Chapter 9

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

This chapter gives the conclusion of the thesis and foreseeable enhancements that are possible from this work.

9.1 Conclusion

Software agents work autonomously on a delegated task on behalf of its users. Delegation leads to a paradigm shift in the form of functioning as well as in the form of interaction the agent has to support. This thesis focused on the interaction aspect of delegation and identified that collaborative natural language interaction (CNLI) and dynamic multilingualism were the two essential aspects to support interactions for delegation form of functioning of agents.

The study of the language ability of existing agents which helped to result in an evolutionary taxonomy of the language ability of agents revealed that CNLI and multilingualism are either provided exclusively of each other or do not fulfill the required agent properties in them. Further, certain conceptual and design limitations in the language ability of agents were identified. This led to hypothesizing about the language ability of agents from both conceptual and architectural perspectives.

In the foremost step towards realizing these hypotheses, two-dimensions of language autonomy was found to be essential. The two-dimensions of autonomy lead to conceptualizing a new type of agent for which suitable architecture and implementation models had to be provided. This thesis describes about the work that was carried out to conceptualize, architect and implement agents with two-dimensional language autonomy for fulfilling the interaction requirements of task delegation.
The two-dimensional language autonomy has been defined to comprise of language ability management autonomy and language behavior autonomy. Using the two-dimensional autonomy and the solutions for dynamic multilingualism and modular linguistic structure, the conceptual model of the language ability of an agent is described. The model has been analyzed for its complexity to evince that its complexity is comparable to that of an agent with single dimension of autonomy and supporting a single language only. The model is also validated against the enlisted model requirements.

The conceptual model was used to derive the internal state components that were required to explicit the reasoning process of the language faculty. This resulted in a new Belief, Task, Behavior paradigm whose semantics is represented in first-order logic and dynamism is expressed as a control loop.

The conceptual model and the internal state components has been used to formulate the architecture of the language faculty at the macro and micro levels. The architecture has been expounded to result in the role-based design model and aspect-oriented implementation models.

The implementation model has been used to develop a Multilingual natural language Agent Interface (MULLAI) for an E-mail server. The architectural model has also been extended to fulfill the language ability requirements of a Multi-Agent System. This model was used to develop a Multilingual Multi-Agent System (MMAS). The case study discussion is followed by an evaluation of the agent with two-dimensional language autonomy and the existing multilingual dialoguing agents.

The generality of the developed conceptual, architectural and implementation models has been ensured so that they are not only applicable for language faculty, but also to elevate any functional behavior of an agent into a faculty, which is essential when an agent has to perform a multi-faceted function.

9.2 Future Research Directions

Any research activity is a travel in an endless path towards excellence, and any result achieved is a milestone attained in this path. The foreseeable enhancements give a
preview of the next or the next few milestones that could be approached in this path. The above work describes about a milestone that was reached in the research venture towards attributing language ability to agents. Since the language faculty centers on the behavior management, fulfilling a subset of the properties of self-management, provisioning for the other self-management related properties is a foreseeable enhancement as described below.

**Self-Healing** – the language faculty is able to self heal itself by initiating corrective actions.

**Self-Optimization** - the language faculty is able to optimize its size and functionality according to the environment in which it is offering its services.

**Self-Protection** - the language faculty can protect itself against malicious or unintentional attacks to keep its resources intact.

These enhancements are specific to the language faculty. In addition, generic enhancements like that of methodologies, agent development frameworks and metrics for developing agents with two-dimensional functional autonomy could be facilitated.