COMPUTATIONAL SUPPORT FOR THE ACQUISITION OF ARABIC CLOSED-CLASS ITEMS

A THESIS SUBMITTED TO THE UNIVERSITY OF MANCHESTER FOR THE DEGREE OF MASTER OF PHILOSOPHY IN THE FACULTY OF ENGINEERING AND PHYSICAL SCIENCES

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School of Computer Science

2017
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<th>Description</th>
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<tr>
<td>AFL</td>
<td>Arabic as a foreign language</td>
</tr>
<tr>
<td>AL</td>
<td>Arabic Letters</td>
</tr>
<tr>
<td>BC</td>
<td>Backward Chaining</td>
</tr>
<tr>
<td>BK</td>
<td>Background Knowledge</td>
</tr>
<tr>
<td>BW</td>
<td>Buckwalter</td>
</tr>
<tr>
<td>CALL</td>
<td>Computer-Assisted Language Learning</td>
</tr>
<tr>
<td>CCI</td>
<td>Closed-Class Items</td>
</tr>
<tr>
<td>CMC</td>
<td>Computer-Mediated Communication</td>
</tr>
<tr>
<td>ELT</td>
<td>English Language Teaching</td>
</tr>
<tr>
<td>ESL</td>
<td>English as a Second Language</td>
</tr>
<tr>
<td>F</td>
<td>Figure</td>
</tr>
<tr>
<td>G</td>
<td>Ground</td>
</tr>
<tr>
<td>HPSG</td>
<td>Head-driven Phrase Structure Grammar</td>
</tr>
<tr>
<td>IE</td>
<td>Informal Equivalents</td>
</tr>
<tr>
<td>LAD</td>
<td>Language Acquisition Device</td>
</tr>
<tr>
<td>LFs</td>
<td>Logical Forms</td>
</tr>
<tr>
<td>MALL</td>
<td>Mobile Assisted Learning Language</td>
</tr>
<tr>
<td>MALU</td>
<td>Mobile Assisted Language Use</td>
</tr>
<tr>
<td>MB</td>
<td>Model Builder</td>
</tr>
<tr>
<td>MPs</td>
<td>Meaning Postulates</td>
</tr>
<tr>
<td>MT</td>
<td>Mother Tongue</td>
</tr>
<tr>
<td>NP</td>
<td>Noun Phrase</td>
</tr>
<tr>
<td>RL</td>
<td>Rote Learning</td>
</tr>
<tr>
<td>SLA</td>
<td>Second Language Acquisition</td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>TA</td>
<td>Teaching assistant</td>
</tr>
<tr>
<td>TL</td>
<td>Target Language</td>
</tr>
<tr>
<td>TP</td>
<td>Theorem Prover</td>
</tr>
</tbody>
</table>
Buckwalter Arabic Translation

Throughout this thesis, we use Buckwalter (BW) scheme to romanise Arabic examples, as well as we add the informal equivalents (IE) for the Arabic letters (AL) to the virtual keyboard in our website. Table 1 lists the characters’ representation used in the research.

Table 0.1: Arabic letters as presented in Buckwalter

<table>
<thead>
<tr>
<th>AL</th>
<th>Unicode name</th>
<th>BW</th>
<th>IE</th>
<th>AL</th>
<th>Unicode name</th>
<th>BW</th>
<th>IE</th>
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<tbody>
<tr>
<td>ء</td>
<td>HAMZA</td>
<td>'</td>
<td>2</td>
<td>س</td>
<td>seen</td>
<td>s</td>
<td>s</td>
</tr>
<tr>
<td>i</td>
<td>ALEF WITH MADD ABOVE</td>
<td>l</td>
<td>1</td>
<td>ش</td>
<td>SHEEN</td>
<td>$</td>
<td>sh</td>
</tr>
<tr>
<td>i</td>
<td>ALEF WITH HAMZA ABOVE</td>
<td>o</td>
<td>2’</td>
<td>ص</td>
<td>SAD</td>
<td>S</td>
<td>9</td>
</tr>
<tr>
<td>ؤ</td>
<td>WAW WITH HAMZA ABOVE</td>
<td>w</td>
<td>2</td>
<td>ض</td>
<td>DAD</td>
<td>D</td>
<td>9’</td>
</tr>
<tr>
<td>ء</td>
<td>ALEF WITH HAMZA BELOW</td>
<td>i</td>
<td>2</td>
<td>ط</td>
<td>TAH</td>
<td>T</td>
<td>6</td>
</tr>
<tr>
<td>ئ</td>
<td>YEH WITH HAMZA ABOVE</td>
<td>}</td>
<td>2</td>
<td>ظ</td>
<td>ZAH</td>
<td>Z</td>
<td>6’</td>
</tr>
<tr>
<td>أ</td>
<td>ALEF</td>
<td>A</td>
<td>a</td>
<td>غ</td>
<td>GHAIN</td>
<td>g</td>
<td>3’</td>
</tr>
<tr>
<td>ب</td>
<td>BEH</td>
<td>b</td>
<td>b</td>
<td>ف</td>
<td>FEH</td>
<td>f</td>
<td>f</td>
</tr>
<tr>
<td>ة</td>
<td>TEH MARBUTA</td>
<td>p</td>
<td>a</td>
<td>ق</td>
<td>QAF</td>
<td>q</td>
<td>8</td>
</tr>
<tr>
<td>ت</td>
<td>TEH</td>
<td>t</td>
<td>t</td>
<td>ك</td>
<td>KAF</td>
<td>k</td>
<td>k</td>
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<tr>
<td>ث</td>
<td>THEH</td>
<td>v</td>
<td>th</td>
<td>ل</td>
<td>LAM</td>
<td>l</td>
<td>1</td>
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<tr>
<td>ج</td>
<td>JEEM</td>
<td>j</td>
<td>j</td>
<td>م</td>
<td>MEEM</td>
<td>m</td>
<td>m</td>
</tr>
<tr>
<td>ح</td>
<td>HAH</td>
<td>H</td>
<td>7</td>
<td>ن</td>
<td>NOON</td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td>خ</td>
<td>KHAY</td>
<td>x</td>
<td>5</td>
<td>ه</td>
<td>HEH</td>
<td>h</td>
<td>h</td>
</tr>
<tr>
<td>د</td>
<td>DAL</td>
<td>d</td>
<td>d</td>
<td>و</td>
<td>WAW</td>
<td>w</td>
<td>w</td>
</tr>
<tr>
<td>ذ</td>
<td>THAL</td>
<td>*</td>
<td>4</td>
<td>ي</td>
<td>YEH</td>
<td>y</td>
<td>i</td>
</tr>
<tr>
<td>ر</td>
<td>REH</td>
<td>r</td>
<td>r</td>
<td>ع</td>
<td>ALEF MAKSUR</td>
<td>y</td>
<td>-</td>
</tr>
<tr>
<td>ز</td>
<td>ZAIN</td>
<td>z</td>
<td>z</td>
<td>م</td>
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Abstract

Computational Support for the Acquisition of Arabic of Closed Class Items

Hayat Alrefaie

A thesis submitted to the University of Manchester
for the degree of Master of Philosophy, 2017

The process of language learning involves the mastery of several tasks: making the constituent sounds of the language being learned, learning grammatical patterns, and acquiring the requisite vocabulary for reception and production. While a plethora of computational tools exist to facilitate the first and second of these tasks, a number of challenges arise with respect to enabling the third. This thesis aimed to develop a Computer-Assisted Language Learning (CALL) tool intended to support Arabic language learners with the challenge of understanding the use of ‘closed-class’ lexical items; in this case, the correct use of prepositions.

While the process of learning open class words is relatively simple and should be possible by means of simple repetition of the word; for example, that the Arabic for ‘office’ is مكتب (mktb), it is much more difficult to learn and correctly use the Arabic equivalent of the word ‘on’, where the choice of the correct Arabic preposition depends on properties of the two items being linked. Therefore, a mechanism for the delivery of diagnostic information regarding specific lexical examples is needed in such a tool, with the aim of clearly demonstrating why a particular translation of a given closed-class item may be appropriate in certain situations, thereby helping learners to understand and use these terms correctly.

The process of building this tool involved the implementation of several substantial pieces of software capable of performing two tasks: model building and abductive reasoning. The main system design was based on requirements analysis and the finished tool was piloted to
assess the feasibility of its use. The tool was subsequently evaluated in a classroom setting on a sample of 10 Arabic students who were asked to complete two sessions with identical content, which were interspersed by a period of one week in order to assess whether they benefited from using the system.

The findings of this study reiterated that providing diagnostic information does indeed seem to help Arabic language learners, with evidence being indicative of the usefulness of this tool, although the data were not of sufficient quantity to form any solid conclusions based on reliable statistical analyses due to the limited sample size. In addition, analysis of user behaviour based on all expected paths of interaction showed a relationship between improved learning outcomes and the use of all available resources provided by the system, including diagnostic messages and text models. These two types of evidence seem to be encouraging and suggest that there is a need for further assessment, and possibly improvement, of the developed tool.
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Dedication

To my parents: Mohammed Awad Alrefaie and Mona Saleh Almishari; thank you for your unconditional love and devoted spirit that allowed me to dare to dream.
Acknowledgements

First and foremost, I would like to show my gratitude and appreciation to God Almighty, who inspired me and blessed my life. I would also like to express my heartfelt thanks to people who supported and guided me through this journey.

Especially, I would like to offer my sincerest thanks to Professor Allan Ramsay for his endless patience, continuous support and invaluable guidance. His useful suggestions and helpful advice have guided the completion of this project and made it possible to overcome the challenges that I faced during this journey of learning.

I would also like to offer special thanks to my parents, who gave me encouragement and help throughout my personal and academic life, and who inspired me to have dreams and to strive to make them a reality; thank you for all the support, prayers and inspiration.

I would like also to express immense gratitude to my siblings for the company, encouragement and love; special thanks go to my sister Hanan, who always supported me and helped in looking after my kids.

Last but not least, I would like to offer sincere thanks, from the bottom of my heart, to my beloved husband, Waleed. You have literally lived every moment of this journey with me, both the ups and downs, and you have always known how to cheer me up when life became difficult. I sincerely appreciate the sacrifices that you have made for me to finish this project. Immense thanks also go to my three lovely boys, Khalid, Mohammed and Salman, who are always making me smile and who are always patient when I have been absent, working on my thesis instead of taking care of them; only God knows how much I love all of you. Thank you.
Chapter 1

Introduction

1.1 Research Overview

The aim of this work is to help people trying to learn Arabic to understand how to use closed-class items (CCIs) correctly, particularly prepositions whose primary meaning is spatial. In general, learning vocabulary takes much work because, in order to be fluent in a language, you need to know a large number of words (a typical adult speaker will have active knowledge of 10,000-40,000 Arabic words). Although the acquisition of these words may require a substantial investment of time and effort, it often just involves the memorisation of a large number of word pairs and can therefore be as straightforward as learning that the equivalent of ‘office’ is (مكتبة, |mkṭb|), the equivalent of ‘man’ is (رجل, |rgl|), or the equivalent of ‘boy’ is (ولد, |wld|).

Closed-class items, however, pose a different kind of problem. There are, by definition, not that many of them. There are a few dozen English prepositions, and a similar set of Arabic ones. Their meanings, however, are very tricky, and the correct choice of preposition for locating one item with respect to another is difficult to predict. When one wants to know the meaning of a word, it is common practice to look it up in a dictionary. With a word like ‘in’, however, this turns out not to be a very effective strategy. A typical dictionary definition of ‘in’ says ‘used to indicate location or position within something’. When you look up ‘within’ in the same dictionary, you find ‘inside something’, and when you look up ‘inside’ you find ‘an interior or internal part or place: the part within’. Dictionary definitions of prepositions generally take you in circles in this way, without resulting in anything which will tell you whether you should use ‘in’ or ‘on’ in any given case (e.g. why do people get in a car but on a bus? Why is my office in the computer science building
but on the second floor?).

The key to understanding how prepositions work is the observation that they express a relationship between some parts or some facets of the entities being related. The second part of this statement involves ideas related to Pustejovsky’s (1991) notion of ‘qualia structure’ or Dowty’s (1979) more general notion of ‘logical space’:

There will be as many axes of logical space as there are kinds of measurement[...]. Each axis might have a different mathematical structure according to the discriminations that can be appropriately made in each case (p. 126).

Consider the examples below:

(1.1) (a) I read it in the park.
    (b) I read it in the Guardian.
    (c) I read it in January.

Each of these examples describes a relationship between a reading event and another entity through the use of the same preposition: (1.1 a) relates the reading event to a place; (1.1 b) expresses a relationship between the reading event and a source of information; and (1.1 c) links the reading event with an interval. It can be difficult to understand that an entity can be linked to such different objects through the same relationship. Therefore, an assumption can be made with respect to the varied ways in which these objects can be perceived, so the preposition begins by determining compatible views of the figure and ground. This allows (1.1 a) to be concerned with the physical act of looking at an object and using received light to create a picture of that object on your retina; (1.1 b) to describe the abstract transferral of information from an external source into your mind; and (1.1 c) to focus on the temporal view, with something that begins at one point in time and ends at a later point in time.

Once compatible views of the figure and ground have been found, the preposition then provides information on the relationship between given views of the two entities being related. For example, the word ‘in’ states that the (selected view of the) ground has an interior which encloses some region in the relevant space, and that every part of the (compatible view of the) figure is contained in this region. In contrast, the word ‘on’ says that the (selected view of the) ground has an orientable surface, and that the (compatible view of the) figure has a set of contiguous points that lie an arbitrarily small distance from the surface.
Use of the dictionary definition doesn’t really help or explain how interior means enclosed region or how the entity has an orientable surface, but this notion could be reduced to more precise characterisations in terms of some precise technical definition. This technical definition will not be used but the fact this definition is possible.

For example, reducing ‘F in G’ to \((S, S') \& (\text{view}(F, S) \subseteq \text{interior}(\text{view}(G, S')))\) avoids the circularity of saying that ‘in’ means ‘inside’ because precise definitions can be given of the interior of some entity in a given space. For example:

- If \(X\) has an embedding \(E\) into \(R^n\), then \(\text{interior}(X)\) is the set of members \(p\) of \(X\) such that \(E(p)\) is not a member of \(X\) but there are members \(p_1, p_2\) of \(X\) such that \(E(p)\) lies on the line from \(E(p_1)\) to \(E(p_2)\). Insofar as our everyday notion of physical space can be captured by mapping points in space to \(R^3\), this enables us to talk about the interiors of physical objects.

- If \(X\) is a dense partially ordered set of points, an interval has a set of lower bounds (points which are not preceded by any other point in the set) and upper bounds (defined likewise). The interior of an interval is then the interior of the set consisting of its lower and upper bounds. Most of the common-sense approaches to time discussed by authors such as (Reichenbach, 1956, 1958; Allen, 1984), and linguistic approaches discussed by authors such as (Smith, 1991; Kamp, 1984), involve at least dense partial orderings, and hence can be covered by this definition.

- The interior of a simple unstructured set is the set itself. To say that someone is in my class is simply to say that they are a member of the set of people who I am teaching.

In other words, if two items are placed in some abstract space with an appropriate structure (distance if we want to use ‘at’, regionhood if we want to use ‘in’, vertical direction if we want to use ‘on’, . . .) then they can be located with respect to each other in that space using clear definitions that exploit the structure of the space. Of course, the two items have to exist in the same space – it is not possible to say that a physical object is contained in a temporal space (*‘London is in January’), or that a temporal object is contained in an abstract space (*‘January is in my best paper on syntax’). Hence, the first task when interpreting a preposition is to find views of the entities in question which are in the same space.
Not every item in a given space, however, has the properties required by a given preposition. It is perfectly possible to have a physical object which does not have a non-empty interior (* ‘my office is in the second floor’), or an interval that does not have upper and lower bounds (* ‘I have been knowing how to play tennis since I was 12’ is problematic because once you know something, you don’t stop knowing it, so the interval denoted by the verb ‘know’ has no (natural) upper bound). For a preposition to locate one entity with respect to another, the entities in question have to have the right properties as well as being of the right general kinds. This will be discussed in Chapter 3.

