

Chapter 3

PROBLEM STATEMENT AND RESEARCH APPROACH

The definition of a problem forms the triggering force behind any research work. A problem may be identified as the necessity to find new solution(s) for an otherwise overlooked problem, or for providing an improved solution by overcoming certain drawbacks and limitations in an existing solution or a combination of both. The research work is a methodical process carried out to find a solution to this problem using a research approach.

This chapter describes the problem statement and the research approach followed for developing agents with two-dimensional language autonomy. The overlooked problems in the language ability of agents which project themselves as limitations are described first. This would help to justify why a new solution for the language ability of agents was necessary in the first place when multiple solutions as explained in the evolutionary taxonomy are available. In addition, it would help to reinforce the motivation for this research work.

The problem statement given subsequently helps to define the focus with which this work has been carried out. The approach describes the activities that were carried out in the process of finding solution(s) to the defined problem. Thus, the objectives of this chapter are to

- Delineate the limitations that triggered this research work
- Define the problem to set focus of this research work and
- Describe the research approach that was followed in this research work.

3.1 Limitations in the Language Ability of Existing Agents

There are many agents with versatile language abilities attributed as those described in the literature review. But still, elicitation of limitations was inevitable when considering the language ability of agents from an agent perspective. This is because in all the above types of agents, the computational linguistic and multilingual

computing contributions had a profound influence in designing and implementing the language ability aspect of an agent that inevitably eclipsed the language ability requirements of agent perspective. Actually, the language ability of agents when approached from an agent perspective imposes semantically richer language ability requirements which are beyond the scope of computational linguistics or multilingual computing. These requirements have been overlooked in the language ability of existing agents and thereby they tend to project as limitations which are described below. However, the contributions of computational linguistics and multilingual computing cannot be denied in using them as the technological basis in realizing the language ability of agents.

The discussion below elaborates on the limitations that are identified due to the change of dimension from computational linguistics and multilingual computing perspectives to agent technology perspective in focusing upon the language ability aspects of agents. These limitations are divulged in the following two categories.

- Conceptual Limitations
- Design Limitations.

The conceptual limitations delineate the obvious shortfalls that unveil from a hypothetical perspective. The conceptual limitations are further divulged into limitations from a monolingual perspective and multilingual perspective. The design limitations critically explore the design perspective of the language ability attributed in the existing agents. *The limitations are identified in the form of questions which are unanswered in the literature.* The subsequent discussion enlists each of these questions and describes them.

3.1.1 Conceptual Limitations – Monolingual Perspective

Here, the limitations with respect to the monolingual perspective are described first followed by the limitations with respect to multilingual perspective.

- *What language abilities are required for task delegation?*

Researchers in the computational linguistic domain have tried to contribute different forms of language abilities (Cole et al, 1997) Researchers in the multilingual domain have tried to contribute multilingual support for agents.

These have been adopted in various agents in different ways resulting in agents with different types of language abilities available, as has been described in chapter 2. But, though agents have been conceived as delegated entities and the interaction requirement of delegation has been delineated, there have not been enough reporting in the literature which specifies what should constitute the language ability of an agent for the interaction purposes of an agent in a delegation form of interaction. Though it is only requirement based, a clear conceptualization of the language ability of the agent for task delegation is yet to be perceived. Only then it is possible to differentiate the language ability of agent software from that of any other software.

How the language abilities are characterized with respect to agent properties?

The characterization of the language ability of agents with respect to the agent properties has to be performed. The functional ability of the agent has been characterized with various properties like autonomy, reactivity, proactivity and social ability. What each of the above properties implies with respect to functional competency has also been clearly explained in various works. With respect to language ability, the agent properties should have to be clearly explored. Since an agent is to be realized as a complementary of language ability and functional ability for task delegation, this activity needs comprehensive introspection.

Whether the language should be external or internal to the agent?

