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A Generalized Framework for working with Multiagent Systems

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***Abstract*—**The present paper discusses the basic concepts and the underlying principles of Multi-Agent Systems (MAS) along with an interdisciplinary exploitation of these principles. It has been found that they have been utilized for lots of research and studies on various systems spanning across diverse engineering and scientific realms showing the need of development of a proper generalized framework. Such framework has been developed for the Multi-Agent Systems and it has been generalized keeping in mind the diverse areas where they find application. All the related aspects have been categorized and a general definition has been given where ever possible.

***Keywords*—**Generalized Framework, Multiagent systems

I. Introduction

FOR the past two decades immense research work has been carried out on MAS ever since Artificial Intelligence (AI) has drawn the attention of the scientific world. In the core of the research of AI is the urge to instill human behavioral attributes and intellectual capabilities in machines/robots. Various approaches were devised for developing machine intelligence. Soft computing, Parallel Programming, Machine learning algorithms etc. are the different techniques which are the outcome of rigorous work done in this field. Due to the severe constraints imposed upon computation time and the demand for more robust and feasible approach for solving the real life issues Multi-Agent Systems were developed and they lead to new branch of Artificial Intelligence named Distributed Artificial Intelligence (DAI).

II. Definition of Agent and MAS

It has now been established that the study of DAI has turned interdisciplinary. The concepts of cooperative interactions are used for robotic systems like soccer robotics, surveillance robots etc.as discussed in [1] and [5]. But they are also now being used for solving issues which are related other fields. The diversity of the application of the MAS concept can be illustrated by citing [7] as an illustration where the authors have considered the problem solving environment as a collection of loosely coupled intelligent agents. In [8] an automatic control system for water conservancy is treated as a MAS and its various components for regulating and monitoring water flow are treated as individual agents.

The capability of MAS to solve problems by distribution of tasks among agents has been utilized in the field of bioinformatics in [10] as a tool to identify the DNA/protein sequences.

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Here the authors have first identified various transcriptional regulatory elements that determine the factors affecting the data mining of specific DNA/protein sequences from the databases and then have defined the architecture of MAS considering the parameters affecting DNA/protein sequence identification as the constituting agents. So it becomes quintessential that the definition of the MAS and the constituting agents be properly specified where ever they are implemented.

III. Attributes of MAS

Certain number of attributes should be defined for the MAS. These are the properties of an agent are crucial for their studies both as a single entity and as an integral part of a system. These attributes also define the way they behave in a particular experiment. An analogy to the defined attributes can be found in many research papers in form of States, Knowledge etc. The attributes can be broadly classified as "Physical Attributes" and "Intellectual Attributes".

A. Physical Attributes

These are the features of an agent that can be perceived physically or in other words can be described for measuring them outside the literature of Multi-Agent systems. As an example we can consider the agents constituting a Soccer Robotic Team (which is a MAS). The individual agent has following physical attributes.

1) Dimensions of each robot
2) Communication frequency of transmitter/receiver
3) The Power Consumption by a robot
4) Path/Trajectory of the agent

B. Intellectual Attributes

These are the attributes which cannot be perceived in terms of some physical entity but can be evaluated using their interaction with attributes or the surrounding environment which includes other agents of MAS. The states of the multiple robots used for demonstrating collision avoidance scheme in [5] can be described as Intellectual Attributes which are as follows.

1) Angle of the robot with the reference axis.
2) The reaction time of the robots

There may be attributes which have same value for all the agents and there may be some other attributes for which each agent has his own different value. Again these attributes may be Local or global. The above Physical and Intellectual Attributes are Local attributes.

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C. Global Attributes

These are the attributes of the MAS as a whole and can be differentiated from those which are specific to the agents individually.

Some of the Global attributes of a MAS can be as follows:

1) Number of Agents constituting the MAS.
2) Total space spanned by the MAS or the arena size.
3) The computation time for implementation of plan developed for the whole MAS.