Integrating such an observation into a Computer-Assisted Language Learning (CALL) tool is not a simple task. We identified two possible ways to make progress while using the selected set of meaning postulates (MPs); these two approaches are generally semi-independent:

• To use abduction based on the MPs in order to diagnose errors in the use of prepositions.

• To compare models based on the MPs along with a bilingual dictionary in order to diagnose errors in translation.

In order to achieve this, an existing tool ‘Parasite’ was adopted to do the set tasks. The machinery of the built CALL tool, which was made to do these two jobs, is discussed later (Chapters 4 and 5).

1.2 Research Goals and Objectives

The overall purpose of this thesis is to help learners of the Arabic language to learn how to use Arabic (CCIs, i.e. spatial prepositions) correctly. In order to achieve that, an in-depth investigation of certain linguistic features of Arabic and English CCIs will be conducted by developing and employing computational linguistic techniques. To achieve the aim of this research, the following objectives will be addressed:

• To represent the meaning of English and Arabic prepositions in an appropriate formal framework.

• To design and implement an architecture for identifying mismatches between models of English and Arabic sentences.

1 Also known as computer-assisted instruction (CAI), computer-aided instruction (CAI), or computer-aided language learning (CALL)
• To design and implement presentation tools for target exercises.

• To evaluate these tools in a classroom setting.

1.3 Research Questions

The principle aim of this PhD project is to help non-native Arabic learners to understand how to use Arabic closed-class items by developing CALL tool, which will provide them with diagnostic error messages. The major questions that this research attempted to answer were:

RQ1: Can the differences between English and Arabic prepositions be accounted for by treating all prepositions as spatial and looking at the different spatial metaphors that each language associates with various words?

RQ2: Can this be used to help people learn how to use the right prepositions?

1.4 Research Contribution

The main contributions of this research are:

C.1 A precise, formal description of the ways that English and Arabic spatial prepositions are used to locate a figure with respect to a ground.

C.2 Implementation of an abductive inference engine for finding missing information in the use of prepositions.

C.3 Development of a tool for displaying this information to a learner.

C.4 Evaluation of the effectiveness of the developed tool.

1.5 Publications

The work that was carried out contributed to a wider project in Arabic Closed Class Items, leading to a joint publication of a research paper entitled “Supporting Language Learners with the Meanings of Closed-Class Items”, International Journal of Artificial Intelligence & Applications (IJAIA) 6(3), May 2015.
Our work has also led to a joint publication of a paper entitled “Diagnosing Learner Errors on Arabic Closed-Class Items”, which was an oral presentation at the Second International Conference on Computer Science and Information Technology (COSIT 2015) March 2015.

1.6 Thesis Outline

This introduction has presented an overview of the research problem and the main challenges involved in the use of Arabic closed-class items. The aims, objectives, research questions and research contributions have been highlighted. The remainder of this thesis is organised as follows:

Chapter 2 Offers an overview of the theoretical dimensions of the research, and looks at Language Acquisition and Learning theories related to CALL. The concept of CALL and a number of atheoretical systems are also discussed.

Chapter 3 Provides an outline of the linguistic and computational description of English and Arabic CCIs, in particular, spatial prepositions. It examines the properties of CCIs and identifies the characteristics that make English and Arabic CCIs difficult to learn.

Chapter 4 Describes the development of a CALL system. This chapter begin with a discussion of the requirements analysis that took into account the experiences of experts in this field, followed by a general discussion covering ‘Parasite’ software, which is the basis of this tool, and finally, the integration of all this machinery.

Chapter 5 Is a chapter on abductive reasoning, which investigates how the theorem prover can be adapted to work abductively, trying to fill in the gaps in the use of the prepositions.

Chapter 6 Presents classroom experiments, which were carried out with Arabic learners in order to assess the effectiveness of the CALL tool.

Chapter 7 Summarises the research outcomes and makes suggestions for future work.
Chapter 2

CALL and Language Learning

2.1 Introduction

This chapter begins by explaining the theoretical dimensions of Language Acquisition and Learning related to CALL. The concept of CALL and some atheoretical systems are also discussed.

2.2 Theories of Language Acquisition and Learning

The process by which we learn language involves the cognitive process of increasing our knowledge or learning a skill. In the case of language, this denotes the process of learning how the words of a target language are produced, recognised, arranged into meaningful order and then utilised in the expression of ideas. However, some linguists have argued that a distinction should be drawn between language acquisition and language learning. As an example of this, the Language Acquisition Device (LAD) theory states “every human is born with innate principles of language, and children learn language spontaneously and speak creatively” (Chomsky, 2014).

Therefore, the theory of language acquisition describes the natural assimilation of languages, which may be a subconscious process resulting from non-simulated human interaction that occurs within the normal culture of the target language. In this environment, the language learner is an active participant in the development of the ability to communicate. In contrast, language learning is concerned with the intellectual understanding and analysis of the system of language in order to gain an understanding of the underlying structure and generate related knowledge (Heift and Schulze, 2003).
In this vein, second language acquisition (SLA) is the process of learning an extra language in addition to one’s native language at some point after childhood (Selinker and Gass, 2008). This discussion highlights the complexity of language learning, with many attendant theories in existence. Some of these theories will now be discussed, as they inform the later work on CALL undertaken in this study.

2.2.1 Rote Learning

Rote learning (RL) is based on behaviourism, which is focused on the examination of observable and measurable behaviours (Good and Brophy, 1990). This learning theory considers that it is possible to quantitatively observe a response to any given stimulus, ignoring the underlying thought processes (Mergel, 1998). Behaviourist learning theory is very influential in education, having been instrumental in the development of curricula, workbooks and a variety of pedagogical tools. This theory has also been used in the development of certain skills that can be learned through repetition, or rote, through continuous practice.

RL is a method that employs repetition and memorisation (Gairns and Redman, 1993; Moore, 2012). This kind of learning describes the ability to repeat something automatically from memory instead of necessarily being able to understand it. This method is an effective way of learning some materials, such as alphabets, lists of vocabulary, or even certain grammatical structures like conjugation of verbs. However, it provides no explanation of the origin or meaning of content, which could be helpful to some learners. Therefore, it can be said that such strategies primarily store incoming information for later use, meaning that it is possible to argue that RL is basically a simple and passive process.

2.2.2 Monitor Hypothesis

The theories of Stephen Krashen became extremely prominent in SLA in the 1980s. Krashen’s theory of second language acquisition, sometimes known as the Input Hypothesis, is based on five main tenets:

- Acquisition and learning are two different processes (spontaneous vs. conscious)
- Natural order (grammar is acquired in a predictable order in a natural setting)
- Monitor (learning functions only as an editor, or monitor)
• Input (comprehensible input is essential for acquisition)

• Affective filter (acquisition occurs when affective conditions are optimal, i.e. low anxiety, motivation, confidence, etc.) (Krashen, 1987)

This hypothesis suggests that second language acquisition is driven by language input that learners can understand, comprehensible input, which is then implemented, inspected and used, which is the acquisition system. While Krashen agrees that monitoring can increase the accuracy of an utterance, its use should be limited, as this editing process can potentially obstruct communication by slowing production in the focus on accuracy.

Krashen’s monitor model was based on Fodor’s theory of ‘Modularity’, which describes the development of modules for perception that can be integrated for communication. The modular perspective is based on a view of the brain as being compartmentalised into groups of cells that have different abilities, which act in isolation from modules to which they are not directly linked (Fodor, 1983). This theory argues that a central processor can monitor the output of these modules, select appropriate actions and therefore generate expressed behaviour (Bryson, 2005).

2.2.3 Constructivism

Constructivist theory is based on the idea that knowledge is a “web of relationships” (Tuncer, 2009), and that this web can be actively constructed, enabling learners to understand their experiences and environment. These constructivist assumptions about learning can be explained as

“Knowledge is actively constructed by learners as they are trying to make sense of their experiences; learners form, elaborate and test candidate mental structures until a satisfactory one emerges” (Perkins, 1992, p.20)

This means that conflicting experiences can disturb the new structures, allowing them to be restructured and reconstructed in order to make sense of the new information (Bruner, 1966; Vygotsky, 1978; Piaget, 1973). Effectively, it is argued that construction of knowledge is self-regulating and self-created rather than compiled from empirical data, which would make it impossible to know how much knowledge reflects external reality (Glasersfeld, 1996). Indeed, this is also seen in the social negotiation of meaning, which describes how it is possible to uncover how individuals and groups participate and therefore how they negotiate the perceived reality (Vygotsky, 1978).
Proponents of constructivism hold that knowledge acquisition is a process of continuous self-construction in which language plays a central role in development and learning. This idea argues that children make sense of their environment through language as they develop, meaning that language acquisition is an important aspect of this self-construction (Piaget, 1973).

The necessary constructivist conditions for learning can be summarised as follows.

- Embedded learning in complex, realistic and relevant environments (Duffy and Jonassen, 1992; Knuth and Cunningham, 1993; Honebein, 1996).

- Provide for social negotiation (cooperative and socio-moral atmosphere) as an integral part of learning (Piaget, 1973; Vygotsky, 1978; Bruner, 1966; DeVries, 2002).


- Encourage ownership in learning (Cunningham and Duffy, 1996; Honebein, 1996).

- Provide adequate time for learners’ investigation and in-depth engagement (DeVries, 2002).

- Nurture self-awareness of the knowledge construction process (Jonassen et al., 2003; Cunningham and Duffy, 1996).

The discussion of language learning theories can play an important role in understanding of how the CALL tools are intended to support language learning. The following sections carry out an exploration of pedagogical aspects of computer technologies, such as CALL, in learning.

2.3 CALL tools in Language Learning

2.3.1 Importance of CALL

Currently, language tutoring is in high demand as an increasing number of people are required to learn a non-native language, which they find to be an essential tool for success under different circumstances, either for the purpose of conducting business or for normal day to day interactions (Massaro, 2004). When learning a language, a learner will face a wide range of difficulties in relation to the various facets of the language learning
experience, such as morphological, vocabulary, grammatical, writing system, listening, reading and pronunciation problems. In particular, an aspect of language learning which is especially difficult is closed-class items (CCIs), known as spatial prepositions, due to the existence of a degree of overlap between these items, for instance in their use. Biber (1999) outlines the issue of overlap in the use of prepositions and other word categories, including adjectives, nouns and adverbs, and this point is further discussed in sufficient detail in Chapter 3.

Recent literature also highlighted the use of technological tools in learning languages due to the utility of such tools in improving and facilitating learning a new language. Interestingly, Zhao (2003) argues that technology can provide a degree of support to language learners, which is as valuable and effective as human tutors, or even more so. Similarly, Nutta (1998) observed students of English as a Second Language (ESL) who dedicated one hour each day for a week to learning English verb tenses. There were two separate groups of students in this study: (1) students who were enrolled in regular classes and instructed by teachers only without any computer or technology related learning tools, and (2) students who used a multimedia programme that provided options of using audio and video material, in addition to the facility of recording and play-back. This investigation suggested that the students who were digitally instructed showed performance of a similar or significantly superior level to those who were instructed in regular classes.

2.4 CALL Tools in Language Learning

Computer-Assisted Language Learning (CALL) has changed over time. What began as a mechanical tutor that featured extensive drills became an effective tool that gives students the ability to respond and adapt to changes, rather than training through a single method to achieve a task. Similarly, the role of human teachers and tutors evolved over time as well. In this time of information and technology, instructors do not constitute the only source of language learning. Effectively, cognitive theory suggests that teachers do not stream knowledge into the minds of their students, instead, students are the ones who interpret and arrange the information they receive, which they then fit around the knowledge they had beforehand or they review and reshape their prior knowledge based on newly-learned information (Van Dijk et al., 1983). Therefore, the role of teacher has changed drastically to a facilitator of learning instead of the exclusive source of knowledge. This role of a
facilitator imposes on the instructor to make every effort to provide information in various different ways according to the requirements of the learners in order to advance their language skills and improve their performance (Warschauer and Healey, 1998).

The preparation and design of CALL materials is normally informed by principles of language education and methodology. These guiding principles can be drawn from various learning theories (behaviourist, cognitive, constructivist) and second language learning theories, such as Krashen’s monitor hypothesis. In recognition of this, the different theories of language learning in a CALL environment will now be discussed including how they influence second language acquisition.

### 2.4.1 Rote Learning

In RL, computers become timesaving tools that also offer the opportunity for immediate feedback. As stated above, RL is based on a behaviourist perspective of language theory, and in language teaching, this generally correlates with the audio-lingual approach. The main aim of rote learning through drill and practice is to review content or background knowledge, as well as to assist learners in mastering separate language skills. Drill and practice consists of three steps: stimulus, active responses from the learner, and the provision of immediate feedback.

When properly designed, these programmes can record a learner’s progress and the time spent on each exercise. It is also possible to add timing features in order to manage their speed while practising. In the early years of CALL programmes, rote learning based drill and practice was produced by classroom teachers and focused on separately developing language skills and components such as grammar, vocabulary, and particular skills such as reading. Limitations of these exercises include a lack of interaction and the use of content materials that are not authentic, meaningful, and contextualised (Felix, 1998). This may be the reason that it is widely believed that the accessible language drill and practice programmes of the 1960s and 1970s did not produce sufficient authentic communication opportunities for students. (Warschauer and Healey, 1998)

### 2.4.2 Monitor Hypothesis

The monitor hypothesis (also known as the input hypothesis) has become increasingly influential in several CALL applications. The Input Hypothesis is a mind-centred theory that holds acquisition results “from exposure to meaningful written and aural input” (Col-
lentine, 1998). Given that the principles of the Input Hypothesis are currently being questioned, this means that the efficacy of relevant applications should also be re-evaluated. As Salaberry states:

“Krashen’s theoretical approach does not invalidate the pedagogical value of those CALL programs. However, it does raise some concerns about the validity of embracing such a monolithic approach in a field of inquiry with so many theoretical perspectives. More specifically, the history of support of Krashen’s perspective is not comforting considering the fact that many researchers have argued forcefully against Krashen’s hypotheses” (Salaberry, 1996, p. 9).

A number of studies have shown that the input frequency of certain grammatical structures has a positive correlation to second language acquisition. This would seem to indicate that input frequency is an important factor. In terms of CALL, the information input load is larger than in a traditional setting. However, the input frequency of a specific word or grammatical structure is likely to be better in traditional settings than in early stages of CALL because the teacher can purposefully repeat the target language. In a sense, multi-dimensional input can therefore be helpful in maintaining the attention of learners to a structure or a word, with hyperlinks to ensure the availability of supporting knowledge (Beatty, 2013; Li, 2011).

Swain (1985) argues that comprehensible output can help acquisition, with learners being pushed along the continuum of acquisition. However, the output cannot be independent of communication (Ellis, 1994). In this sense, CALL offers learners more authentic communication, with multimedia offering learners of different competence levels greater opportunities regarding communicative topics. This authenticity can increase the interest of students and therefore promote their desire to speak.

Comprehensible input facilitates second language acquisition, although it is not necessarily universally essential. For example, it has been claimed that in non-interactive mode, speech rate, elaborative modifications and bimodal input of spoken and written language can affect comprehensible input, which influences second language acquisition (Ellis, 1994). The input from CALL is also a viable way to precisely adjust speech rate to meet the real language competence of learners, while simultaneously enabling repetition, explanation and replacement with synonyms in order to facilitate comprehensible input. CALL seems to be highly effective in the adaptive input of spoken and written language, which is almost impossible for teachers (Li, 2011).
2.4.3 Constructivism

Constructivist learning principles hold that online learning and teaching of languages may be an effective way of promoting language and communicative skills, in addition to fostering learner autonomy, giving improved opportunities for self-study and collaboration. These asynchronous learning environments can give students the time to research and acquire the necessary skills for further knowledge construction. The acquisition of these social and interactive skills contributes to their development into more confident, proactive, responsible and social individuals (Tuncer, 2009).

