Chapter 1

INTRODUCTION

Software Technology has been evolving since its inception which began with the development of computers. This has resulted in the development of various types of software in every phase of evolution. In every phase, the software has been useful for various classes of people, depending upon the level of abstraction it provided for interacting with it. For example, the lowest level of abstraction for interaction and task execution provided by the binary programs and assembly language programs made them to be used only for scientific calculations performed by computer experts. When software development using high-level language came into use, command driven interfaces became prevalent. These software could be used by computer trained people. Since, high-level language enabled the development of commercial applications also, which was intended to be used by all people, the need for user-friendliness was realized. This need was fulfilled by Graphical User Interfaces (GUI) that provided a much higher level of abstraction for interaction, than using commands.

The IT developments of today impose a much higher demand in the level of abstraction to be provided by the software. This evoked the evolution of software technology towards developing intelligent software that can work on task delegation. This evolution resulted in a change of metaphor from direct manipulation of software to indirect management of user interaction, which would help the services of the software to be rendered to any user. The software technology that helps to realize task delegation is called a Software Agent.

1.1 Task Delegation

Software Agents work as delegated entities and help to carry out a task on behalf of the user. Thus, agents are popularly viewed as automated personal assistants that can reduce the overhead and complexity involved in a user performing a task himself (Maes, 1997). In addition, delegation provides another advantage in that the user need
not spell out every detail of the task to be performed. The agent is able to pursue its task based on an abstract task specification given by the user (Negroponte, 1997).

The necessity for delegation and hence the need for agents could be attributed to the following reasons (Janca and Gilbert, 2002):

- Desktop applications are becoming so feature-rich that users can master only a small part of their capabilities. Agents mask the complexity and help the user do what he/she wants.
- Sources of information are increasing, and their content is also increasing. Agents help do the data mining as well as help locate the most productive mines.
- The availability of greater network bandwidth enables more data to be transferred to users. But, in order to manage the volume of the information, the agent could send only the information the user considers essential.
- Rapidly increasing use of the internet and the World Wide Web is creating a much more complex computing environment where many services are available. The user faces the difficulty in figuring out these services. The agents can help to find the required and most appropriate forms of services available.

Thus, agents are incorporated within many applications, where they can assist people and act on their behalf. The following are the features that attribute for their significance in working as assistants (Janca and Gilbert, 2002):

- **Delegation**: The user entrusts the agent to tackle some or all of an activity.
- **Personalization**: The agent learns about the user and adapts its actions accordingly.
- **Sociability**: The agent is able to interact with other agents in ways similar to interpersonal communications.
- **Predictability**: The user has a reasonable expectation of the results.
- **Mobility**: The ability to go out – usually onto the network – to accomplish the delegated task.
- **Cost Effective**: The benefits gained by the user in terms of time, information, filtering, etc. are of greater value than the resources incurred for the agent.
- **Skills**: The agent has its own expertise in performing a task.
- **Living within constraints**: The agent is able to perform the delegation in accordance to the constraints given by the user in performing the task.

The discussion below describes how language ability is an important aspect of interaction while working on task delegation.

### 1.2 Language Ability and Task Delegation

The necessity to work on delegation by users put forth a major requirement on the agents - which is their ability to comprehend user's request that is presented in natural language (Norman, 1997). This is because Human Computer Interaction studies have revealed that users prefer a seamless interaction with computers as it is with other individuals. Hence, the interaction capabilities of agents have also evolved from a command-based, to GUI-based, to natural language-based and hence to delegation-based interaction. Delegation-based interaction not only requires natural language interaction but also requires an intelligent interface whereby the agent is able to collaborate with the user to explicate his abstract request or suggest him alternative ways of carrying out a task (Bradshaw, 1997). This in turn requires advanced form of natural language capability to meet the interfacing requirements of delegation.

A complementary requirement of natural language support is the ability of the agent to support multiple languages or provide for multilingualism. This is because the software agents contribute for a sophisticated information society tool whose services should be available across language barriers in order to be globally reachable. For example, considering the information services available in the internet domain in multiple languages, it is very likely that agents would be required to provide the services to the people of the corresponding languages. In the ubiquitous computing environments, it is naturally obvious that the services of the agent would be used by people of many languages. For example, consider a train ticket booking agent which has to serve the public for making ticket reservations. In a country like India which is known for its language diversity, the agent's services have to be rendered to people of various languages. Hence, the ticket booking agent has to support interaction in
multiple languages and has to dynamically configure itself according to the language required by the user.

Thus, language ability forms an important component of delegation, in addition to the task ability to perform the delegated task and user-modeling ability to perform the task in a customized manner. The task and user modeling abilities have been realized in agents through research in each of the corresponding domain.