In certain agents, language is external to the agent, whereas in other agents language is internal and inherent of the agent. When it is external, the agent uses external language-based entities to handle the language issues and the agent perceives and responds in a language-independent manner. For example, in the agents which uses translator, language is externally handled by the translator. Whereas, the natural language processing agents possess internal NLP modules to process the request and comprehend it. When both the external and internal options of handling language are available, which one is appropriate for the agent for task delegation has to be identified. Since this issue has not been within the scope of the reported works in the literature, the appropriate option has to be explored.

- *If language is internal how the influence of language is modularized in different layers and how the associated issues are handled?*

When language is external to the agent, the influence of language is also external and hence the agent does not have any concern of language issues. But, if language should be provisioned internally, then the influence of language may be felt in multiple layers of the agent. How every layer handles language and the related competencies required have to be specified very clearly so that the agent is able to handle the language issues with less overhead. These have received little interest in the agent literature.

3.1.2. Conceptual Limitations – Multilingual Perspective

The limitations elicited from the multiple language support perspective are described in this section.

- *Which of the available approaches is appropriate for achieving multilingualism in agents?*

As several drawbacks are inherent in each of the techniques available for supporting multilingualism, which method to use for achieving multilingualism forms an issue.

- *How multilingualism is characterized with respect to agent properties?*

Characterization of multilingual behavior helps to explicate how the agent properties are exhibited in the multilingual behavior of the agent. But, the literature describes about how multilingualism is achieved in agents but not the attributes that are required of the multilingual behavior of agents.

- *Whether multilingualism is internal or external to the agent?*

When the agent supports multiple languages, its multilingualism could be internal or external. In the former case, it should be internally aware that it supports multiple languages such that, it has beliefs regarding the various languages supported and its capabilities in handling the corresponding languages. But, it is not so and the existing techniques for achieving multilingualism treat multilingual support externally.

For example, in neither of the approaches of achieving multilingualism like Parallel Agent versions or Translation or Localization, is the agent internally aware that it is able to support multiple languages. When parallel version is used, every agent supports a single language only. In translation, multilingual support is only at the translator level. Internally these agents have beliefs of a single language only. When localization is used, the localized agent supports a single language only. So, even though an agent provides its services in multiple languages, the presence of multiple languages is nowhere known to the agent either in its beliefs or in its capabilities. The advantage of this is that the agent is internally not concerned with multiple language issues, which reduces the overhead of the agent. But, the limitation is that either the belief held by an agent is incomplete or, an agent considered individually is able to support a single language only. This incompleteness limits the knowledge discovery capability of the agent which is explained below.

Whether the agent should be capable of new knowledge discovery from the available languages and if so, how it has to be provisioned?

When multiple language knowledge are held by the agent, then it naturally should provision for discovering new language knowledge from the language knowledge available. For example, functions like finding the equivalent of a word in another language, comparison of the number of characters and character types between languages, etc. should be possible through simple inference. This knowledge discovery would enable the agent to construct multilingual vocabularies by it whereby it could comprehend requests containing words in more than one language. Thereby, the language ability of the agent would improve. This knowledge discovery is not properly provisioned for. This is because the existing methods used for achieving multilingualism treat multilingualism only externally.

For example, in parallel language versions of agents, every agent has only the language knowledge and resources corresponding to the language that it supports, i.e., language knowledge beliefs are spread across agents. In the case of translation, it is spread across the translators or the Translation Agents. Hence, inference of knowledge is possible only by a cooperation of these agents. Even if

this knowledge is inferred, it is not required by any agent as they are concerned with a single language only. However, every agent is capable of updating its own knowledge, for example, updating the lexicon with new words, which enables depth-wise growth of language knowledge. But knowledge discovery across languages, which is an obvious natural function in human language ability, is unnecessarily inhibited or limited. Since, knowledge discovery ability itself has not been in the focus of the literature, it does not throw light on how it could be provisioned in agents.