This perspective argues that students are more likely to learn for themselves when solving real life problems and achieving goals in groups, effectively functioning as micro-societies. These programmes therefore seek to create language interaction in the form of problematic situations or conditions that learners can solve through their decisions. For this reason, many simulation programmes are entertaining and educational problem-solving games (Jonassen et al., 1995). The formation of societies in the classroom seeks to encourage learning by simulating solutions to real life problems. As an example of this, in an early simulation problem solving game, Oregon Trail (1995-1998), students make a number of decisions to guide a wagon from Missouri to Oregon. These decisions begin with choosing a departure date, through the daily decisions relating to pace, restocking and direction. The learners face a series of obstacles: fires, floods, injuries, lack of water, bad-quality water, lack of grass, food spoilage, etc. The learners have to make decision in simulated life-or-death situations. Though Oregon Trail is not directly designed for English Language Teaching ELT classes, the teacher can create learning activities in both receptive and productive skills. Simulations and problem solving are utilised in order to foster analysis, critical thinking, discussion and writing activities, as well as comprehensive negotiation of meaning (Dalgarno, 2001).

An examination of some of the existing and potential connections between foreign language methodology and CALL (Arnold and Ducate, 2006) highlighted the positive and negative aspects of learning theories from behaviourism to constructivism, especially in the way they have been manifested in CALL activities. They note that new computer-mediated communication (CMC) tools, now popular among the younger generation (chat, blogs, podcasts), offer their users multiple ways to interact with, and process information with, one another and with experts, facilitating a constructivist approach to language learning. CALLs have the ability to collect, analyse, and disperse information in fast, sys-
tematised ways that can present students with large quantities of authentic, comprehensible input. CALLs also encourage learners to express themselves in their foreign/second language in such a way that they develop higher level language skills related to cultural interaction, social relations, and cognitive strategies, which are an integral part of language instruction in the future (Luke and Britten, 2007).

One of the most important implications of constructivism is that the students are encouraged to use reflective thinking to control, assess and reflect on their achievements. That leads into a discussion of reflection as language-learning theory, which this CALL tool will be based on.

### 2.4.4 Reflection

Reflection is mentioned and discussed in all language learning theories. Indeed, highlighting the signification of reflection in learning may be the most important single message of cognitive research. Ryan (2013) argues that reflection is a commonly expected process in higher education, formally, in the case of assessments, and informally, when reflecting on, and adopting, feedback. The process of reflection, also known as reflective practice, has a long history with philosophy at its root, and this can be found in particular in Dewey’s (1933) accounts on reflective thought for the purpose of personal and intellectual development. Another pioneer in the area of reflective practice is Hegel (2012) with his ‘sensible history of the mind’ in the domain of phenomenology. He proposed the idea of progressive understanding of human experience in life, which continuously rises in its meaning and complexity. This is because thinking and experiencing life is a phenomenon that is understood and assimilated in a personal and conscious manner. Dewey’s learning theory revolves around the idea that meaningful connection is established based on reflection. Dewey (1933) argues that learning is essentially a “reconstruction or reorganization of experience, which adds to the meaning of experience” (p.76). The concept of reflective learning refers to the host of processes which allow learners to derive meaning from life experiences in connection to themselves, their surroundings, and the range of continuous experiences that occur prior to, or after, the experience in question. Therefore, reflection serves the purpose of rendering the learning process discernible to the learners themselves, and hence, increasing its availability to be deepened, enriched and connected to personal understanding. Carol Rodgers writes:

“The function of reflection is to make meaning: to formulate the ‘relationships
Drawing on Dewey’s work, Rodgers proposes that understanding of oneself is formed and shaped by profound reflection, and that the reflective practice can be assisted or precluded by affective reactions. Therefore, this reflective process is an essential component that contributes to guidance of students through development on personal, academic, professional and other levels. Reflection provides depth to processes, assisting learners to critically evaluate previous experiences, assess aims and choices, formulate informed decisions, and obtain and adopt feedback (Eynon et al., 2014).

Arguably, technology-based tools, audio and video resources, and books, among other learning materials, are only able to make information available to learners. Undeniably, learners themselves take on the task of learning using a range of intellectual processes that are involved in thinking. These intellectual processes can be made possible through learning activities based on instructional tools, including computer-based technology. As stated by Jonassen (1992), a more effective strategy to improve learning may be to concentrate efforts on developing methods that learners can adopt for more effective thinking when completing tasks, instead of fixating on making complex learning devices. Said differently, computer-based technology can be best used to offer learners effective thinking tools that aid their thought processes. In this way, these technologies should be able to activate methods of cognitive language learning, directing students to knowledge creation and organisation. Reflection on a student’s personal learning should be a continuously required process, and therefore, an integral component of this research is to provide learners with assistance to reflect better; for instance, it is not sufficient to learn the use of a preposition, but rather, the student is encouraged to think about the reason for using the preposition in one instance and not in another. Some of the provided feedback is graded (you erred here and there...), and enables the students to reflect about their performance. This practice is consistent with Rodgers’s idea that learner’s self-understanding is shaped by reflection. It is a common belief that reflection is merely an unclear and unorganised thought process; however, Rodgers, consistent with Dewey, discusses that “reflection is a systematic, rigorous, disciplined way of thinking, with its roots in scientific inquiry.” (Rodgers, 2002), p.845) She arranges the structure of Dewey’s ideal reflective thought procedure, starting
from experience to narrative portrayal, followed by analysis and concluding with applying the acquired insight to making and developing new, exploratory actions (Eynon et al., 2014). Learners are, therefore, able to critically analyse the activities and practices involved in their learning process. As an example in this work, the developed CALL tool enables a learner to become more aware of the differences in using different prepositions. Hence, this highlights the requirement to offer the chance to Arabic learners to reflect on, analyse and describe the learning experiences they have when they use the developed tool, which is assisted by providing the learners with gradual, structured feedback which prompts them to think on (why they chose this preposition incorrectly) and take action to (try to correct their mistakes). This CALL tool is designed and built according to the theories on language learning highlighted above; however, not every CALL programme is based on pedagogical learning theories. Indeed, some tools are classified as atheoretical, which means that they do not originate from, and are not connected to, relevant theoretical frameworks. This is applicable in particular to several commercial tools, as highlighted below.

Since reflection is crucial component of the learning process, it follows that diagnosing errors represents a key element in pedagogical strategies. Consequently, as one of the components of our CALL tool is providing students with diagnostic error messages, we therefore give a brief outline of error diagnosis.

2.5 Diagnosing Errors

Detecting errors of second language learners is an important component of the learning process for theoretical and pedagogical purposes. However, the process of identifying these errors seems, in itself, to be overwhelmingly intuitive and, therefore, difficult to explain. The only existing methodical and imitable approach is likely the process of error identification proposed by (Corder, 1973).

Corder (1973) suggests that error analysis serves two objectives: a theoretical one and an applied one. The theoretical objective is to validate theories; in other words, this concerns the psycholinguistic theory of transfer. The applied objective is related to pedagogical purposes. The analysis of errors can lead to the identification of the nature of challenges and obstacles that face L2 learners, and this in turn makes it possible for teachers to change their approach to teaching and to assess their teaching resources. Corder
“Errors provide feedback; they tell the teacher something about the effectiveness of his teaching materials and his teaching techniques, and show him what parts of the syllabus he has been following have been adequately learned or taught and need further attention. They enable him to decide whether he can move on to the next item on the syllabus or whether he must devote more time to the item he has been working on.”

Richards (2015) argue that error analysis, in pragmatic classroom experience, continuously provides a tool for teachers to evaluate learning and teaching and shapes priorities of future efforts. Diagnosing errors made by learners represents an important task for teachers, learners and researchers for several reasons (Izumi et al., 2005; Corder, 1982). First, identified errors can offer teachers hints and clues about the degree to which the students have effectively assimilated the language system and what is still required of them to learn. In addition, making and identifying errors can be one of the most effective learning strategies for learners, which can serve to assess the inter-language theory that learners have built (Izumi et al., 2005).

Five sources of error have been reported by Selinker (2013): language transfer, training transfer, second language learning strategies, second language communication strategies, and overgeneralisation of Target Language (TL) linguistic materials. However, Corder (1975) determined three sources: language transfer, analogy or overgeneralisation, and approaches or materials used in instruction (teaching-induced error). In addition, Richards (2015) identified seven sources: language transfer, intra-lingual interference, sociolinguistic situations, modality, age, successions of approximate systems, and universal hierarchy of difficulty. It can be argued that these sources of error tend to overlap leading to further complexity.

Our system can be used to analyse errors made by learners, which can also serve as a diagnostic tool that provides the students with diagnostic messages about the errors, specifying whether the reason is a mistranslation of open words or misuse of prepositions; this process is explained in more detail in Chapter 5. This CALL tool is designed and made based on the theories of language learning discussed previously; however, not all CALL programmes are built according to pedagogical learning consideration. Indeed, there are certain tools which are classified as atheoretical, which means that they do not originate
from, and are not connected to, relevant theoretical frameworks. This is applicable in particular to several commercial tools, as highlighted below.

2.6 Atheoretical Systems

This section discusses a few commercial software tools that help to learn Arabic online without the assistance of a teacher: Byki Express, ArabicPod 101 Software, and Declan Software.

2.6.1 ByKi Express Language-Learning Software

ByKi Express language learning software is a useful product for beginners to learn Arabic as a foreign language. Many other language-learning programmes start by teaching grammar, but Byki is different. It leverages the fact that adults learn foreign languages by collecting words and phrases in their memory. It teaches the most important Arabic words, phrases, and accents using native speaker sounds.

2.6.2 ArabicPod101 Software

ArabicPod101 is a supportive commercial software tool for learning Arabic that contains lesson transcripts and learning materials. Lessons in this software are well organised and designed to address selected difficult aspects of learning the Arabic language, such as the letters that are typically associated with pronunciation issues and cultural colloquial expressions. The dialect taught on this podcast is ‘common colloquial’ Arabic, common to all Arabic dialects, as well as Standard Arabic. It is available as a mobile app, desktop software and a website.

2.6.3 Declan Software (Learn Arabic)

This is a commercial multimedia Arabic teaching software programme for beginners. This software helps teach over 1600 common Arabic words and expressions using native speaker audio. Arabic Declan has an easy to use, point and click interface that enables a user to listen to pronunciation, record their own voice, and then compare it to native speakers. Users are also able to watch animated illustrations of how letters are written, teaching them how letters are joined into words and then how to read words and sentences. This programme includes flashcard review and exercises to aid memorisation.
2.7 Conclusion

This chapter set out to provide a background discussion on the topics needed for this research. These topics covered the research aim of developing a CALL tool based on language acquisition and learning theories. Following this review of the concept of CALL and of some atheoretical systems, the linguistic and computational description of English and Arabic CCIs will be discussed.
Chapter 3

Closed Class Items

3.1 Introduction

In linguistics, the term ‘closed class’ refers to those groups of words that generally have a small number of items, and which cannot have new items added to them. Common examples of this in many languages are “adpositions (prepositions and postpositions), determiners, conjunctions, and pronouns” (Akmajian et al. 2001, p.22).

This chapter provides an overview of the linguistic and computational description of English and Arabic closed class items (CCIs), particularly spatial prepositions by examining the properties of CCIs and identifying the characteristics that make English and Arabic CCIs hard to learn.

3.2 Prepositions

Prepositions are grammatical words or function words that mainly contribute to the grammatical structure of a sentence (Thornbury, 2006). Essentially, prepositions explain how the ideas in a prepositional phrase relate to the remainder of the sentence. They seem to be used in two distinct ways. Prepositions can have the same purpose as case in that they indicate the spatial and similar relationships that exist between things,(Rieux and Rollin, 1975), as explained in greater detail later (see subsection 3.3) but also can be used as a case marker to indicate the role that an object can play with in an event. The majority of prepositions can fulfill multiple functions (Swan, 2005). According to Allsop, “prepositions are words which show relationship between things, people or events” (1986, p.105). Prepositions describe relationships between things in terms of time or space, as
well as “purpose, possession, and result” (Allsop, 1986, p.107), or as Kosur explains, “time, possession, accompaniment or comparison” (2009). Most commonly prepositions modify sentences by providing information about place or time (Byrd and Benson, 2001). In English, the most frequently used prepositions are simple and comprise a single word (such as at, in, on and for). Although complex, multi-word prepositions are also extremely important (such as along with, away from, out of, up to) (Quirk et al., 1985).

Most prepositions are highly polysemous and they can also be involved in a large number of metaphorical uses (approximately 40% of the use of prepositions is metaphorical). Jamrozik and Gentner hold the view that analysing the semantics of prepositions is a rather delicate and risky task, but of much importance for any application that requires even a simple form of understanding. Essentially, spatial and temporal prepositions have received a relatively in-depth study in a number of languages (Steen et al., 2010; Jamrozik and Gentner, 2011).

Moreover, representation of the meaning of prepositions requires illustrating the idea of geometric relationships in the case of spatial prepositions, as shown in Figure 3.1 (Jamrozik and Gentner, 2011). According to Kalita and Badler, “geometric constraints provide information regarding how one or more objects or sub-parts of objects relate to one another in terms of physical contact, absolute or relative location, inter-object distance, absolute orientation or path of motion” (Kalita and Badler, 1991, p.105).

Figure 3.1: The meaning of some spatial prepositions illustrated by pictures (Jamrozik and Gentner, 2011)
Prepositions in many languages are presented in terms of their form, meaning, and use. It has been argued that one of the most significant challenges in teaching prepositions is providing understanding of their meaning, which can be much more complex than teaching form, with uses that seem to be counter-intuitive or even contradictory in the case of some multi-word prepositions (Celce-Murcia and Larsen-Freeman, 1999). This necessarily creates difficulties in using prepositions as there may be situations in which many prepositions may be viable choices, with small or even no difference in outcome, such as some uses that signify time/period; for instance, ‘it happened in/during 2008’.

3.2.1 Form

As prepositions perform formal functions in language, a complete understanding of their function requires the examination of their form, with particular attention to three key elements: transitivity, case marking and cliticisation.

3.2.1.1 Transitivity

Many words that are described as prepositions can be used as other parts of speech, such as noun, adjective and adverb (Biber et al., 1999), therefore, the decision about whether a word is a preposition is dependent on its use. In English, these rules of usage are often complex, with the choice of what a word is doing potentially being a matter of ensuring accuracy (Wahlen and Acock, 1995). Indeed, this complexity of prepositions has caused a number of problems for teachers and students in learning English as a second language (ESL). This is compounded by the many similarities in form that exist between prepositions, particles and adverbs. Therefore, in order to see how prepositions, adverbs, and conjunctions are linked, it is necessary to consider transitivity and the arguments that an item can take. To see what this means, we start by looking at transitivity patterns of verbs.

A verb has various constructions that differ according to its given sub-categorisation frame. Some verbs can be (3.1a) intransitive, requiring only a subject; (3.1b) transitive, requiring one object; (3.1c) ditransitive, requiring two objects; or (3.1d) sentential complement, requiring a sentence as its complement. See the examples in (3.1)

(3.1) (a) I have already eaten. (Intransitive)

(b) I have eaten your dinner. (Transitive)

(c) He told him a story. (Ditransitive)
(d) He told me that he had seen a dragon. (Sentential complement)

In much the same way, the differences between the prepositions and adverbs can be characterised in terms of transitivity, as highlighted in the following examples.

(3.2) (a) Down the stairs / downstairs / He fell down.

(b) Under the ground / underground.