IV. Resources

A. Local/Individualistic Resources

These are the resources which are present at disposal for each agent separately and may be different for different agents.

B. Global/Shared resources

These are the resources which are available to all the agents of a MAS and are utilized by them in a proper way (by implementing a particular scheme. such as priority base scheme etc.).

V. Desired Characteristics in MAS

The development in field of MAS has actually been supplemental to the extensive research in the field of AI and machine learning. So the MAS are expected to display those qualities or characteristics that are attributed to human intelligence and behavior.

Some of the characteristics that are desired for a MAS to possess are:

1) Cooperation
2) Adaptability
3) Coordination
4) Reliability
5) Robustness
6) Repeatability
7) Efficiency

Various researchers have sorted to different approaches to instill these characteristics in various MAS. While the authors in [5] have treated Adaptive coordination algorithm selection problem as a reinforcement learning problem, in [9] "cooperation" has been defined as interdependency between participating agents and is checked by dividing the task in sub-tasks (that are assigned to individual agents) and finding relations among these divisions. The "characteristics" of a MAS can be specified by various 'attributes' of the constituting agents e.g. in [1] the authors have used soft computing approach to develop motion-planners for MAS and then has defined adaptability of the MAS in terms of ability to cope with change in one of its attribute that is "path" of the agent.

However we can derive a general approach for calculating the Degree of (attainment of) the desired characteristic as follows:

1) Sort out among the desired characteristics, those which are attributed to a single agent (Local Characteristic) and those which are attributed to the whole system (Global Characteristic).
2) List out the parameters whose values influence the desired characteristic. The parameters may be:
   i. Attributes if the agent
   ii. Combination of their attributes
   iii. Utilization of resources.
3) Deciding an "Ideal" value for these Parameters that are selected for calculating the "Degree" of (attainment of) a particular desired characteristic. If the characteristic is such that it is defined for the whole system then its ideal value can be assumed to same for each agent of the MAS.

Let us assume that for a particular MAS consisting of 'n' number of agents, there exist a characteristic 'X' which need to be quantified for each agent as well as for the whole MAS, and there are 'k' number of Parameters on the basis of which quantification of 'X' for the can be done and for MAS the 'l' be the number of parameters for the same characteristic 'X' for the whole MAS.

The degrees of desired Characteristic (Local) 'X' for an Agent "i" of MAS = $\left[\frac{[\sum_{j=1}^{k}(P_X)_j]_i}{\sum_{f=1}^{k}\{(P_X)_j\}_{ideal}} \right]$.

In the expression above for an Agent 'i ', the notations has following meanings :

$(P_X)_j$ = The j^{th} Parameter that influences Characteristic 'X' of agent "i" and j = 1,2,3,…k.

$\{[P_X]_j\}_I$= Value of the j^{th} parameter for Agent "i".

$\{[P_X]_j\}_{ideal}$ = Ideal value for the j^{th} parameter.

In a similar fashion the characteristic of the whole MAS can be computed for a particular plan/scheme for comparison when various plans/schemes are available for the MAS.

The degrees of desired Characteristic (Local) 'X' for an Plan "f " = $\left[\frac{\sum_{m=1}^{n}([\sum_{j=1}^{l}(P_X)_j]_i)}{n \times [\sum_{j=1}^{l}\{(P_X)_j\}_{ideal}]} \right]$.

Here it is assumed that all the 'n' agents of the MAS has same ideal value for the j^{th} parameter.

VI. Scope for Further Research

The generalized framework can be perceived as an aid for the researchers who are trying to implement the underlying principles of multi-agent systems. The various aspects of the framework can serve as modules to develop an efficient MAS. The essence of successfully implementing the framework lies on the proper identification of the members that can be treated as constituting agents of the MAS and then categorizing their attributes so that they can be used to define the desired characteristics of the MAS. Though the idea of MAS has been used in certain fields for a long time which includes Soccer robotics, Communication networks etc. but this frame work can serve to provide guidelines to those who are beginners in these fields.

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