CHAPTER 8

CONCLUSIONS AND FUTURE DIRECTIONS

In this work, a model called behavior model has been designed, which describes cooperation, coordination, and communication issues of distributed AI systems. In this model, each collaborator is associated with two trust factors, Local Trust Factor (LTF) and Behavior Trust factor (BTF) to tackle the cooperative and noncooperative environment respectively. The LTF is computed by Trust Computing Agent (TCA) based on the reports generated by Data Analysis Agent (DAA). The BTF is computed by Behavior Analysis Agent (BAA), and is calculated after every problem is solved. Similarity study is performed by Similarity Analysis Agent (SAA), and the outputs are passed to BAA for BTF calculation. The Mind Protocol Agent (MPA) constructs the relationship graph based on BTF values to select the most promising collaborators to form an effective collaborative group. In order to reduce excessive communication among the group members, the Skill Managing Agent (SMA) generates a specially designed software agent called Catalyst Agent (CA) for the purpose of information gathering and exchange. The MPA uses CA for negotiation, at the time of subtask allocation. The task decomposition is carried out by the DA, based on the background knowledge about each collaborator by the Decomposing Agent (DA). To adjust to the dynamically changing scenario, the Incremental Learning Agent (ILA) uses the Action-Research learning technique, and produces linguistic summaries (impressions). The significant features of this model are given below:-

- In real world applications, it cannot always be assumed that the members taking part in the collaboration are of the same homogeneous type. The
reason is that, such applications need different expertise, capacities, capabilities etc. Thus, generally the group is of type heterogeneous. The model in this work, is designed to tackle both homogeneous and heterogeneous groups.

- While deciding the members of a group, formed to tackle complex problems, human beings look into the capabilities, experience, and past behavior of the probable members before selection. The model discussed in this work, analyzes information about collaborators collected over a period of time before deciding on the members of a group.

- In most of the cases problem is decomposed based only on the domain knowledge of the problem to be solved. The decomposed modules are then distributed among the group members, irrespective of their skills, interest etc. However, in order to make the task decomposition more effective, the model developed here also considers the background knowledge about the characteristics of the collaborators including present state of each collaborator before decomposition. This ensures that the task has been decomposed to suit the capabilities of each member of the group.

- The model described here considers a number of personality characteristics such as interest, willingness, capability etc., before performing task allocation. A specially designed Catalyst Agent is used for negotiation before the actual task allocation to each collaborator. However, the extent of negotiation necessary is minimal because, task allocation has already considered each collaborator's characteristics.

- In this model the consolidation of subgoals or partial results sent by each collaborator is made more effective by associating a judgement factor along with the information sent by each collaborator. The consolidation process
can then reconcile disparities, and merge results based on these judgement or trust factors.

- In distributed AI systems, the problem solving environment is normally assumed to be highly cooperative, and the information (partial results or subgoals) sent by each member of the collaborative group is assumed to be correct and accurate. However, in this model, each collaborator itself analyzes and rates its performance, and associates a judgement factor or trust factor LTF (Local Trust Factor) which in a cooperative environment it is willing to share with other collaborators of the group. By utilizing this LTF associated with information sent by each collaborator, the group can arrive at a more trustworthy solution to the global problem.

- In real world situation it is possible that members of the collaborative group do not trust each other completely, that is the model deals with a competitive environment, in other words noncooperative environment. In this scenario, the LTF associated with the information sent by each collaborator cannot be accepted as it is. Therefore, the model uses other parameters to judge the information sent by its co-collaborators. For this purpose the model uses past behavior of co-collaborators as an important parameter. This behavior is quantified by a trust factor called BTF, which is used to define relationships between collaborators. This relationship and BTF is then used as a basis for coordination, and cooperation issues such as deciding on group formation, resolving disparities and consolidating partial results / subgoals etc., in the noncooperative environment.