(c) I got up this morning.

(d) I got up the stairs.

In examples 3.2 (a, b) above, down the stairs / under the ground are prepositional phrases with down / under as prepositions, whereas downstairs / underground are said to be adverbs. From the perspective of transitivity, these adverbs can be treated as intransitive prepositions rather than transitive prepositions, which require the selection of a complement. Some adverbs clearly originate from the combination of a given preposition and its complement, while other prepositions have adverb-like functions and no complement, as in the example: He fell down, where down is an adverb. This means that prepositions require an object, whereas adverbs do not.

Additionally, in examples 3.2 (c, d), it can be seen that when a word is used as a preposition, the entire prepositional phrase acts as an item that modifies the verb. This is clearly illustrated in (3.2 c), where up is an intransitive prepositions acting as a spatial modifier and this morning is a separate temporal modifier, and the single phrase ‘up the stairs’ is spatial modifier on ‘got’. These words are the headwords of modifiers; they can have no daughters, or they can have noun phrase (NP) daughters and sentential daughters in exactly the same way that verbs can have no complement, NP complements or sentential complements.

This proves the close relationship that prepositions have with particles and adverbs, while simultaneously highlighting the key differences “in their syntactic distribution” (Rauh, 1993). Likewise, it has been argued that an overlap exists between prepositions and conjunctions that can be treated as prepositions, such as before, after and since. Al-
though people might use different terms for these types of words, they basically do the same job, for example:

(3.3) (a) I have had a cold *since* the end of the summer.
(b) I have had a cold *since* the summer ended.

As can be seen from the examples in (3.3), exactly like a verb can take NP complements or sentential complements, in an identical structure, we have two modifiers headed by *since*. The first parts of these sentences are identical with the head daughter of *since* being the end of the summer and the summer ended, respectively. These have the same meaning; *since* here is introducing the temporal modifiers in both sentences and determining some description of time. However, the head daughter of the end of the summer is a noun, while the head daughter of the summer ended is a verb, which is why the form of *since* in this example is called a conjunction. Nevertheless, when considered in terms of its actual function in these sentences, *since* is doing the serving the same purpose: identifying when the speaker caught a cold.

In this subsection, several concepts were introduced to discuss how prepositions, adverbs and conjunctions are linked in terms of transitivity. The subsection that follows moves on to consider the similarity between some prepositions and morphological case markings.

### 3.2.1.2 Case Marking

Previously, we discussed how prepositions are used to add spatial or temporal relations, which is optional, extra information to describe a particular situation. However, the examples below illustrate the idea put forward by Rieux that prepositions fulfill the same function as case, which is not to provide additional information (Rieux and Rollin, 1975). There is a high degree of similarity between some prepositions and morphological case markers. Certainly, it is possible for prepositions in one language to be exactly compatible with case markings in another language. Indeed, agreement morphology describes case as a morpho-syntactic feature of both English (nominative and accusative) and Arabic (nominative, accusative and genitive). Both prepositions and case markers allow relations between various elements in the sentence to be shown.

The expression ‘prepositional case’ can be completely inappropriate in some languages
because the forms of nouns that are chosen by prepositions can also occur in other non-prepositional contexts (Ramsay and Schäler, 1997). In English, for example, both prepositions and verbs require their complements to take the accusative case, while in Arabic, prepositions can govern the accusative or genitive, neither of which is only associated with prepositions. According to Dryer (2005), “many languages have case markers which are not separate words phonologically, but whose position is still determined syntactically”, and Arabic is one of these languages, as shown in the examples in (3.4) below:

(3.4) (a) OnA OETythu hdyp. / I gave him a present.

(b) OnA OETyt hdyp lhu. / I gave a present to him.

In these examples, I is the agent of the event, him is the recipient, and a present is the object. In both examples, the subject must be the agent. In the second example, the argument him was assigned through the use of the case marking to, to clearly mark the recipient, which shows the use of case marking rather than the use of a preposition.

In example (3.4b), we can see how Arabic uses the genitive case lhu, which is a case marker that is attached to a modifier of the noun. Here, it is treated as an instance of a preposition, since it combines syntactically with a noun phrase, despite not being a separate phonological word. While English achieves this by word order (3.4a), it can also use prepositions like to, as in example (3.4b), as a type of case marking.

Although there is a functional similarity between prepositions and case markers, these items are different grammatical categories. Prepositions group syntactically with their complement phrase, which can be of many different categories, while case markers primarily group together with the noun category, to which they attach morphologically (Dryer, 2005). Having discussed transitivity and case, we now turn to the discussion of cliticisation, and how prepositions can be treated as a prepositional clitic.

3.2.1.3 Cliticisation

Cliticisation occurs in morphology and syntax. A clitic is a type of morpheme that has “the syntactic characteristics of a word, but depends phonologically on another word or phrase” (Schulze, 2004, p.107). Hamdallah explains that Arabic prepositions are divided into two morphological classes: the first are called attached prepositions, and are comprised of a consonant and one short vowel, which are used as clitics or prefixes to the complement;
the second are called detached prepositions (Hamdallah and Tushyeh, 1993). Both classes are shown in Table 3.1 below.

Table 3.1: Types of Arabic prepositions (Hamdallah and Tushyeh, 1993)

<table>
<thead>
<tr>
<th>Attached Prepositions</th>
<th>Gloss</th>
<th>Detached prepositions</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>b</td>
<td>at, by, in, with</td>
<td>fy</td>
<td>in</td>
</tr>
<tr>
<td>k</td>
<td>as, like</td>
<td>ElY</td>
<td>on</td>
</tr>
<tr>
<td>f</td>
<td>then, in</td>
<td>mn</td>
<td>from</td>
</tr>
<tr>
<td>t</td>
<td>by (in swearing)</td>
<td>IlY</td>
<td>to</td>
</tr>
<tr>
<td>w</td>
<td>by (in swearing)</td>
<td>End</td>
<td>at</td>
</tr>
</tbody>
</table>

In Arabic, attached prepositions affix to direct object pronouns, indirect object pronouns or noun phrases (NP). The forms that attach to words usually end in a short vowel, as in the example (3.5) below.

(3.5) Aklt AlTEAm bAlmlEqp. / I ate food with a spoon.

In this example, the preposition \( b \) can be treated as a prepositional clitic, which attaches to modifiers of the noun, AlmlEqp / spoon. In English, this phrase occurs through the combination of separate words (preposition + noun).

Like Arabic, English has different forms of prepositions which can be treated as attached prepositions or clitics, such as into / onto. These prepositions are written as one word with no gap existing between the words even in spoken language. These prepositions are called compound prepositions and serve to indicate the completion of an action. They are usually used when the preposition is the last word in a sentence or when it comes directly before an adverbial (Stevens, 2009) Thus, the distinction between whether or not clitic words are used has nothing to do with meaning, but rather with pronunciation. See example (3.6)

(3.6) (a) Now what kind of problem have you got yourself into?
(b) Jack threw his keys onto the table.

However, as pointed out in the introduction to this section, prepositions are presented in terms of their form, meaning and use. Having defined what is meant by form in relation to prepositions, I will now move on to discuss their meaning and use.
3.2.2 Meaning and Use

Spatial reasoning is essential to many human tasks. Sharing spatial information and relationships between entities can be achieved through a number of methods, one of which is through the use of prepositions. These types of utterances entail a minimum of two objects, “a reference object (the ground) and a located object (the figure)” (Fortis and Fagard, 2010). These notions were introduced by Talmy (1972) to refer to the located and the locating entity, respectively. The function of a preposition is to describe the relationship between these two items.

Table 3.2: Characteristics of Figure and Ground (Fortis and Fagard, 2010)

<table>
<thead>
<tr>
<th></th>
<th>Figure (F)</th>
<th>Ground (G)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definitional</strong></td>
<td>Has unknown spatial (or temporal) properties to be determined</td>
<td>Acts as a reference entity, having known properties that can characterize the Figure’s unknowns</td>
</tr>
<tr>
<td><strong>characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Associated</strong></td>
<td>More movable</td>
<td>More permanently located</td>
</tr>
<tr>
<td></td>
<td>Smaller</td>
<td>Larger</td>
</tr>
<tr>
<td></td>
<td>Geometrically simpler</td>
<td>Geometrically more complex</td>
</tr>
<tr>
<td></td>
<td>More recently on the scene / in awareness</td>
<td>More familiar, expected</td>
</tr>
<tr>
<td></td>
<td>Of greater concern / relevance Less immediately perceivable</td>
<td>More immediately perceivable</td>
</tr>
<tr>
<td></td>
<td>More salient, once perceived</td>
<td>More backgrounded, once</td>
</tr>
<tr>
<td></td>
<td>More dependent</td>
<td>More independent</td>
</tr>
</tbody>
</table>

Table 3.2 shows the characteristics distinguishing figure (F) from ground (G), which makes the issue of asymmetry quite clear. Although many prepositions have converses (in front of / behind, OmAm/xlf ... etc.) and some are symmetric (near, qryb ... etc.) the two possible designations of the roles of subject and object of the preposition are not equivalent. This means that the ground or reference object will be large and fixed with respect to the figure or located object. See the following examples.

(3.7) (a) The house is near the car. / Almnzl qryb mn AlsyArp.

(b) The house is near where the car is. / Almnzl qAryb mn mwqE AlsyArp.

The example (3.7 a) above is not acceptable, even if the addressee knows the place where
the car is parked. The correct sentence expressing this situation would be as in the second example. In (3.7 b), a fixed reference entity (a place) is used instead of the typically mobile car. This means that F and G are both assumed to be key factors in identifying a location.

According to Ramsay (2005), prepositions are widely used in many natural languages to denote the relationships between various kinds of entities, as we discussed in the introduction, including physical entities and their locations in space, temporal entities and their locations in time, and abstract entities in a variety of ways (such as between ‘ideas’ and their ‘mental locations’ (Ramsay, 2005). Consider the following set of sentence:

(3.8) (a) I met Jon in the park.
(b) I met him in May.
(c) I have got an idea for a paper about time in my mind, but I do not know how it will work out.
(d) I have got 230 people in my AI class next term.

As seen in (3.8 a), the G for the relation denoted by the PP is a physical location; in (3.8 b) it is a temporal location; and in (3.8 c, d) it seems to be some sort of abstract entity. All of these examples provide a useful account of how the prepositions affect the meaning of a sentence, particularly in terms of the perception of the temporal structure of a given event, which occurs from the interplay between the core meanings of a preposition being combined with the particular properties of the particular entities that are being related. The key observation here is that most objects can be seen from multiple points of view. The following sections outline an exploration of the terms: spatial prepositions and spatial metaphors.

### 3.3 Spatial Preposition and Spatial Metaphors

A very common characteristic of spatial prepositions is that they are extremely polysemous. In particular, locative prepositions provide categorical description of relations in space (Pinker, 2007; Talmy, 2000). The English language offers schemes of space to describe location in a specific manner by using the locative prepositions: *at*, *on*, and *in*. *At* defines a zero dimensional position in space in relation to a certain location; *on* provides a meaning of contact, in which an object shares a relation of support with a two-dimensional
surface; whereas *in* signifies a relation of an object being contained in a three-dimensional area in space.

These prepositions are used to describe relations both in space and time (for example, in the room / in March), a feature shared by other languages including Arabic. These spatial and temporal relationships have been examined in relation to the metaphoric mapping theory, which argues that individuals possess a cognitive propensity to conceptualise temporal relationships based on their spatial meaning by metaphorically superimposing time on space (Kemmerer, 2005).

Therefore, this concept is intended to play a key part in the applications carried out in this study; particularly, that an object can be viewed as belonging to various types of metaphorical space. In other words, when a preposition is used to link two objects, a common space must be found to contain those two objects. The general idea, therefore, is that prepositions pick out ‘compatible views’ of the figure and ground and relate entities of those ‘selected views’. Later in Chapter 4 (Section 4.5.2), a more detailed discussion will follow on how our meaning is postulated based on finding these ‘compatible views’ for entities to be located (subsection, 4.5.2).

According to cognitive linguistics, conceptual or cognitive metaphors are frequently adopted to conceptualise ideas and theories. A cognitive metaphor bases an idea on another by forming a link between the two to facilitate comprehension. Lakoff and Johnson (1980) are reported to have pioneered the use of this term in their book ‘Metaphors we live by’, in which they proposed that cognitive metaphors not only define the way we communicate but also direct our thinking and behaviour. In this line, Johnson (1987) argues that having meaningful cognitive metaphors requires the understanding that embodiment experience causes image schemas to exist in a cognitive system. These image schemas are built based on a set of sensory and perceptual experiences that come from our interactions with our surroundings and changes in our relationship with the world. To illustrate this point, since humans move in an upright position, with their heads at the top and legs at the bottom of their bodies, and since gravity attracts objects that are not supported, it follows that the human body shows functional asymmetry along its vertical axis. This means the top and bottom parts of the human body are asymmetrical, i.e. they have different features.

An image schema is characteristically a recurrent framework in the conceptual processing system which builds trends and patterns of comprehension and logical thinking.
based on experiences of our body's physical interactions. Modern cognitive linguistics defines image schemas as a pre-linguistic embodiment of experiences that gives rise to the processes of cognitive metaphor mapping. The link established between the embodied experience of an individual and their cognitive structure provides the theoretical basis of image schemas. The basis of image schemas is a fairly conceptual representation of our daily interactions and connections with our surroundings. Image schemas tend to be less specific and more illustrative as they propose representative trends originating from image-like areas or fields, for example a container/enclosure, a trajectory/path, a connection/link, or a balance/equilibrium, all of which are recurrent in various embodied domains and shape our physical experience (Croft and Cruse, 2004). Since image schemas occur due to interactions with real world surroundings, they have a tendency to be naturally meaningful with inherently predictable implications (Evans and Green, 2006). Furthermore, image schemas have the ability to generate very specific ideas that reflect certain characteristics of the schema in question. The present study proposes to use this concept as a theoretical basis to support establishing a level of comprehension of the characteristics of prepositions (Tompkins and Lawley, 2009).

Despite the emergence of a substantial amount of new information in the image schema discourse related to the basic domains, such as a container, a path/trajectory, and surface/plane, one crucial element is to establish a clear idea about schemas. These domains will now be defined in relation to the concepts of prepositions.

- **A Container** implies the existence of an interior, an exterior, and a territory/boundary (Figure 3.2), which are the basic prerequisites to have an enclosed space and to fulfill the concept of containment Lakoff (1987).
The diagram in Figure 3.2 does not specifically look like any container in particular but provides a meaning of containment nonetheless. The theoretical basis of such representation is taking the meaning of the image to its plain essence by maintaining only the characteristics common to all the models under the concept of containment.

Let us now consider the following example of the Container schema lexicalised by the preposition *in*:

The image schema in Figure 3.2 shows the general idea of containment; the schema in Figure 3.3 shows how the preposition *in* makes use of this idea for location with respect to such a Container. This means that *in* as preposition is often used for locating an F entity with respect to G if G has a suitable interior, and in order to have an interior, G needs to be a type of Container.

For a preposition to signify location of one entity with respect to another, the entities in this example have to possess the right properties. In other words, *in* means that (the selected view of) G has an interior which encloses some region in the relevant space, and
that every part of (the compatible view of) F is contained in this region.

- **Path** represents a type of composite image schemas of the Source-Path-Goal, or in
  simple terms, Path schema (Figure 3.4).

![Figure 3.4: Path image schema, (Tompkins and Lawley, 2009)](image)

As seen in Figure 3.4, Path schema implies real or otherwise metaphorical motion from
one location to another, and comprises a point of origin or a source, a point of destination
or a goal, and a set of locations in between, a Path (Johnson, 1987).

