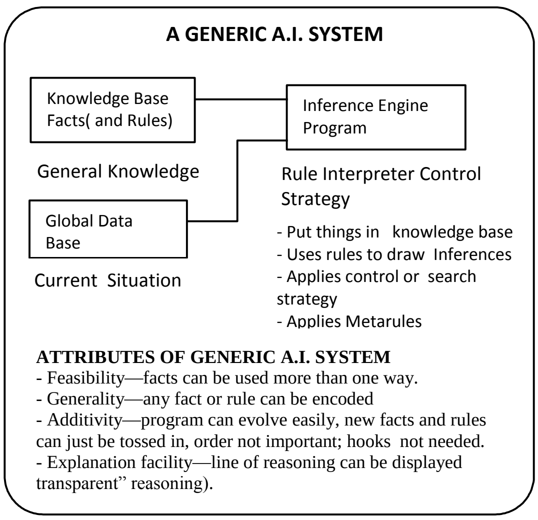

Figure 8: Technology for Designing Artificial Intelligence System.

V. WHY DAI

Distributed Intelligent Multi-Agent Systems offer modular, flexible, scalable and generalizable algorithms and systems solutions for information retrieval, extraction, fusion, and data-driven knowledge discovery using heterogeneous, distributed data and knowledge sources in information rich, open environments [27]. They can also include:-

First way: Necessity to treat distributed knowledge in applications that are geographically dispersed such as sensor networks, air-traffic control, or cooperation between robots.

Second way: Attempts to extend the man-machine cooperation with an approach based on the distributed resolution between man and machine(s). To accomplish this, we need to build intelligent machines capable to reason about human intentions.

Third way: DAI brings perspective in knowledge representation and problem solving, by providing richer scientific formulations and more realistic representation in practice.

Finally: DAI sheds light on the cognitive sciences and artificial intelligence.

A. *Classification of Distributed Artificial Intelligence.*

Design and operation of DAI systems which perform as expected present significant challenges. Since the system control is distributed, each agent has limited capabilities and information, data is decentralized, and the computations are asynchronous, the only way to guarantee desired performance of DAI systems is to allow appropriate interactions among agents. Hence, the issues of which agents should interact, how they should interact, what should be their strategies and how to resolve any conflicts that may arise are crucial for DAI systems. The figure below shows a distributed AI [28,29].

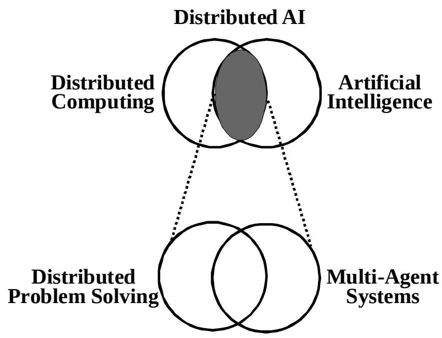

Figure 9: Distributed Artificial Intelligence

Given the multidisciplinary nature of DAI, there is significant diversity in the field and the tools used. Hence a classification of the issues is useful to get an overview of the state-of-the-art in the field. The issues related to DAI can be studied from different perspectives:

Individual Perspective:- This focuses on the issues of design and understanding of individual agents, decision makers or problem solvers. The issues of agents studied in these characteristic includes; reactive, deliberate, intentional, cooperative, self-interested and social as well as internal knowledge structure and knowledge maintenance. The development of reasoning mechanisms; logic based or utility based are paramount because agent also needs the ability to reason about their own action and of other agents. Finally, the need to adapt to changing situations.

System Perspective:- This level is concerned with performance issues of the entire organization; viz-a-viz; bottom-up methods where individual agent capabilities are identified that result in appropriate interactions at the group level; and top down methods, where group level norms are developed which constrain the agent level interactions in order achieve the desired performance. Thus agent use coordination methods, negotiations, distributed planning schemes and cooperation strategies in order to achieve group level coherence [31,32].

Implementation Perspective:- deals with issues related to building multi-agent systems, test-beds, design tools and applications. However, the designers have to ensure interoperability, ability to deal with spatial distribution, varying degrees of agent autonomy, ability to function as an open system and domain independence when developing industrial applications.

VI. Expert Systems

An expert system encapsulates the specialist knowledge gained from a human expert (such as a trader or an engineer) and applies that knowledge automatically to make decisions. For example, the knowledge of doctors about how to diagnose a disease can be encapsulated in software. The process of acquiring the knowledge from the experts and their documentation and successfully incorporating it in the software is called knowledge engineering, and requires considerable skill to perform successfully[33,34].

The list and definition of the major components of an ES are:

* **Knowledge base**--the software that represents the knowledge.
* **Inference engine**--the reasoning mechanism.
* **User interface**--the hardware and software that provide the dialogue between people and then computer. Others include;

Domain expert:-the individual who is considered an expert.
Knowledge engineer:-the individual who acquires and represents the knowledge.
Explanation facility--the software that answers questions such as "Why" and "How."
Blackboard:-a workplace for storing and working on intermediate information.
Reasoning improvement:-a facility (not available commercially) for improving the reasoning capabilities of an ES.
User:-the non-expert who uses the machine for consultation.
Hardware:-the hardware that is needed to support the ES.

The three major components are marked by an asterisk (*). These correspond nicely to the Decision support system (DSS) components of database management system, model base management system, and user interface.