To realize the task capability, agent architectures like deliberative, reactive and hybrid architectures are available (Wooldridge, 1999) Architectures available for interface agents (Kay, 1990) describe how it can accommodate for the user modeling competence that is characteristic of interface agents. To realize language capability in agents, which has also been identified as an essential component of delegation, the findings from the field of computational linguistics have been used. The various methods of language comprehension like Natural Language Processing, Translation and Natural Language Dialoguing for generating natural language replies and interacting with the user are used.

1.3 Motivation of the Thesis

The revolutionary developments in the field of information technology brought the use of software beyond the boundaries of research laboratories to commercial use by the common people. The language diversity across the globe necessitated that the software is able to support interaction in native languages to provide its services to people across global boundaries. This language requirement triggered the research across the globe on language-based systems that help to accommodate language in the system.

Several superficial approaches like that of font level support, translation, localization etc. were developed for the support of native languages (Kuppuswami et al, 2003). In all these approaches, the language was accommodated only at the interface level. This led to various limitations. Hence, a need for a technology that can accommodate language inherently and naturally in the system was realized. This necessity initiated
the research and development activities in the area of language-based systems at the Department of Computer Science, Pondicherry University.

The first outcome of the research activity is the PONN system which is a multilingual system. This system supports multiple languages and can provide interaction in the language chosen by the user by dynamically configuring to that language. The PONN system (Prasanna Venkatesan et al, 2002) was developed using the multilingual technology evolved at the Department of Computer Science by the researchers (Kuppuswami et al, 2003). An extended outcome of PONN system was SPECS (Specialized Computer System) for the visually handicapped (Kuppuswami et al, 1999)

The subsequent research in the area of language-based systems was focused on developing intelligent language-based systems. This was accomplished by incorporating agents for purposes like handling various language issues internally, while interfacing PONN/SPECS with the conventional systems and for providing a customized language behavior (Kuppuswami et al, 2000). The use of agents proved very useful for meeting these purposes. Thus, the subsequent language-based systems developed for the internet (MAYAN - A Framework for Dynamic Multilingual Web Page Construction) (Chithralekha et al, 2001) and mobile environment (Multilingual SMS system) (Chithralekha et al, 2002) were also developed as agent-based systems.

At this juncture in the roadmap of language-based system research, a new avenue of research with emphasis on agents was identified. Language abilities were found to be inevitable for an agent so that the users of the agent would be able to delegate tasks to the agent by just giving an abstract specification of the task in natural language. The language ability would liberate the user from the intricacies or confines of the static command-driven / GUI form of interaction. If there is any ambiguity or incompleteness in the abstract task specification, or if the agent has to get or offer suggestions to the user, the agent would collaborate with the user. Thereby, not only the functional, but also the interaction responsibilities of performing a task shifts from the user to the agent, thus helping to realize delegation at both functional and interaction levels in the agent.
A study of the existing agents with language ability reveals that agents with different forms of language abilities are available. These agents have imbibed the contributions of computational linguistics to provide for their language abilities. There are agents with simple natural language interaction to complex collaborative form of interaction. But, though language ability is an important aspect of delegation, the language abilities and their corresponding properties that are essentially needed to fulfill the requirements of delegation have not received much focus.

From a language perspective, ability to support interaction in multiple languages is considered to be very essential of any software to enable global reach. Since agents have to work as personal assistants for users, this necessity is more pronounced as they have to serve users of various languages. This multiple language support is required to be dynamic. That is, the agents have to support multiple languages and dynamically configure to the required language, especially when the agent is pervasive in ubiquitous environments. This is because these environments would be dynamically inhabited by users of various languages and the agents in these environments should dynamically adapt to the languages of the users. The existing approaches of achieving multilingualism have not focused on a single agent supporting multiple languages and how it can alter its languages dynamically.

When the agent has to support multiple languages, its competency and knowledge is as much as the number of languages supported. In this case, how the agent has to manage these multiple languages and alternate between the language behaviors so as to provide interaction in the corresponding languages dynamically requires further deliberation. Moreover, when natural language interaction in multiple languages have to be provided by an agent, it leads to additional language ability requirements to be fulfilled by the agent. This has not received the required focus in the literature. This deliberation is required because the conventional behavior level autonomy enables an agent to autonomously carry out natural language interaction in a particular language only. To manage and control its language behaviors in multiple languages a management level autonomy is required, in addition to the behavior autonomy. The necessity of this autonomy, though inevitable, has not been realized and hence has not been conceptualized in the literature. This has led to various limitations.
In order to realize an agent with language ability for delegation, by supporting both language management and behavior autonomies, the necessary issues have to be analyzed and suitable solutions have to be provided starting from the conceptualization till its implementation. This has been the motivation of the thesis.