- While working in a noncooperative environment, the Mind Protocol designed in this work, considers and communicates with the probable members of a group based on the relationship between collaborators, instead of broadcasting to all nodes in the environment.
The basis of trust factors used in this work is the dynamically changing accumulated information, each collaborator maintains and analyses about other collaborators. This accumulation of information requires constant information gathering which is performed in this model by the specially designed agent, the catalyst agent.

Since each collaborator in this model maintains dynamically changing intelligent information about other collaborators, it is possible for it to use this information for learning purposes. This learning capability enables collaborators to plan their activities, to take decisions, to predict future activities etc. The proposed model uses Action-Research (learning from experience) learning method.

The salient features of the Behavior Model, catalyst agents, and Mind protocol have been highlighted through various applications. A global software development is considered as an example to bring out the salient features of the Behavior Model, proposed in this thesis. In the application considered, the success of the software development depends to a great degree on appropriate selection of group members taking part in the collaboration. At the outset, the individual members have to be selected based on their capability, past behavior, mutual understanding etc. After this is done, contact is established with the appropriate members, negotiations are undertaken before finally arriving at the appropriate developers group. The very essence of successful group formation is the use of previous knowledge about potential team members gathered based on past experience. The model designed in this work uses a Mind Protocol to select the most appropriate members based on this knowledge collected over a period of time. A group formation process using Mind Protocol, thus works even in noncooperative environment since the most promising members are selected for collaboration. The Mind protocol uses the relationship between the members, which is based on the past behavior of particular collaborators. That is, in this
model, each member computes the behavior (by considering 12 personality parameters) of its co-collaborators by observation and this quantity is represented by a judgement factor or trust factor BTF. This factor helps in predicting the future behavior, and is used by the Mind protocol to form an effective collaborative group. After having selected the group members, the next step in the software development is task decomposition and allocation. This is normally done by project leaders, based on each member's past experience, interest, capability, and also current workload of each group member. In the model, decomposition is based on the same criterion, here, available in the form of background knowledge. Further, the model uses negotiation approach for subtask allocation through a specially designed agent called the Catalyst agent. However, the effectiveness of the group formation and decomposition, ensures that there is only limited negotiation. The Mind Protocol also uses the catalyst agent to allocate subtasks to the members. To develop a single global product, the members have to interact with each other to exchange information (partial results or subgoals), plan, and to coordinate each other's activities. That is, in collaborative software development, the communication mechanism between the developers plays a crucial role.

In this model, the use of catalyst agents for communication purposes, ensures effecting communication mechanism, but at the same time, ensures that the collaborators do not get physically involved in the communication process. The characteristics of catalyst agents also allows collaborators not interested in participating in the communication process to avoid responding to the catalyst agent. Another important issue in software development is the problem of obtaining multiple solutions for the same problem or getting solutions with different accuracy. The model resolves these disparities based on trust factors, LTF in the case of cooperative, and BTF in the case of noncooperative environments. The model resolves disparities based on the epistemic utility theory, which is in this work now incorporated with the appropriate trust factors.
As the software developers are distributed over the Internet, design of reliable product becomes an even more important issue. This is because, the subtasks are developed at different places by different software developers with no physical interaction. Therefore, the reliability of the product and of the developers must be controlled or monitored in the early stages of the development cycle itself. Thus, in this model (Anandakumar 1999d), the group leader uses catalyst agents to periodically gather reliability information (values) from the members to check overall reliability of the product, and at the same time, the leader computes the group reliability and the internal consistency reliability to control, and to issue necessary instructions to the members. Similarly, the members also use catalyst agents to exchange reliability information among them, to achieve required reliability level of the global product.

Software review process is another example used for highlighting catalyst agent concepts. The review process is one of the most important phases in the software development cycle. In this process, there will be a review team of three to six members. They exchange various types of forms, and discuss the various aspects of the problem, in order to help the project leader. Thus, the review members spend most of their time in consultation and in integration of results. The model (Anandakumar 1999g) uses catalyst agent to automate this review process. Here, the catalyst agent carries review forms between the members.