![Figure 3.5: The prepositions from and to used to indicate the start and end points in a
path image schema](image)

Applying the Path (P) embodied schema to our perspective in relation to P, which we
intend to use for the link entities of prepositions using P, or part of it, in their definition.
A Path is a set of two-dimensional points. It has a start and an end point; for any two
points in P, there is another point in between that lies in P. Therefore, a source, which
underlies the concept of *from* as preposition, is location F with respect to G, if G is the
start point for F and vice versa with the GOAL or preposition *to*, G needs to have an end
point in its properties.
• **Point** is an integral element of the Path image schema since a Path is a series of points of one-dimensional properties. Each point represent an exact single location in the P. At can be shown, in Figure 3.6, to denote a one-dimensional illustration of location, which expresses the location of a certain entity as being at particular point (Snider, 2010).

![Figure 3.6: The preposition at as a Point in a Path embodied schema (Reproduced from Kranjec et al., 2010)](image)

• **Surface** embodied image schema refers to a two-dimensional area or field, usually flat. Normally, this image schema means the outer surface of an object. Surfaces are essential in providing the basis of support relations (Figure 3.7).

![Figure 3.7: The preposition on as a Surface embodied schema (Reproduced from Kranjec et al., 2010)](image)

Figure 3.7 is a meaningful illustration that preposition ‘on’ names relationships that involve contact between the F and G (Kranjec et al., 2010). In our perspective, ‘on’, says that the (selected view of the) G has an orientable surface, and that the (compatible view of the) figure has a set of contiguous points that lie an arbitrarily small distance from the surface.

Schemas represent patterns that are meaningful and dynamic, with relevance to real life thought and behaviour, and therefore, they enable us to conceptualise our experiences, emotions and observations. Schemas tend to appeal to a common intuitive notion of space without actually explaining what the notion is. Therefore, although they are helpful for
understanding concepts, they cannot actually be used as a basis for any kind of automated reasoning, but this notion can be used as a basis for writing meaning postulates, which we will later describe in more detail in Chapter 4. We now turning to discussing the difficulties faced by the learners when they learn English and Arabic prepositions.

3.4 Why is Learning Closed Class Items Difficult?

Due to a number of different factors, learning closed class items (spatial prepositions), is one of the most problematic issues for learners of English and Arabic languages (AlYaari and Almaflehi, 2013; Alayesh, 2012; Hasan and Abdullah, 2009). These factors will be discussed below:

3.4.1 Partial Overlap

One of the most notable difficulties facing learners is correct use of closed class items as there is often partial overlap between items. Langendoen states that: “the same relation may be introduced by a variety of prepositions and the same preposition may be used to introduce many different relations” (1970). This demonstrates that meaning can be described through the use of multiple prepositions while, at the same time, one preposition can be used appropriately in a number of different contexts and descriptions of meaning.

Early studies in English as a second Language (ESL) identified understanding the functions and uses of prepositions in English as being one of the main challenges faced by students, with the majority of their learning being dependent on memorisation and practice rather than on developing mastery of their use based on intuition. Takahaski (1969) even claims that if intuition is essential in the correct understanding and usage of prepositions, then only a small proportion of ESL students will ever become accomplished in their use.

From these discussion points, it may be possible to translate a given Arabic preposition into one of many English prepositions, and vice versa. AlYaari and Almaflehi (2013) propose that the issue of relevance here is not only in recognition of the corresponding preposition, but extends to awareness about its use in Arabic communication. This assertion can give rise to several complications for students because errors in translating the meaning of a certain preposition can lead to using a preposition that fails to deliver the corresponding meaning, usually resulting in missing the intended meaning or overlap with other meanings that are implied but not intended.
3.4.2 Relational Meaning

It has been claimed that many native English speakers cannot provide logical explanations for the particular use of a given preposition in a particular situation, particularly in terms of providing reasons for why a given preposition is correct, while others are not (Takahaski, 1969). This may be because it is difficult to explain the meaning of a certain preposition without using the preposition itself. This non-reducible nature of prepositions means that it is difficult to express their inherent ideas in a more simple way. For example, any explanation of the meaning of the word *on* will tend to rely upon describing something as being ‘*on* a surface or above it’.

Indeed, in English the meanings of prepositions can often be unpredictable, in that the linguistic context plays a crucial role in determining the choice and use of the preposition. As an illustration of this, the Oxford English Dictionary (Dictionary, 2010) provides nine separate meanings for the preposition *in*, with each basic meaning having a variety of sub-meanings. Consider some of these definitions;

1. “Expressing the situation of something that is or appears to be enclosed or surrounded by something else”
2. “Expressing motion with the result that something ends up within or surrounded by something else”
3. “Expressing a period of time during which an event happens or a situation remains the case”
4. “Expressing the length of time before a future event is expected to happen”
5. “Expressing inclusion or involvement”

If we look at these definitions we will see that the first two define *in* in terms of enclosed, surrounded or within; but each of these itself will be defined using *in*! Similarly the third definition describes *in* by using *during*, which again will be defined by using *in*. Number 4 does say something slightly different, but 5 yet again just refers to inclusion or involvement. These definitions are seemingly useless because all they say is that *in* means *in*.

Likewise, the Longman Dictionary offers about 30 meanings for the preposition *on*, and there is usually a need in these dictionaries to provide extensive examples to illustrate each meaning (Watson, 1976). According to Mukattash (1984), the collection of possibilities related to prepositions and lexical items do not have a one-to-one correspondence in
English and Arabic. For example, in English we say *laugh at*, whereas in Arabic we say *yDHk ElY* (*laugh on*).

A pertinent reason for this perceived complexity is that ESL students often tend to link the use of prepositions to the preposition system in their native language. As a usual consequence of this tendency, the discrepancies in the number of prepositions between the two languages lead to the absence of one-to-one equivalence between English and Arabic, resulting in complications in the choice of prepositions (Hasan and Abdullah, 2009).

### 3.5 Relations between Arabic and English Prepositions

Several studies investigated differences related to the use of English prepositions out of their normal contexts (Al-Adam, 2011; Charlop *et al.*, 2012; AlYaari and Almaflehi, 2013; Humeid, 2013). These reports discussed that the process of correct mapping of prepositions from English to Arabic represents a very challenging exercise for ESL learners. Despite the fact that Arabic and English have various common features related to prepositions, these items are still different both in terms of use and number, which justifies the difficulty of mapping prepositions across languages. Out of the 20 Arabic prepositions, the main and most widely used ones are five (*fy, mn, ElY, IlY, End*), whereas in the English language, there are 150 prepositions (Alayesh, 2012).

Not only the recognition of which preposition to use is a complicated task, the choice is further complicated by the need to understand its use in the target language, as there are inherent differences in usage of prepositions between Arabic and English. As explained earlier, it is evident that many uses of prepositions are metaphorical extensions of their original spatial meanings. Different languages employ different metaphors, which can make it hard for non-native speakers to choose the right preposition to link two items. From this perspective, the prepositions do not simply relate F and G; they relate some properties of F and properties of G. This means that when we think about items in one of the languages, certain properties are foreground and certain ones are not. As a result, the prepositions partly do not mean the same thing, but partly the way we think about entities is different in the two languages, because of thoughts about F and G themselves.

Therefore, the key element of this project is to provide English learners of Arabic with diagnostic information about their use of essentially spatial prepositions by exploiting the notions described above. The problem is that while a given English preposition may have
a ‘typical’ translation into Arabic, there will be numerous exceptions to this standard translation, and the causes of these exceptions are hard to discern.

Consider example (3.9), where في (fy) and على (ElY) are normally taken to mean in and on, respectively.

(3.9) (a) My office is on the second floor.

(b) مكتبى على الطابق الثاني. (mktby ElY AlTAbq AlvAny.)

(c) مكتبى في الطابق الثاني. (mktby fy AlTAbq AlvAny.)

The natural way for an English person to think of a floor is as a flat surface, with no interior, so that if you want to locate a room with respect to a floor you have to say that the room is on the floor. Arabic speakers, on the other hand, conceptualise a طابق (TAbq) as a container or a region, like a very large room, and hence would say the مكتب (mktb) is inside the طابق (TAbq) rather than on its surface. Why speakers of one language have different ideas of what various everyday objects are like is beyond the scope of the work reported here. It just seems to be the case. What matters is that it does seem to be the case, and it is this underlying conceptual framework that drives the choice of particular prepositions for linking different kinds of F and G. Having defined what is meant by the observation that different events have different sets of related perceptions, we will use this as a theory in the analysis of natural language utterances by constructing a logical forms (LFs) of sentences, which aims to contain the information about CCIs by writing diagnostic rules about words, and then backing this up with a set of postulates related to meaning. This will be discussed in detail in Chapter 4.

3.6 Conclusion

This chapter discussed the linguistic and computational description of English and Arabic CCIs, particularly spatial prepositions, by examining the properties of CCIs and identifying the characteristics that make English and Arabic CCIs hard to learn. Relations between Arabic and English preposition have also been discussed.
Chapter 4

CALL System Architecture

4.1 Introduction

The previous chapter discussed the linguistic description of English and Arabic closed class items (CCIs), particularly spatial prepositions, and the characteristics that make CCIs difficult to learn. In this chapter, we will discuss the machinery of the CALL tool we made, which is going to perform two tasks which are model building and abductive reasoning. Before starting the design of this CALL tool, we believed it would be extremely helpful for our work to have the opportunity to discuss issues relating to this topic with experienced teachers of Arabic as a foreign language (AFL) to find out what learners thought would be most useful, if you want people use a system you should start by finding out what they want.

In this chapter, an account is included of requirements analysis that took into account the experiences of experts in this field, followed by a general discussion covering ‘Parasite’ software, which is the basis of this tool, and finally, the integration of all this machinery, which represented a challenging task, is outlined. To illustrate this mechanism, the system architecture of our CALL tool is detailed in Section 4.4. The implemented tool involved a substantial amount of instruments construction and integration, from writing postulates related to meaning for a large set of open-class words up to converting the output of an abductive reasoner to meaningful diagnostic messages.
4.2 Requirements Analysis

According to Laplante, “requirements analysis is critical to the success or failure of a systems or software project” (2013); this process is important to assist in determining specific feature expectations and identifying users’ needs. It includes those tasks that go into defining the needs or conditions to meet for a new project, taking into consideration the often contradictory requirements of different stakeholders by analysing, documenting, validating and managing software or system requirements (Hay, 2003).

This process involves communication with experienced teachers who know what the system users’ requirements are and what they would like to have. Interviews are a common technique used in requirements analysis. Particularly, when analysing requirements for CALL tools interviews are generally focused upon the perspectives of teachers only because their perspective has the key advantage of collecting a much richer understanding of users’ needs.

To identify much more detail that we needed to be addressed before the main system design went ahead, it was extremely important that CALL tools were designed to be integrated into the students’ overall learning experience. Our work was aimed at developing a tool which would complement the work of a language teacher by providing immediate feedback on exercises involving CCIs (spatial prepositions). It is widely acknowledged that students benefit greatly from such feedback but that it is often not possible for the teachers to supply it on a regular basis. To get more detail about what would be extremely useful we decided to discuss issues related to this area with experienced teachers. We asked teachers not students because: firstly, we believed that teachers knew better about learning than students; and secondly, this tool was not designed as a standalone tool but as part of a curricular plan and we wanted to see how it would complement an existing teacher’s plan. Even though teachers were the focus of this step, we also did a pilot study on the base system to see what students thought; this is discussed in more detail in Chapter 6 (Section 6.2.1).

Despite the fact that interviews constitute a common technique, we could not carry out interviews with teachers because the only place where I could have access to experienced teachers of AFL was an institute for male students, which was not accessible due to the Saudi culture of segregation. Therefore, it was not possible to conduct interviews there and instead we used a structured questionnaire as a substitute. The questionnaire was

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conducted in one language teaching institute for non-native speakers in Saudi Arabia with a sample of ten experienced teachers of AFL. The questionnaire had very strictly defined goals: we needed to know exactly what items cause the most problems, what types of feedback teachers provide, what types of exercise they set, and how they would use a tool like the one we were developing.

The participants received an explanation of the project, and they were made aware of how their participation was important to assist in designing and implementing an effective CALL tool that would help learners of Arabic to understand how to use Arabic prepositions correctly.

Nine open-ended questions to which the participants responded were used to obtain further in-depth information based on their experience about the key difficulties that students faced while they were learning Arabic prepositions. These questions allowed the teachers to express what they thought were the items that cause most difficulty to students. The questions are outlined in order of occurring in the questionnaire as follows:

1. How long have you been teaching Arabic language as a foreign language?
   We asked this question to determine the extent of the respondents’ experience. Gathering in-depth information about the learners’ needs required us to collect this information from experts in learners’ requirements. All participants were experienced in the field; they possessed experience ranging from four to twenty-five years.

2. What are the most significant difficulties that students face while they are learning Arabic prepositions?
   The second question sought to determine the most important aspects of the difficulties that student faced in learning Arabic prepositions. The participants on the whole demonstrated that prepositions usage was an issue for Arabic learners. Also, most of the participants mentioned that most courses were not providing enough exercises and practice tasks about usage of prepositions. Some participants expressed the belief that AFL learners usually tried to relate the use of Arabic prepositions to their mother tongue (MT).
   Moreover, misunderstanding of the correct usage and incorrect transfer from Arabic to English or vice versa was identified as one of the greatest difficulties that faced students. One interviewee stated:

   “We have to depend only on text so that the student will understand the meaning and the usage of the preposition from the context, Intermediate and upper intermediate Arabic learners might be able to recognize the meanings
of the prepositions only when they denote location or time; however, it is very
difficult for them to understand the other terms or phrasal expressions that
include prepositions, for example: ‘for’/‘من أجل’ ‘in this field/في هذا المجال’

Some participants expressed the belief that students neglected the use of prepositions in
the positions they should be used or they changed the preposition which was possible to
change the sentence syntactically or semantically. To be more precise in determining the
items that caused most problems, respondents were asked the third question:

3. In your opinion, what items cause the most difficulties and problems?
A number of items were identified to be particularly difficult, with which students showed a
characteristic lack of knowledge in meaning and usage. Another identified area of difficulty
was confusion between prepositions and other particles and their usage in a sentence, as
well as when some prepositions are used for other purposes, such as (l), which is used as a
preposition but has other functions with verbs and nouns. An interviewee alluded to the
notion of students’ comparing Arabic prepositions with English ones and trying to transfer
meaning from their MT as one of the reasons that often cause this problem. It was also
suggested that prepositions should not be taught as individual words but in context. Very
clear and efficient examples should be used for this purpose.

4. Suppose each student had a 24 hour-teaching assistant (TA) to help them with their
work. This TA can mark simple translation exercises, and can give feedback at various
levels about what students have done wrong. If your students had someone like that to help
them, how would you use that person?
The majority commented that the TA should understand very well the objectives and the
outcomes expected from the learners at each level. In addition, the TA should understand
that he/she is evaluating the learners all the time and observing their progress. A variety
of views were expressed that the TA could assist with simple tasks, such as translation
exercises, but cannot help students with reading, pronunciation and conversation. Another
interviewee argued a different view:

“I would like to use the TA as a marker for homework and exercises. But
the TA should AVOID TRANSLATION and should use other instruments and
tools which are very much handy nowadays... Questions and discussion should
be encouraged so that the learner gives answers and sentences that include
prepositions”
This is a good argument but we are not going to make a tool that supports pronunciation and conversation. Therefore, translation exercises cannot be avoided because, as other participants pointed out, translation is a simple exercise that would be helpful for the learners. Further, to help us paint a rich picture of the most useful exercises for learners, the following question was asked:

5. **What kinds of exercises would you set? What kinds of exercises don’t you set?**

The overall response to this question was consistent with the notion that Arabic learners should not be given exercises beyond their levels. In addition, the majority of those who responded to this item recommended very simple exercises, which contained a limited number of prepositions, with examples that included true or false tasks, multiple choice questions, correct the mistake exercises, and fill in the gaps tasks. One participant commented:

“Exercises should be supported by images or videos, especially when the prepositions denote places or time. Also, exercises should rely on modeling... I mean some examples should be used as models so that the learner can form sentences or phrases similar to them and it should be communicative.” One of the most important arguments that came out of this question stated: “it should show a comparison between Arabic and English to indicate the properties in each language.”