- ***Whether the agent should be capable of new language acquisition to increase the degree of multilingualism?***

The literature does not provide answers regarding whether language acquisition has to be provisioned for in the agent's language ability as it is available in human language ability and if so, how to provision for this in the agent. If language acquisition is facilitated, it would be very useful especially in a country like India, when it has to be installed for service providing functions in places of public use like railway stations. For example, the ticket booking agent in a railway station could be made to acquire the required language(s) before installing in a railway station.

- ***What is the nature of multilingualism – static or dynamic?***

Multiple language support is to facilitate interaction in multiple languages. Hence, the agent should be able to dynamically configure itself to the required language at any instance. But, from the description of agents with language abilities, as explained in the literature review, it could be inferred that only static configuration to language is possible. That is, once an agent is configured to a particular language it can work in that language only, as is the case with localized agents. But, if this dynamic configuration is supported, then a single agent can be interacted with, in any or a combination of the languages supported.

3.1.3. Design Limitations – Monolingual Perspective

The limitations with respect to the design used for designing the language ability and hence the language behavior of an agent are identified. In the following discussion, the limitations from a monolingual perspective are described.

- ***What is the architectural basis for the language ability of an agent ?***

Since the conceptualization of language ability of an agent is yet to be perceived, the design of language aspect of the existing agents have different architectural basis like that of distributed architecture, agent-based architecture, ontology-based architecture, dialoguing-based architecture etc. and help to realize the contributions of computational linguistics, or distributed systems but not that of language ability characteristic of agents.

- ***How the language knowledge and competence of an agent should be organized?***

This question requires deliberation because in the existing agents, the language knowledge and its handling is language processing based. This gives rise to the following limitations.

- Any modification or update at the language knowledge organization, representation, storage, or language knowledge influences the processing module. So, in addition to the language processing works, the above works also concern the processing module. Similarly, modifications in the processing module would also render problems in using the language knowledge.
- Since the language knowledge is processing based, the available language knowledge could not be made available to any other type of language processing. Because of this coupling, the agent cannot alter its language processing technique even if it has to support multiple processing methods. That is, it does not have any control over its language processing behavior so as to decide and use the required language processing technique.

3.1.4. Design Limitations – Multilingual Perspective

The following are the design limitations identified from a multilingual perspective

- *Which architecture is suitable for supporting and maintaining multiple language knowledge and competencies?*

The necessity to support multiple languages dynamically requires an architecture that supports it. But, the study of existing agents with language ability revealed that this design aspect has not received the required focus as dynamic multilingualism itself has not been supported within agents

- *How multiple language management is facilitated with the architecture?*

There is an ardent need for language management architecture that facilitates for maintaining the multiple language competencies and knowledge, and which caters to overcome all of the conceptual limitations identified above. This is because, when the number of languages supported by the agent increases, the amount of language knowledge to be managed becomes an overhead. So, unless there is an architecture defined for maintaining this language knowledge, it is difficult to cope with the volumnity of the language knowledge available. At present, considering all of the above described architectures, it is obvious that a suitable architecture to facilitate for language management that overcomes all the limitations described above could not be found.

These limitations had been the motivating factor behind this research work. The problem statement below describes the hypothesis that had been formulated for the language ability of agents and the research approach provides the roadmap of the subsequent works that were carried out in order to prove this hypothesis.

3.2 Problem Statement

The plethora of limitations described above vividly illustrates that the language ability of agents has not been achieved based on an appropriate hypothesis. This is because the contributions of the field of computational linguistics were directly incorporated to agents to achieve the desired form of natural language interaction and that of the field of multilingual computing to achieve multilingualism.

But, the language ability of agents requires an integration and intersection of these contributions, whereby it has to absorb each of these contributions as well as be able to fulfill the required agent properties in its language ability. Only then will the language ability be a one which is characteristic of agents. In the present scenario, the agents have language abilities that fulfill the requirements arising from the individual contributing fields, but have not considered them collectively from an agent perspective. This has led to causing the above said limitations.