The concepts of the behavior model is explained with another application. Internet-based publishing can be used for advertising, providing services, establishing marketing presence, and creating an on-line shopping catalog. Customers have access to vast amount of product related advertisement, which may however sometimes contain misleading information. Due to the high competition, each vendor tries to highlight their product features and at the same time try to suppress other vendor's product features. This competition means that, the environment changes to noncooperative. The customer may be
confused with the dynamically changing information. In such an environment, the customer cannot completely trust the information provided by the vendors, and the advertisement needs to be evaluated. The customer thus needs a yardstick to measure the various product advertisements. The behavior model of the work helps in this regard and selects the products intelligently. Here, the behavior model is used both at the customer side, as well as the vendor side. The vendor uses the LTF of the behavior model to represent his/her confidence, which then is attached with the product. The customer uses the vendor's past behavior, requirements of the product, and information gathered from other customers to calculate BTF pertaining to the particular vendor. Then, the customer uses this BTF to select the products. In Web-based publication, the Behavior Model is used by the customer to know more about vendor's behavior. The same model may be applied by the vendor, in order to study the customer's behavior.

The major contribution of this work is the design of high-level protocol called Mind Protocol. In this work, it is compared with Contract Net Protocol, by considering global software development, where the domain is cooperative. In Mind Protocol, the more promising software developers are chosen based on the behavior model by the Mind Protocol. Then the Mind Protocol follows the sequence of steps similar to the Contract Net Protocol and comparison of results are tabulated. The results show that the Mind Protocol takes less time in each phase. This is because, the collaborative group which is formed initially, depends on the past behavior (reflected in behavior model) and the background knowledge accumulated. The Mind Protocol and the Contract Net Protocol is compared under three different cases: Best case, Average case and Worst case. The results for various group sizes are also tabulated. From the results obtained, it is observed that, in case of Contact Net Protocol, the group size is directly proportional to the time taken, where as in Mind Protocol, as the group size increases, the total time taken decreases in both the cases of best and average. In worst case, the Mind Protocol behaves like Contract Net Protocol.
The Mind Protocol is specially designed to tackle noncooperative and partially cooperative environment. However, the Contract Net Protocol works in the same way irrespective of the type of environment. The effectiveness of Mind Protocol is illustrated by the results, which show that it takes less time for interaction compared to Contract Net Protocol in noncooperative environment, where the difference in time is much more marked. Again by considering different group sizes it is observed that Mind Protocol takes less time as compared to Contract Net Protocol in Best case and Average case. However, in case of Worst case the Mind Protocol behaves just like Contract Net Protocol.

FUTURE DIRECTIONS

The model may be enhanced by the following factors. (1) The assumption of uniform distribution of data may be removed. Data may be given priorities depending on their importance and heuristic values may be set accordingly. However, the determining priorities and setting heuristics value requires analysis of a large amount of real time data. This gathering of real time data and its analysis is not within the purview of this work. (2) In the work, the knowledge management part (accumulated knowledge) is neglected, care may be taken in this direction also. Knowledge representation and management is an area by itself and has not being dealt with here. (3) In the model, all the personality parameters are treated equally. This assumption can be removed and they may be assigned with weights depending on their importance. In order to assign weights with particular personality parameters, one needs to study human engineering in general and developers personalities in a distributed development scenario in particular, from a management perspective. This is again out side the scope of this work.

Another important ratio in distributed processing is aspects of communication link security. In this work, it has been assumed that security exists. However as the future enhancement, the behavior model could also
consider relationship between collaborators based on communication security. Moreover the mind protocol could dictate security levels based on inter collaboration collaborators. A potential application of the work designed here, is the use of the model as a framework for e-commerce applications. However the model and the protocol proposed here needs to be modified to account for security aspects. The model can help in most stages of an e-commerce buying process, including need identification product brokering, merchant brokering and negotiation.