On the other hand, respondents recommended avoiding open exercises, which ask about prepositions grammar and explaining usage rules, and those that require the student to “write your own sentence using a preposition.” As mentioned previously, students benefit enormously from feedback, and therefore more information was collected about feedback that teachers see useful for students.

6. **What kind of feedback would you want the TA to provide? How many levels? How much detail?**

Essentially, our tool can be considered as TA. In order to extract more useful information that can help in the design of the feedback stage, we asked the teachers more about their views on feedback. There were some suggestions that the TA should observe the learner’s progress and recognise the learner’s needs to achieve more effective progress. Also, the TA should show learners their errors and how they could correct them. One respondent reported that the TA should give a brief idea about the lesson and explain the main grammatical basis in detail to help the learners understand the goal of the lesson, and
subsequently show them the correct answer. On the other hand, another teacher asserted: “the TA feedback should be at three levels and shouldn’t be detailed, but can just show the error then explain and clarify why this was wrong, then provide some examples.”

Obviously, the requirements analysis for CALL tools is generally focused on teachers’ perspectives, and therefore, it was important to ask them the following question:

7. If a student mistranslates a preposition, what do you do? Do you just mark it as wrong? Do you tell them what it should be? Do you try to explain to them why it should be that? How do you express such an explanation?

Talking about this issue, an interviewee said: “I will show the error then compare it with the learner’s MT, then explain this error to be sure the learner is aware and understands the mistake then show the correct answer.” Some interviewees argued that direct correction should be avoided because it will not make the learner understand the meaning and usage of prepositions, while others recommended giving the correct answer first then supporting it with some examples. The participants expressed the belief that the right tools (images, texts, examples... etc.) should be provided so that the learner understands the correct meaning of the preposition. The aim is that the learner should be able to form and use correct phrases or sentences that include the preposition in question. This will confirm that the learner understands the preposition and uses it correctly.

8. What would you like the TA to tell you about the student? How many mistakes they made? What kinds of mistakes they made? (What kinds of mistakes are there? Is it just ‘mistakes with ‘fy’ or is it subtler than that?), What else would you like to know?

The majority of respondents commented that the TA should report all learners’ errors, which will naturally be various, then survey the mistakes that occur frequently, to help clarify them for students with some examples to help them understand these errors in order to avoid making them in future. Also, if they mistranslate a preposition, these should not just be marked as wrong but the TA should highlight the USAGE mistakes in prepositions, and should try to explain to the students why they should be use a particular preposition as opposed to another. Moreover, in response to the question:

9. If your students had a TA, would that affect your lesson planning? Would you want them to use the TA during lessons or just for homework?

A range of responses was very positive. One participant commented:

“The availability of a TA will be very helpful to provide more practice and support my plan. However, the TA should understand very well the objectives
of every unit, standards in every language skill, curriculum contents and maps, instructional methodology and the main outcomes expected from the learner.”

Some participants believed the TA could help the student just with homework, but not during lessons, while others thought that students should use the TA to help them with the lessons first then they could use that assistance if they face difficulties with their homework. Generally, there were some suggestions that the TA should present the learner’s strengths and weaknesses in each skill and at each competency level. All the TA’s comments should be used for evaluating the learners. The TA should report the learners’ needs so that tools, exercises and other instruments of learning should be prepared and utilised. Continuous and on-going assessment should be processed to keep improving the tools, resources, examples and texts.

We took all of these suggestions into consideration; all of these types of questions and their detailed answers helped us immensely in designing our tool, particularly when we started designing the exercises as well as feedback, and generating error messages. Before discussing employing these suggestions in our tool machinery, it is necessary to have a general discussion about the Parasite software, which this tool is based on and was deemed appropriate to do the required tasks.

### 4.3 Overview of Parasite Software

We used the Parasite language-processing tool (Ramsay and Seville, 2001) for reasons which we will discuss below. This tool has been used to analyse numerous languages such as English, Arabic, Persian, German and Somali as a natural language processing (NLP) system. It has been used in other CALL tools because it is almost entirely constraint-based, enabling errors to be dealt with uniformly by relaxing constraints. However, for the current tool we chose Parasite because it produces appropriate logical forms (LFs) for Arabic and English texts, and we are not aware of any other system that does this uniformly for the two languages. In addition, this Parasite version already does model building, which we will use for this CALL tool and this is one of the areas we want to explore in detail in the next chapter. There are other systems that can do model building, but this feature is already integrated in Parasite which make it easier to use than an external tool. Also, it is an open source

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2This acronym stands for PrAgmatic ReAsoning about the Speaker’s InTEnsions; the manual for the system is available at: http://www.cs.man.ac.uk/~ramsay/SYSTEMS/
system, and in particular, it is easy to add meaning postulates and make any changes to
the inference engine.

Although Parasite contains an existing parser that uses (Arabic and English) grammatical theoretical rules that describe the morphological and syntactic component of it, we required a much more detailed description of the dictionary, so we extended it with a much larger set of open-class words. Parasite produces morphological, syntactic and semantic analyses of textual input and was employed to develop system-generated error detection, reasoning about the speaker’s goals and diagnosis. Our research focused on meaning representation and background knowledge (BK).

Our reason for describing Parasite in detail is to allow the reader to understand how we extended some parts and reconstructed it in a way to allow employing it in our CALL system by writing Arabic and English meaning postulates for the main spatial prepositions, with a much larger set of words and meaningful diagnostic messages. A detailed analysis of the existing computational CALL tool will be described in the following sections. Figure 4.1 shows the general outline of the Parasite system.

![Flowchart of the Parasite system](image)

Figure 4.1: Flowchart of the Parasite system
4.4 Structure of the System

Figure 4.2: CALL system architecture
The architecture of our CALL system was designed as a web-based page that combines the Parasite system and links it with the web page, which we will explain in more detail. All the work on the linguistic engine was carried out using Prolog; our system design is explained in Figure 4.2. In this figure, Parasite is shown to be embedded in this larger architecture, and the parts that are shaded have not been changed in our system.

This diagram shows that our system stores English and Arabic text in a database, followed by a detailed analysis of the existing parser that uses grammatical theory (Arabic and English rules), then the labeled parse tree is obtained, which leads to meaning representation for both. Meaning representation is a semantic approach, which is based on the notion that the meaning of linguistic utterances can be captured in a formal structure. There are frameworks that are used to specify the language aspects like syntax and semantics correspondingly; most specifically, what is needed is representation that can bridge the gap between linguistic input and the kind of non-linguistic knowledge needed to perform a variety of tasks involving the meaning of linguistic input. We therefore needed some background knowledge to perform these tasks. In the representational approach being explored here, we took linguistic input and constructed meaning representations that are made up of the same kind of input to present that type of data.

Thus, we used the semantic composition rules to produce the logical forms (LFs) for both English and Arabic text. Therefore, the sentences in this system are translated from natural language into LFs. The system represents the meaning of natural language into LFs to provide all the necessary elements of logical forms, such as tense aspects, events and referral expressions. The logical forms, which will be discussed in Section 4.5.1, were constructed by classical compositional techniques, it easy to derive different interpretations. An important point for this technique is that it succeeded in representing the meaning of natural language formally. Thus, the LFs of Arabic and English text were then used with the background knowledge (BK) rules to do the basic two steps in this study. In order to do this, we required a much more detailed description of the BK rules, and therefore, we wrote a set of meaning postulates (MPs). These MPs are embodied in English and Arabic BK, some shared BK, and translation rules. Hence, there is defined machinery in this research, and we used these MPs to perform two tasks, which are semi-independent:

- Diagnose misuse of prepositions by abduction using these meaning postulates.
Diagnose other mistranslations by comparing models (which were built using meaning postulates) and a bilingual dictionary.

Importantly, we carried out abductive inference by using these MPs and the LFs to try to see whether the way that a preposition is used in a given text achieves the goal of locating one entity with respect to another. This provided the diagnostic information and produced diagnostic error messages. We will explain this feature in more detail in Chapter 5 (Section 5.2.1). In addition, we used a model builder (MB) that we will also explore in Chapter 5 (Section 5.2.2) to draw a picture of what the world could be like according to what we described in the utterances and BK. In other words, we used the MPs with English and Arabic LFs to produce a model of each text to be compared against one another in order to check whether the Arabic sentences had the same meaning of the English ones and vice versa. We performed the model building to compare and match the relations expressed in the English and Arabic model to look for words that had not been translated, meaning that we looked for items that are in one but not in the other in order to be able to provide the learners with feedback about areas they had not included in translation at all.

4.5 Meanings, Models and Inference

To make any computational sense of this idea, we had to provide a precise characterisation of how the various prepositions work, and we had to describe the entities which they can link. We used a framework in which natural language texts were translated, through compositional rules, into some suitable logic; we then wrote meaning postulates to capture the consequences of using particular combinations of words; and finally we carried out abductive inference (which will be discussed in the next chapter) to investigate the use of different prepositions for linking the same figure and ground in two languages (Alrefaie and Ramsay, 2015).

4.5.1 Logical Forms

The framework we utilised was consistent with the convention pioneered by Montague (1974) that relies on outlining grammar rules using semantic descriptions with a view to ‘construct an interpretation by combining the interpretations of the parts’ Dowty et al. (1981). This framework allows the construction of formal meanings of LFs following an
appropriate logic in relation to the sentences that can undergo parsing. Further developments were introduced to Montague’s initial illustration of this idea; particularly, choosing an appropriate logic has been extended to cover the notion that natural language is situated, which means that words and constructs must be understood in relation to the context in which they are used (Kamp, 1984; Barwise and Perry, 1983; Heim, 1983; Groenendijk and Stokhof, 1991). The notion that certain constructs, including defaults (Reiter, 1980; Asher, 1992) and propositional attitudes, are heavily used in natural language and hence should receive particular consideration as these constructs necessitate a logic that is highly expressive. However, the overall principle that is generally maintained describes that structural analysis carried out on a text using grammatical rules can be done by annotating these rules using semantic interpretation notions which serve to construct LFs. When the LFs are present with an appropriate logic that has its own inference engine, reasoning about utterances becomes possible. It has been noted that it is very difficult to do compositions semantic interpretation text because you need annotation of grammatical rules; of a particular interest, a system has been described by Bos (2008), which can provide semantic annotations for a relatively extensive grammar, and on the other hand, these parsers that are based on grammar are notoriously slow when handling lengthy (40+ words) sentences. It is impractical to carry out annotation when the induced grammar has an extensive number of rules, ranging in the tens of thousands. Shorter sentences, however, are used in the current context due to the nature of the task, which is to produce comparisons of interpretation of English constructs based on practices of translation to interpretations of putative Arabic translations. Therefore, there is a level of control over the length of constructs used, which affords the possibility of using an HPSG-like grammar with a generally orthodox chart parser. The grammar we chose to use utilises a collection of fundamental principles, along with a limited number of constraints particular to the language in question. This allowed us to use the same overall grammar in the process of parsing both English and Arabic texts, which afforded the major advantage of using the same mechanism to produce LFs in the two languages, with readily comparable outcomes. Consider examples 3.9 (a,c) from the previous chapter, Figure 4.3 shows the LFs for these examples.

a. My office is on the second floor.

c. مكتبى في الطابق الثاني (mktby fy AlTAbq AlvAny)
These LFs are fairly orthodox. The main points to note are:

- The LFs contain the surface utterance type–claim, query... There are two reasons for this: (i) the utterance type is part of the meaning of the utterance, and hence it naturally belongs in the LF; and (ii) in some cases, notably the English determiner 'any', there are quantifiers which are naturally seen as out of the scope of the utterance type; these simply cannot be accommodated without including the utterance type in the LF.

- Referring terms in the original text are represented as reference terms of the form \text{ref}(\lambda(X,. . . X,. . .)). Such terms have to be anchored with respect to the context in order to determine the significance of the utterance (Barwise and Perry, 1983). The terms in the Arabic LF make use of predicates with names like 'mktb desk; office', where we use the bilingual dictionary (BD), which we are going to explain in next chapter (Section 5.2.1). These names show the English gloss and the sense names, which underlie the potential translation, either by the use of the root of the actual lexicon form or the sense that is given in the dictionary.

\begin{verbatim}
utt(claim,
  of(ref(lambda(A, (office(A) & of(A, ref(lambda(B, speaker(B))))))),
  ref(lambda(C, (floor(C) & second(C))))))

utt(claim,
  of(ref(lambda(A, (mktb Desk; office(A) & of(A, ref(lambda(B, speaker(B))))))),
  ref(lambda(C, (mktb Floor; office(A))))))
\end{verbatim}

Figure 4.3: Logical forms for examples in (3.9)
You have to have an inference engine for the chosen logic: there is no point in constructing any kind of meaning representation unless you intend to do something with it. In general, what you want to do when confronted with an utterance is to reason about it: to see what follows from it, to think about why the speaker produced it, and to try to decide what you should do in response to it. This means that you have to have some kind of engine that is capable of carrying out inference over formulae in the form that you have chosen as your representation. This is true no matter whether the meaning representation is just the original string of words and the inference engine is a string-edit distance between sequences of words; or the meaning representation is based on the dependency tree for the text and the inference engine is some form of tree-edit distance (Zhang and Shasha, 1989; Alabbas and Ramsay, 2013), as is commonly employed for textual entailment (Dagan et al., 2006); or whether it is a translation into first-order logic and the inference engine is a theorem prover for first order logic (Bos, 2008).

In order to justify the use of our representation, we decided to discuss the advantages and drawbacks of such a system. Simple string/tree-based representations have two advantages: (i) they are robust because in order to construct the representation, you simply invoke a morphological analyser (for string-based representation) or some type of dependency parser (for tree-based ones). It does not even matter that the analyser may not be particularly accurate since you can obtain some information out of a parse tree even if it contains some mistakes; and (ii) inference engines are fairly easy to implement; string edit distance algorithms, which exploit lexical relations when deciding the cost of substituting one term for another, are straightforward, and the more complex ones, such as that proposed by Zhang and Shasha (1989), are widely downloadable. They do not, however, support detailed chains of reasoning, and they do not generally pay much attention to whether the reasoning that is carried out is sound or not. Indeed, typical measures of success for shallow inference use reports on precision and recall values, where precision means ‘how often are the entailments discovered by the system valid?’ In other words, such systems recognise from the outset that the inference that they are carrying out may not be sound.

Approaches based on translation into logic have the following obverse advantages: (i) they are sound since the target logics have well-defined proof and model theories, so the steps that can be carried out are guaranteed to lead to true conclusions if the premises are true; and (ii) They are efficient, and hence can be used to carry out long chains of
inference. They also have some obverse problems. In particular, it is difficult to construct
them, since the standard approach involves parsing the input text using a grammar which
has been annotated with semantic interpretations. As noted above, most systems for
parsing free text with long sentences use either a grammar which has been inferred from
a treebank, which is very hard to annotate, or no grammar at all.

For the current task, the need to carry out detailed chains of inference outweighed
the difficulties that occurred when trying to parse long natural texts. For our particular
task, we had a great deal of control over what the learner will write because their task is
to choose the right prepositions to translate a set of target texts. If the target texts are
fairly simple (say up to ten or twelve words long), then the texts that users generate will
also be fairly simple; you would hardly translate ‘I am on the train’ into a sentence of 40
words. We therefore used translations into first-order logic as our target representations,
and we used a version of a theorem prover, backward chaining (BC), as our inference
engine. Most common sense knowledge can be expressed in Horn clauses, so a simple BC
will work. Indeed, it is simple and easy to extend and adapt. BC is an inference method
that can be described as working backward from the goals (Feigenbaum et al., 1988); and
therefore, our inference engine will start with the list of goals then work abductively with a
set of rules related to some ‘prepositions’ that exist in our model as the first sub-goal, and
‘located’ as the conclusion. We will explore this area in more detail in the next chapter.