1.4 Objectives of the Thesis

Autonomy is the fundamental property of an agent which is exhibited in its behaviors. The language ability requirements of delegation leads to distinguishing two types of language autonomies viz. language behavior autonomy and language ability management autonomy, where, the management autonomy is a new type of autonomy identified in this thesis. When an agent has to provide for task delegation, it requires possessing these two autonomies in its language abilities. The existing literature of agents have expounded only on the behavior autonomy of an agent. Thus, the existing conceptualization, characteristic properties, internal state definition and its dynamism, architecture and implementation of an agent have been performed only in the context of behavior autonomy. When an agent has to be realized as a combination of behavior autonomy and management autonomy, its implications is felt in all these aspects. Hence, the hypothesis of this new form of autonomy and reiterating all the above works with respect to realizing an agent as a complementary of the two autonomies have to be performed. These are the objectives of the thesis.

1.5 Contributions of the Thesis

The contributions of the thesis comprises of the following with respect to the language ability of an agent:

- Definition of language autonomy from behavior and management dimensions
- Conceptual model of the language faculty.
- New paradigm for the internal state of the language faculty.
- Architectural model of the language faculty.
- Design and Implementation model of the language faculty.
The definition of language autonomy explicates the various aspects that constitute the autonomy and the characteristics of the agent when it supports single and multiple languages. This complementary of autonomies helps the agent to deliver a language behavior which is characteristic of humans. The linguist Noam Chomsky denotes the language faculty of humans using the term 'language faculty' (Lee, 1997). Hence, the same term has been used to denote the language ability of agents. The conceptual model provides a blueprint of the language faculty of the agent with the two dimensional autonomies. This model provides the basis upon which the internal state, architectural model and design and implementation models are constructed.

The internal state and its dynamics help to discern the internal functionality of the language faculty. This describes why the existing Belief, Desire, Intention (BDI) paradigm which is behavior-oriented and which helps to represent the internal state of a behavior-based agent, cannot cater to the requirements of the language faculty. Hence, for representing the internal state of the language faculty that accommodates and manipulates with multiple language abilities, a new Belief, Task and Behavior paradigm has been proposed and described.

In order to transform the conceptual model and the paradigm into the logical domain, a new architecture has been proposed. The novelty of the architecture is that it is both behavior-oriented and also management-oriented, in that, it describes the functional components needed to accommodate and manage the multiple language abilities and provide the language behaviors in the required languages.

The design and implementation model describes about the physical level abstractions that are appropriate to be used to realize the architecture of the language faculty.

The case study describes the experience obtained in developing an agent with behavior and management autonomies.

A second dimension of the contribution is that the defined autonomies, conceptual model, the proposed paradigm, the architecture and the design and implementation models are generic in nature and are suitable for an agent, especially if it should cater
to multiple dimensions of its functional ability, as is the case with supporting multiple language dimensions of the same language ability.

1.6 Organization of the Thesis

Chapter 2 provides a brief introduction to the agent literature with respect to their definitions, properties, architectures and agent-based systems. It also provides an evolutionary taxonomy of the various forms of language abilities available in the existing agents. The advantages, limitations and drawbacks of each type of agent in the taxonomy are also delineated along.

Chapter 3 provides an overview of limitations that have been identified by considering an integrated view of natural language interaction and multilingualism from an agent perspective. This chapter also derives the problem statement from the identified limitations and the research methodology used to progress from the problem domain towards the solution domain.

Chapter 4 describes the hypothesis carried out towards defining the two-dimensional language autonomy of an agent by characterizing the language abilities with respect to agent properties. The various aspects constituting the language autonomy are identified and defined. Finally, using the two-dimensional autonomy, the technique identified for dynamic multilingualism and the organization required for modular linguistic structure of the language faculty, the conceptual model of the language faculty is constructed. An analysis of the complexity of the model is provided to illustrate that the complexity of an agent with two dimensions of autonomy and multilingualism is comparable to that of an agent supporting a single language only.

Chapter 5 delves into the internal state of the language faculty. This helps to deliberate on how the language faculty accommodates language internally. The paradigm corresponding to the internal state is proposed and its semantics and dynamism are defined. The generality of the paradigm and how it helps to overcome certain identified limitations are also explained in this chapter.
Chapter 6 elaborates on the process of formulating the architecture of the language faculty of an agent. It explains how the proposed definition of language autonomy and that of the internal state demands for an architecture that provides for various aspects of self-management to control and manage the language faculty. The evaluation of the architecture illustrates how the architecture is suitable for the language faculty.

Chapter 7 describes the role-based design model and the agent-oriented and aspect-oriented implementation models for the proposed architecture of the language faculty.

Chapter 8 illustrates the application of the architecture, design and implementation models through a case study. It also describes how the architecture is extended to meet the language ability requirements of a multi-agent system and illustrates it with a case study. In addition, an evaluation of the agent with two-dimensional autonomy with the existing multilingual dialoguing agents is carried out.

Chapter 9 provides the conclusion of the thesis and the prospective avenues of future research that are plausible from the work described.