This introspection precipitates into a need for the hypothesis of the language ability of agents that clearly spells out the language ability requirements from computational linguistic, multilingual and agent perspectives both individually as well as collectively. These perspectives have to be considered with conceptual and design focus. Based on these insights, the problem statement for this research work is delineated as the necessity to conceive upon and prove the following hypothesis about the language ability of agents.

Hypothesis I

Language ability is inherent of an agent such that the following are fulfilled:

- Conceptualized language ability/behavior that helps to fulfill the interaction requirements of delegation that is characteristic of agents.
- Support the language behaviors in multiple languages using a proper approach for achieving multilingualism.
- Dynamically configure to the required language and provide language behavior in the corresponding language.
- Internally aware of the languages supported.
- Multilingualism achieved using an appropriate technique that helps in
 - Knowledge discovery across languages and
 - Acquire new languages to extend the degree of multilingualism.

The above hypothesis has a conceptual focus. In order to realize an agent with the above hypothesized language ability, a design focus of the language ability requirements is required. More explicitly, the architectural requirements of the language ability of an agent that forms the basis for the architectural model and its

corresponding design and implementation models for the conceptualized language ability are required. This would enable the developers to use the architecture and implementation models to develop agents with the above specified language ability.

Since the language ability of an agent has been hypothesized as part of this work, there has not been any architecture that fulfills the same, as is obvious from the review of literature. Moreover, the existing architectures suffer from the limitations that have been described. Hence, it is essential to hypothesize the architectural requirement of the language ability of agents as follows.

Hypothesis II

The architecture for the language ability of an agent should help to fulfill hypothesis I with the following attribute requirements:

- *Usability*: provide for the language ability behaviors in the supported languages.
- *Modularity*: possess a language management architecture that helps to manage the multiple language competencies and knowledge modularly such that the competence and knowledge have least coupling between them.
- *Openness*: should be open with respect to the number, type of languages and the function performed by the agent.
- *Dynamicity*: enable to support multiple languages and dynamically configure to the required language.
- *Performance*: exhibit a performance which is comparable to that of an agent supporting a single language.
- *Scalability*: enable to augment the degree of multilingualism.
- *Maintainability*: facilitate update and maintenance of language knowledge and competence.
- *Reusability*: provide for a generic architecture capable of being used for language ability as well as for other functional abilities of an agent.

The above two hypothesis have been derived by considering the conceptual and design limitations elaborated above. This thesis deals with describing how the above

two hypothesis were necessary to conceive upon and how they have been realized in an agent.

3.3 Research Approach

The research approach explains the process that has been followed in carrying out this research work.

The multiplicity of the limitations identified as a result of the literature review instills the fact that there is a need for a fundamental rethinking about the language ability of agents. Hence, at the outset, a hypothesis of the solution that would help to overcome the conceptual limitations of the language ability of agents and which forms the basis for overcoming the design limitations is required to be made. This solution hypothesis has to be realized.

As a first step, a conceptual model of the proposed solution is required to be formulated based on the solution hypothesis. This conceptual model should be made to progress into the logical domain by transforming into an architecture. In order to design the architecture, supportive components which complement the solution hypothesis as well as which are instrumental in designing the architecture are required to be identified and crystallized.

This architecture should be extended into the physical domain by providing the appropriate design and implementation models that would help to realize the architecture. Finally, the design and implementation models are to be used to develop a typical agent with the required language ability. This would help to prove and also illustrate that the solution hypothesis is the most appropriate solution for the proposed problem.

3.4 Summary

This chapter provides an overview of the limitations that triggered this research work. From these limitations, the problem statement is crystallized in the form of hypotheses. This helps to set the focus of this thesis. The research approach describes the steps carried out in the itinerary from the problem domain to the solution domain.