4.5.2 Meaning Postulates

As indicated in the previous chapter, Arabic and English prepositions share the character-
istic of conveying meanings of space and time. Table 4.1 presents an informal summary of
the meanings of Arabic spatial and temporal prepositions (Cantarino, 1974; cited in Asma,
2010). This summary is typical of such attempts to describe the meanings of prepositions.
In the work below we will formalise these notions as a set of MPs.
Table 4.1: Spatial and temporal meanings of some standard Arabic prepositions (based on Cantarino, 1974, pp. 262-358)

<table>
<thead>
<tr>
<th>Prepositions</th>
<th>Spatial meanings</th>
<th>Temporal meanings</th>
</tr>
</thead>
<tbody>
<tr>
<td>fy</td>
<td>Introduces the act of staying ‘in’, ‘within’, ‘inside’ a place introduces the location in which the verbal action is completed; e.g. <em>kana yakdi fasla echitaa fy elbeiti</em>. <em>(He used to spend the winter in the house.)</em> Has a meaning of motion into a palace derived from the above-mentioned idea of staying in a Has a meaning of motion into a place derived from the above-mentioned idea of staying in a place. e.g. <em>yatanawalo minho lokmatan yadosoha fii famihi</em> <em>(Taking from it a small morsel which he put into his mouth.)</em></td>
<td>Expresses the temporal extension in which or during the action take place, e.g. <em>kana takso fy hada el fasi jamilan</em> <em>(The weather this season was beautiful.)</em> <em>ata ele khadimo fy elleile</em> <em>(The servant arrived in the evening.)</em></td>
</tr>
<tr>
<td>b</td>
<td>Used to express the idea of closeness or vicinity, e.g. <em>qaryaton bibabi el kahirati</em> <em>(A village at the gate of El-Kahirati.)</em> When ‘bi’ means ‘in’, it is used to refer to a larger geographical area; e.g. <em>konto bimisra</em> <em>(I was in Egypt.)</em></td>
<td>The local idea expressed by ‘bi’ may be applied to time, e.g. <em>yasiro elleila wa yakhtafi binahari</em> <em>(He travels at night and hides during the day.)</em></td>
</tr>
<tr>
<td>fwq</td>
<td>Indicates a local idea, which can be understood as either static or as in motion, e.g. <em>thoma wadaa asabiaho bilotfin fawka kalbiha</em> <em>(Then he gently placed his fingers over her heart.)</em></td>
<td>When modifying temporal motion, it has the meaning of “more than”, e.g. <em>ana fawka elkhamsin</em> <em>(I am over fifty.)</em></td>
</tr>
<tr>
<td>ElY</td>
<td>Its local meaning approaches the one expressed by ‘on’ and ‘over’, e.g. <em>kona nanamo ElY elard</em> <em>(We used to sleep on the floor.)</em></td>
<td>Expresses a temporal occasion, e.g. <em>ElY hin an kola wahid yahtajo ila el akhari</em> <em>(At a time when one needs the other.)</em></td>
</tr>
<tr>
<td>byn</td>
<td>Indicates a separation or an intervening place as something that separates, e.g. <em>fy hada el beiti elmonfaridi bayna el hadaaki walbasatin</em> <em>(In this isolated house among fields and gardens.)</em></td>
<td>Indicates a separation between two periods of time, e.g. <em>sawfa naltaki bayna essaati 3:30 wa 4:00</em> <em>(We will meet between 3:30 and 4 p.m.)</em></td>
</tr>
</tbody>
</table>

However, in order to reason about the consequences of some utterances, one has to have some knowledge to reason with. If you have a perfect translation from English or Arabic into some formalism and you have a theorem prover for that formalism, you will still not be able to do anything unless you also have an appropriate body of BK.
The knowledge that we require involves describing the circumstances under which some preposition can be used for locating one entity with respect to another. We divided our meaning postulates into four sections; firstly, the shared Knowledge, which covers some very basic principles. Translation rules were used to extract certain facts about words from our bilingual dictionary, in order to try to deal with lexical ambiguity. This translation rules were used when we build the models. Finally, we generated a large set of English and Arabic rules for the main spatial prepositions and a large set of open-class words as well as those for general use, such referring to the interior of a space, to a point, or to a surface of an object. As seen in Figures 4.4 and 4.5, we wrote these rules down as meaning postulates using first-order logic typical rules to describe the use of prepositions, which is related to the illustrations seen in previous chapter.

The rules in Figure 4.4 describe the conditions under which a preposition can be successfully used to locate a figure (F) with respect to a ground (G). The first one, for instance, says that in can be used to locate A with respect to B if there are views of these entities that inhabit the same space, where the relevant view of is bigger than that of A, and is

\[
\forall A, \forall B :: \{\text{in}(A, B),
\text{forall}(C),
\forall E :: \{\text{view}(E, B)\& \text{type}(E, C),
\text{forall}(F :: \{\text{view}(A, F)\& \text{type}(F, C)\&(E > F),
\text{forall}(G :: \{\text{partOf}(E, G) \& \text{region}(G),
\text{located}(A, B)\}\}\}\}\}
\]

\[
\forall A, \forall B :: \{\text{on}(A, B),
\text{forall}(C),
\forall D, \forall E :: \{\text{view}(A, E)\& \text{type}(E, C),
\text{forall}(F :: \{\text{view}(B, F)\& \text{type}(F, D)\&(F > E),
\text{forall}(G :: \{\text{partOf}(F, G)\& \text{surface}(G), \text{touching}(E, G)
\text{located}(A, B)\}\}\}\}\}
\]

Figure 4.4: Meaning postulates for *in* and *on*

The rules in Figure 4.4 describe the conditions under which a preposition can be successfully used to locate a figure (F) with respect to a ground (G). The first one, for instance, says that in can be used to locate A with respect to B if there are views of these entities that inhabit the same space, where the relevant view of is bigger than that of A, and is
some kind of region. In other words, you can say ‘A is in B’ if B is the kind of thing that can contain A. This has the same feeling of circularity that is present in the informal descriptions in table 4.1 or the dictionary definitions in (Section 3.4.2) What makes this rule non-vacuous is that it forces you to check that the entities in question do indeed have the required properties?

So, our definition looks at the entity and what properties they have; “to locate one with respect to the other, they have to have same type, and compatible views and other antecedents to have the consequences of locate them”.

```
forall(A,
  forall(B :: {at(A, _B)},
    forall(C,
      forall(D :: {view(A, _D) & type(_D, _C)},
        forall(E :: {view(_B, _E) & type(_E, _C)},
          forall(F :: {referencePoint(_E, _F)}, dist(F, _D, 0) & located(_A, _B))))))
  forall(A,
    forall(B :: {from(A, _B)},
      forall(C,
        forall(D :: {view(A, _D) & type(_D, _C)},
          forall(E :: {view(_B, _E) & type(_E, _C)},
            forall(F :: {partOf(_D, _F) & start(F)}, dist(_E, _F, 0) & located(_A, _B))))))
    forall(A,
      forall(B :: {to(A, _B)},
        forall(C,
          forall(D :: {view(A, _D) & type(_D, _C)},
            forall(E :: {view(_B, _E) & type(_E, _C)},
              forall(F :: {partOf(_D, _F) & end(F)}, dist(_D, _F, 0) & located(_A, _B))))))
```

**Figure 4.5:** Meaning postulates for *at, from* and *to*

In addition, the rest of the other prepositions rules are shown in Figure 4.5. The figure explains that the prepositions at, from and to might be used to locate F with respect to G if G has different properties and views in each. In the first part explain the meaning of at, G has a view, which has a reference point with a distance 0 between F and G. In the part about both from and to, the view of F is part of G, which has a view as a start for from and a view as an end for to, with the notion that both has 0 as a distance between F
and G. Given that Arabic has prepositions, في (fy), على (ElY), من (mn), إلى (ILY) and
، and (End), which seem to carry the same meanings as ‘in’, ‘on’, ‘from’, ‘to’, and
‘at’, we can write parallel meaning postulates for them. The Arabic spatial prepositions
seem to mean the same as the English ones, and hence, we use exactly the same rules for
them. We also need meaning postulates to tell us what views, with what properties, are
induced by particular words. The two languages do differ in this point; to continue with
our running example (10), ‘office’ and مكتب (‘mkthoffice’) both denote entities which
describe a region, and although ‘floor’ and طابق (‘Tbq.floor’) are roughly equivalent, a
floor is a 2D surface, with no interior, whereas a طابق is a 3D space with an interior and no
surface. To capture these observations, we needed some general rules (shared knowledge)
about what types of entities have interiors, paths, surfaces, and so on. We tried to be
more precise in writing shared rules to help us cover all the common properties; such rules
are shown in Figure 4.6

```
forall(_A::{interior(_A)},
    region(_A))
forall(_A,
    forall(_B :: {interior(_A, _B)},
        interior(_B) & properPartOf(_A, _B)))
forall(_A :: {path(_A)},
    exists(_B,start(_B) & of(_B, _A))
    & exists(_C,end(_C) & of(_C, _A))
forall(_A, 
    forall(_B :: {surface(_B) & of(_B, _A)},
        properPartOf(_A, _B)))
```

Figure 4.6: Examples of shared rules

The first rule in Figure 4.6 explains that everything that has an interior is a region,
and the other two rules say that anything that is a part of an entity, which has an interior,
has the same interior as this entity. The second rule describes that anything which is a path has to have a start point and an end point. The last of these rules states that if something has a surface, then this surface is a proper part of the same entity. Therefore, what we really needed is to be able to say what types of entities are regions and what properties an entity has to have to be path and so on. We then needed to describe particular entities. It is at this point that the nuances of different languages emerge.

Figure 4.7: Describing a building, an office and a floor

Figure 4.7 describes that the English and Arabic words for building denote entities with the same spatial properties, whereas the words ‘office’, ‘floor’ and ‘mkthb_office’ ‘Tbq_floor’, despite being rough translations of one another as both are the same type of physical object, differ when looked at them in detail– any room has a floor and that floor is a 2D surface, a multi-storey building is made out of different levels, while an ‘office’ is a room on that floor. However, ‘Tbq_floor’ is a 3D region bigger than a ‘mkthb_office’ so that the
‘mkth\textunderscore office’ is contained in the ‘Tbq\_floor’.

Given these descriptions, it is easy to see why Arabic speakers use the preposition (‘in’, في (fy)) which denotes regions and interiors for locating an office with respect to a building, but English speakers use (‘on’) which relates entities to surfaces when locating an office with respect to a floor. This means that ‘in’ will not work for locating the office with respect to the floor because a floor is not a region.

4.6 Conclusion

This chapter began by reviewing requirements analysis, which was carried out in order to help us design the CALL tool, followed by describing the machinery for CALL tool in details, and then covering the technical terminology, such as logical forms and meaning postulates. Having discussed how to construct meaning postulates, which is the core of this study, it is now necessary to explain the model building and abductive reasoning in the next chapter.
Chapter 5

Abductive Reasoning

5.1 Introduction

This chapter follows on from the previous chapter, which outlined the machinery of the tool used in this research. As was mentioned in the previous chapter, we used the selected meaning postulates (MPs) to perform model building or abductive reasoning, which this chapter will discuss in detail. In addition, it is important to discuss other needed instruments, such as the bilingual dictionary and the generation of diagnostic messages.

5.2 Models vs Abduction

Turning the ideas described in Chapter 4 into a CALL tool is not straightforward. There are two plausible ways to proceed: we can either use the theorem prover (TP) as a model builder, and compare the models that are generated from English utterances and the English meaning postulates and Arabic utterances and the Arabic meaning postulates; or we can adapt the TP to work abductively, trying to fill in the gaps in the use of prepositions.

5.2.1 Model Building

Given a set of axioms, a backward chaining (BC) theorem prover can be used as a model builder. In order to use a backward chaining engine to construct a model, one has to backtrack through the list of goals in order to find all possible ways of proving each. We cannot find all provable ground instantiations of goals in this way since there may be an infinite number of those, but we can find all function-free instantiations, which will be
enough to construct partial models.

First, we have to illustrate what a model is; a model deals with the relationships between descriptions and the structures that satisfy these descriptions. According to Briscoe (2011 p. 5), model-theoretic semantics

“... represents the world as a mathematical abstraction made up of sets and relates linguistic expressions to this model. This is an external theory of meaning par excellence because every type of linguistic expression must pick out something in the model.”

Hence, a model of a set of sentences is an assignment of entities to terms and a set of assignments of set of tuples of entities to predicates in such way as to make the modelled sentences true. The problem is that you cannot always make a model because it can be infinite. In other words, if we have a set of sentences, in order to make them all true, we may actually need an infinite set of terms, so we cannot generally build the model. Therefore, we tend to make partial models, which make everything that is in the formal paraphrase of the utterance and all the consequences that mention only the terms that appear in the paraphrase true.

The partial models we are going to concentrate on, therefore, are the ones where all the terms in the sentences represent ground and function-free entails. We do this by iterating our rules, looking for all possible ground function-free provable instantiations of the consequents of our rules (which are all Horn, and therefore, do not lead to alternative incomplete models). Hence, if we found a proof of a ground fact G then we cache it as a new fact and we remember it as a fact we already know; however, the set of literals that make up a new fact is what makes a model. Indeed, the set of positive literals is a Herbrand model.

Note that the goals always match the confirmed formulae of the consequences, and even then, their antecedents are considered as the new goals, which in the end must match known facts (Chein and Mugnier, 2008). Suppose, then, that we apply the machinery of BC theorem prover to a consistent set of Horn clauses; if at some point we find that we have a new fact, and that there is nothing further that can be added to the clauses, the set of positive literals (facts) are then said to be a model.

We constructed partial models to show a simple picture of Arabic and English sentences so that we could inspect everything and see if there is anything evidently wrong in order to assist in identifying areas where the learner mistranslated open class items.
Suppose we take two sentences, one in English and one in Arabic, and try to build models for them along with an axiomatisation of the background knowledge relating to the terms that they contain. If the two sentences mean the same, then we may expect the models to be equivalent. If they are not, then it is a reasonable supposition that the differences between them reflect different connections between the terms that they contain and the relevant background knowledge. The model has two functions; one is to enable us to look for open class words that have not been translated; and the other is that it might be helpful to the learner to use the models to see how terms that appear to be mutually equivalent differ when used in different contexts.

To illustrate this point, imagine that the learner was asked to translate مكتبي في الطابق الثاني (mktby fy AlTAbq AlvAny), and they did so by producing the sentence ‘my office is on the second train.’ This is an incorrect translation since طابق (TAbq) means ‘floor’ or ‘storey’, not ‘train’. The models for these two sentences are shown in Figure 5.1.

![Figure 5.1: English and Arabic Models](image)

The two models in Figure 5.1 contain a substantial amount of information that is not present in the original logical forms (LFs) for the two sentences. That is as it should be: a model contains information that arises when you combine an interpretation with a body of background knowledge. If one looks carefully, it is possible to see that the Arabic model contains the fact that ‘mktb_office’ (A0) has been located (A0, A1) with respect to ’Tbq_floor’ (A1), and that this happened because they have the same type and compatible views, and hence ’Tbq_floor’ (A1) is a 3 dimensional region, whereas in the English model, it was not located because the English translation contains some words that do not appear
to have been translated correctly. It is difficult to obtain an understanding of why the
preposition in the English text failed to locate E0 with respect to E3: we will return to
this point below. It is, however, comparatively easy to spot that the term train in the
English model has no corresponding term in the Arabic text, and hence this is probably
a mistranslation.