The types of knowledge that constitute an expertise are listed below:-:

1. Theories about the problem domain.
2. Rules and procedures regarding the general problem area.
3. Rules (heuristics) of what to do in a given problem situation.
4. Global strategies for solving these types of problems.
5. Meta-knowledge (knowledge about knowledge).
6. Facts about the problem area.

A. *The vision.*

The rise of modern science has inspired in theorists the vision of machines which can finally free mankind from the drudgery of labor. Such machines include; dubbed robots which is either almost human or indeed, sometimes super-human, in their behavior [35].

The rise of modern computer technology, in its turn, has made such visions seem more realistic and even attainable in our lifetime. Such expectations have encouraged some of the best minds of our era to work at producing thinking machines, first to be applied to industrial output (complex automation) and then to even replicate human intelligence itself.

The question "how intelligent can machines be?" has been debated by Philosophers and scientists long before the computer age. Interestingly enough, some of the issues that have shaped the philosophical debate are the very ones which today confront those dealing with the various aspects of artificial intelligence-the meanings of knowledge, logic, reason, understanding, insight, perception, instincts, and simple common sense and how to replicate them [36].

B. *The Future*

AI began as an attempt to answer some of the most fundamental questions about human existence by understanding the nature of intelligence but it has grown into a scientific and technological field affecting many aspects of commerce and society.

As AI technology becomes integrated into the fabric of everyday life, AI researchers remain focused on the grand challenges of automating intelligence. Work is progressing on developing systems that converse in natural language, that perceives and responds to their surroundings, encode and provides useful access to all of human knowledge and expertise. The pursuit of the ultimate goals of AI - the design of intelligent artifacts; understanding of human intelligence; abstract understanding of intelligence (possibly superhuman) - continues to have practical consequences in the form of new industries, enhanced functionality for existing systems, increased productivity in general, and improvements in the quality of life. But the ultimate promises of AI are still decades away, and the necessary advances in knowledge and technology will require a sustained fundamental research effort.

VII. Knowledge Representation

A theme common in AI research is that to behave intelligently, computers must come to “know” a good deal of what every human being knows about the world and the organisms that inhabit it. Knowledge representation and reasoning (or KR) is the study of how to impart this knowledge to a computer: how do we write down descriptions of the world in such a way that a computer would be able to draw appropriate conclusions about the world by manipulating them?[1]

Many of the problems machines are expected to solve will require extensive knowledge about the world. Among the things that AI needs to represent are: objects, properties, categories and relations between objects; situations, events, states and time; causes and effects; knowledge about knowledge (what we know about what other people know);[37] and many other, less well researched domains.

For instance a program has common sense if it automatically deduces for itself a sufficiently wide class of immediate consequences of anything it is told and what it already knows. In order for a program to be capable of learning something it must first be capable of being told it [38,39].

VIII. Co-design Of Intelligent Machines

There are many challenges that we face as we consider the future of computer architectures, and as the type of problem that people require such architectures to solve changes in scale and complexity. A recent article written for HPCwire [1] on 'co-design' highlights some of these issues and demonstrates that the High Performance Computing community is very interested in new visions of breakthrough system architectures. Simply scaling up the number of cores of current technologies seems to be getting more difficult, more expensive, and more energy-hungry. One might imagine that in the face of such diminishing returns, there could be innovations in architectures that are vastly different from anything currently in existence. It seems clear that people are becoming more open to the idea that something revolutionary in this area may be required to make the leap to 'exascale' machines and beyond. The desire for larger and more powerful machines is driving people to try to create more 'clever' ways of solving problems (algorithmic and software development), rather than just increasing the speed and sheer number of transistors doing the processing. Co-design is one example of a buzzword that is sneakily spreading these memes which hint at 'clever' computing into the HPC community[40, 41]..

To illustrate the idea with a colorful biological analogy; imagine trying to design a *general purpose animal*: Our beast can fly, run, swim, dig tunnels and climb trees. It can survive in many different environments. However, anyone trying to design such an animal would soon discover that the large wings prevented it from digging tunnels effectively; that the thick fur coat to survive the extreme cold was not helpful in achieving a streamlined, fast swimmer. Any animal that was even slightly more specialized in one of these areas would quickly out-compete our general design. Indeed, for this very reason, natural selection causes specialization and therefore great diversity amongst the species that we see around us. Particular species are very good at surviving in particular environments.

IX. Conclusion

Artificial intelligence is a true general purpose technology. It enables applications in a very wide range of other fields. In particular, scientific and technological research (as well as philosophical thinking). This will be done more effectively when conducted by machines can that mimicked human intellectual reasoning capability thereby enhancing the overall technological progress which is achieved by incorporating certain essential human characteristics which makes them a powerful extension of current computing technology.

The computer only creates possibilities for human development, to be realized when certain technical psychological, and social conditions are met. Unlike other technologies, artificial intelligences are not merely tools. They are potentially independent agents.

After all, humans have achieved human-level intelligence, so it is evidently possible. One way to build the requisite software is to figure out how the human brain works, and copy nature's solution.

The second conclusion is that the creation of such artificial intellects will have wide-ranging consequences for almost all the social, political, economic, commercial, technological, scientific and environmental issues that humanity will confront in this century and beyond.

The level of artificial intelligence is still a long way off. But it is out there, hovering in the distance, however hazily, along with countless other threats, some discernible to us and some not.

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