The problem is that one has to look very carefully in order to identify the relevant
differences between the two models. Therefore, we used these models in conjunction with
a bilingual dictionary, which we mentioned before in the logical forms and are illustrated
below in Sub-subsection, 5.2.1.1, to see whether open-class words were successfully trans-
lated. These models can also be used to perhaps show the learners the full picture which
might tell them something useful.

Given that we are concerned with the use of prepositions for locating one entity with
respect to another, it makes sense to find an alternative way other than this model because,
although it is really useful in identifying mistranslation, it does not offer a way to look
at the preposition and the reasons for misusing it. To have a detailed picture of one’s
incorrect use of a preposition, we have to look at why the chosen preposition failed to
locate the figure with respect to the ground; we will return to this point in Section 5.2.2.
Before that, we will consider how the models described here can be used to identify the
simpler mistranslations that arise with open-class words.

5.2.1.1 Bilingual Dictionary

We generated models to show mismatches between open-class items in the two languages
to determine whether they are equivalent by direct comparison. A requisite is that we
have to be able to link items in the two models, although they are characterised using
different terms, which can be equivalent in the source texts in various languages. This can
be tricky since the conditions under which a term can be given a particular translation are
complex (if these cases were not complex, they would not cause problems for learners).

Consequently, we added a set of open-class words that is needed to serve as separate
bilingual equivalents, with all words added in the bilingual dictionary made up of the
Arabic root and the English gloss. Some words require some degree of disambiguation
because one Arabic word may have two or more different meanings in English. For instance,
if we look at Arabic nouns, such as *mktb*, we will find that in our bilingual dictionary,
it appears with two different translations ‘*mktb_desk;office*’, which are obtained as the
English nouns with equivalent sense given by the dictionary. Therefore, to avoid any ambiguity in words used in our CALL tool, we wrote a set of translation rules as part of our MPs, which are prompted with the bilingual dictionary as seen in Figure 5.2 below. Moreover, we used the bilingual dictionary for contextual disambiguation with another language model for context. Essentially, by looking at these words in their context, the translation can be performed correctly; say in the previous example, the Arabic lexical entry ‘مكتب’ could be translate to office or desk, and the two senses ‘mktb_office’ and ‘mktb_desk’ are the potential translations that can be constructed by the model. Clearly, the rule shown in Figure 5.1 suggests that if the English term desk is used and the Arabic context enquires about where mktb is, while we do not know whether the meant sense is a desk or an office, then the default inference is that mktb is a desk.

\[
\forall X: \{ \text{mktb\_desk; office}(X) \}, \\
\forall Y: \{ \text{desk}(Y) \}, \\
\text{mktb\_desk}(X) \\
\forall X: \{ \text{mktb\_desk; office}(X) \}, \\
\forall Y: \{ \text{office}(Y) \}, \\
\text{mktb\_office}(X) \\
\]

Figure 5.2: Translation rules for the Arabic word ‘mktb’

These are rules that carry a great deal of risk because in certain sentences, such as ‘my desk is in my office’, for the English words ‘desk’ and ‘office’, no attempt is made to establish any connection between ‘English\_desk’ and ‘Arabic\_desk’ as these are different variable. Thus, these rules can lead us to unreliable conclusions in cases where a sentence contains an ambiguous term in one language with a number of its potential translations present in the corresponding sentence in the other language; this will not work as a disambiguation strategy. Nonetheless, in many situations, using the source language text as a disambiguating context for target language words, and vice versa, is a simple, and often effective, approach to the problem of lexical ambiguity in exercises of this kind.

We turn now to discussing how we can carry out abductive inference to investigate the use of different prepositions for linking the same figure and ground in two languages.
5.2.2 Abductive Reasoning

Abductive reasoning or abductive inference is a form of inference which goes from an observation to a theory which accounts for the observation, ideally seeking to find the simplest and most likely explanation (Awbrey and Awbrey, 1995; Magnani, 2001). One can understand abductive reasoning as “inference to the best explanation” (Sober, 2001). There are some problems associated with using comparison between models as a source of feedback. First, you have to be able to link items in the two models despite the fact that they are described using different terms (as they are drawn from source texts in different languages). As noted above, this requires a set of bilingual equivalents so that an item described as a floor in one model can be matched to an item described as a ‘Tbj_floor’ in the other; to avoid this complexity issue, we built up our bilingual dictionary. Second, a single consistent set of formulae can have multiple models. There is no easy guarantee that the first model that is produced for a sentence in one language is the best match for a certain model in the second language. If the English sentence has models $M^E_1, M^E_2, M^E_3$ … and the Arabic sentence has models $M^A_1, M^A_2, M^A_3$ …, then it may be that the best match is achieved between $M^E_5$ and $M^A_7$. However, trying to compare every model in the English language with every model in the Arabic language to find out which ones have the smallest number of mismatches is likely to be extremely time-consuming. In addition, the model just tells us about the open-class words and we need to know about the prepositions misused in detail.

We therefore investigated the use of ‘abductive’ inference. The aim is to find out incorrect use of a preposition by a learner. Given that the function of spatio-temporal prepositions that we are interested in is to locate one entity $F$ with respect to another $G$, the obvious task to do is to look for the rules that might use the given preposition for locating something and see what steps are missing in the chain of inference from the preposition to the conclusion that the location of $F$ is determined with respect to $G$. In general, when we do abduction, we start with a rule that has some preposition that is in our given model as the first sub-goal and located($F$, $G$), as the conclusion. Suppose that our learner has written a sentence using the preposition المطلوب’ $ElY$’ as a translation of the English preposition ‘on’, we have a collection of rules that describe the conditions under which some preposition will successfully locate the figure with respect to the ground, as seen in Figure 4.4 in the previous chapter. Given a model, we can look for places where someone has used a preposition without locating the relevant entities by looking
at each rule that has located \((A0, A1)\) as its consequent, where the first element of the antecedent (which will always specify that some preposition has been used) is satisfied but the consequent is not. We can then use the theorem prover abductively by allowing proofs with missing steps, where we can prespecify the number of steps that can be omitted. In order to find the minimal set of missing steps, we call the theorem prover once allowing one missing step, then allowing two etc. . . . until a proof is found. This does indeed increase the time taken for finding a suitable proof, but if we simply the allowed proofs with unbounded numbers of missing steps then we are likely to be led to incorrect diagnoses. Therefore, if we try to carry out an abductive proof that two items mentioned in the Arabic model are located, we will find that the rule using \((Ely)\) would have worked if we had been able to prove \(\text{surface}(A1)\) for some A. So, the primary reason why Arabic failed to locate \(\text{مكتب} (\text{mktb\_office})\) is that \(\text{طابق} (\text{Tbq\_floor})\) does not have a surface. We could, therefore, provide a message to that effect to the learner as the first round of feedback ‘You tried to use \((Ely)\) as the translation of ‘on’, but it doesn’t work in this case because although \(\text{طابق} (\text{Tbq\_floor})\) is the correct translation of ‘floor’, \(\text{طابق} (\text{Tbq\_floor})\) does not have a surface’. We can follow this up with more detailed feedback. If the learner is not satisfied with this as a comment, he or she can ask why \(\text{طابق} (\text{Tbq\_floor})\) does not have a surface. An abductive proof of surface \((A1)\) produces the response that even though there is a compatible view between \(\text{Tbq\_floor} (A1)\), \(\text{mktb\_office} (A0)\), they have same type and this would have worked if we had been able to show that \(\text{ElY}(A0, A1)\), the preposition failed to locate them because \(\text{mktb\_office}(A0)\) is a region\((A0)\). It is harder to see how this could be turned into a comprehensible diagnostic message for the learner, but the general principle is simple. The reason why some attempted translation fails to produce a target consequence can be found by carrying an abductive proof of the target and recording the missing steps. In many cases, these missing steps can be converted to meaningful diagnostic messages; and if the learner wants to know more about what went wrong, the abductive proofs of the missing steps themselves can be derived. However, as this process goes deeper, the rules that are being used become more and more abstract to the point where they will not produce output which will in fact help the learner to understand what they have done wrong.
5.3 Diagnostic Messages

As noted previously, we indicated that in order to attain high levels of proficiency in the target language, it is necessary to provide feedback. If we want to provide effective learning feedback that will support the students’ learning progress, this feedback will have to be something that makes sense to the learners themselves.

While we are doing abductive proofs to see how the learner has used a preposition to locate some item with the respect to another, we record the missing steps. These missing steps, however, would be meaningless to the users since they take the form of sets of predicates applied to Skolem constants, and therefore the learner is not going to understand what the predicates are as they are unlikely to recognise and interpret the Skolem constants. We therefore needed to convert these constructs into meaningful diagnostic messages.

The general steps that we needed to follow were: we have a set of canned phrases or messages, one for each missing step that we thought could say something about what is missing; these messages have holes in them, and those holes have to be filled by turning the Skolem constant into a descriptor. The way we obtain such descriptors is by looking for a 1-place predicate in the model that has the given constant as its argument and that matches some lexical item in the text that gave rise to the model. Such a lexical item is likely to work satisfactorily as a descriptor for the entity denoted by the constant. Look at the example in Figure 5.3 below; it shows both the model and the missing step. If we look at our model, we can see that every item in this model is denoted by a Skolem constant, such as '#1', or a Skolem function, such as '#30 #1', where a term with two or more # symbols is a Skolem function; '#30 #1' for instance is the Skolem function '#30', applied to the constant '#1'. The missing step says that ElY cannot be used to locate mktb in relation to Tbq because Tbq has no surface. If the user just sees the following:

```plaintext
['missing',
 ['ElY', 'mktb', 'Tbq'],
 [['type', 'mktb', 'physObj'], ['¿', 'Tbq', 'mktb'], ['surface', 'Tbq']]]
```

as the feedback, they will not benefit much from it. Therefore, we generated a readable error message, including descriptors of the constants that are used in order to provide them with something they can make use of in improving their understanding of why the preposition they have used is inappropriate.
getModels('My office is on the second floor.', english, 'mktb by ElY AlTbq AlvAny.', arabic).
['missing',
['ElY', 'mktb', 'Tbq'],
[['type', 'mktb', 'physObj'], ['¿', 'Tbq', 'mktb'], ['surface', 'Tbq']]]
['models',
[['office', '#1'],
['room', '#1'],
['>', '#1', '#30#1'],
['floor', '#1', '#30#1'],
['located', '#1', '#2'],
['of', '#1', '#0'],
['on', '#1', '#2'],
['touching', '#1', '#2'],
['type', '#1', 'physObj'],
[['floor', '#2'],
['second', '#2'],
['storey', '#2'],
['surface', '#2'],
['>', '#2', '#1'],
['>', '#2', '#30#1'],
['type', '#2', 'physObj'],
[['speaker', '#0'],
['animal', '#0'],
['human', '#0'],
['>', '#0', '#1#0'],
['lowestPoint', '#0', '#1#0'],
['type', '#0', 'physObj'],
[['foot', '#1#0'], ['type', '#1#0', 'physObj']],
[['floor', '#30#1'], ['surface', '#30#1'], ['type', '#30#1', 'physObj']],
[['mktb_desk:office', '#10002'],
['mktb_office', '#10002'],
['region', '#10002'],
['ElY', '#10002', '#10003'],
['of', '#10002', '#10001'],
['type', '#10002', 'physObj'],
[['Tbq_floor', '#10003'],
['region', '#10003'],
['vny', '#10003'],
['>', '#10003', '#10002'],
['dim', '#10003', '3'],
['type', '#10003', 'physObj'],
[['speaker', '#10001'],
['animal', '#10001'],
['human', '#10001'],
['>', '#10001', '#1#10001'],
['lowestPoint', '#1#10001', '#1#10001'],
['type', '#1#10001', 'physObj'],
[['foot', '#1#10001'], ['type', '#1#10001', 'physObj']]]

Figure 5.3: An example of a missing step

Therefore, the result of changing these missing steps to provide our users with understandable and meaningful diagnostic messages will be exactly like the example below (Figure
The message in this particular example that the users received if they had missing elements for using a preposition says “in the present example, you can’t use ‘على’ and ‘على’ because the مكتب would have to be a physical object and the مكتب طبق would have to be bigger than it and it would have to be something that had (or was) a surface”. This type of message will be easy to understand for the learners.

Figure 5.4: An example of missing elements in using prepositions (diagnostic messages)

5.4 Conclusion

In this chapter, we discussed aspects of the machinery of the CALL tool by looking at the functionality of the system and the procedure of developing it. We started by describing appropriate ways to perform a model builder and abductive reasoning. The chapter then went on to discuss the bilingual dictionary and how this links to the translation rules. Finally, the methods used in generating diagnostic messages were explained.

The next chapter describes our CALL system interface and the procedures and methods used in the evaluation of the CALL tool.
Chapter 6

Classroom Experiments and Evaluation

6.1 Introduction

This chapter presents the user interface and how the users interact with our CALL tool, followed by a discussion of a pilot study which was conducted in order to assess the system’s suitability. Subsequently, an outline is presented of the setting and findings of classroom experiments which were carried out with Arabic and English learners in order to assess the effectiveness of our CALL tool. This discussed evaluation is intended to investigate how effective is the use of the CALL tool and the mechanism of its function with a view to assist students’ learning as opposed to assessing the tool as a computer programme (Zhao, 2003). This means that the assessment is related to a determination of user performance instead of assessing system performance (King, 2005). The findings of these experiments, as outlined in this chapter, are presented based on improvement in participants’ usage of Arabic prepositions. The usability of the tool and learner behaviour are also discussed in this chapter.

6.2 User Interface

For better understanding of how the system works, one way is to explain what a typical user of the tool tends to do. The home page has a brief introduction about how the use of prepositions is difficult. In addition to that, it provides a detailed description of the CALL tool and clear instructions, which can help the user to understand the many features of
the tool.

Notably, the home page contains considerably more information than a typical webpage. We have chosen to include more detail on the page to provide guidance to the users on how to best utilize the tool. We decided not to have a help page since users’ use of this type of page was doubtful. Hence, help text was included in the home page to make sure that learners could find and use it. The home page also contains the login box, which features a username picked by the user; the username is used in this assessment to identify the user and track their behaviour. As we see in the Figure 6.1, the home page has five links that take the users to the other pages; 4 pages are used to provide a set of exercises, which they can either do in English or Arabic (with full translation or fill in the gaps tasks). The 5th and last link takes the user to a feedback page, which constitutes a very short form they can fill in to provide feedback related to what they think about the tool and reflect about their experience using it, which will help indicate what needs to be done to improve our tool.

![Figure 6.1: Arabic prepositions CALL Login Screen](image)

When the user types their username, the next page appears on the screen, which says “You are currently logged in as . . .” (Figure 6.2 below). The exercise pages contain three options after each question, “submit”, “previous sentence” and “next sentence” to make
navigating through the website easier.

If the user chooses the option “English to Arabic”, he/she can use either an Arabic keyboard as seen in Figure 6.3 or a virtual keyboard provided on the same page; the virtual keyboard provided has either an Arabic alphabet, Arabic with Buckwalter transliteration or Arabic with an informal equivalent.

Whichever option a user chooses - Arabic to English or English to Arabic / full translation or fill in the gaps – the same procedures apply. If the user thinks that what has been shown is correct, they can just submit their answer by clicking on the “submit” button; if the user makes the right translation and correct use of prepositions, the system will tell them that their answer is correct, and give them a chance to see in more detail the model of how the original sentence and their translation compare. In addition, after this, they can...
move on to another exercise. This case is shown in Figure 6.4 below.

Figure 6.4: Arabic prepositions CALL output screen: A case with no error

However, if there is an error in the sentence then the student will be shown in one of two different messages depending on the mistake. If the learner mistranslated certain words from the original text, they will receive the message: “There are some words in the original text that don’t have corresponding terms in your translation”, with the incorrect words marked in red. If the learner clicks on a red word, the tool will open the ‘Mistranslated items’ page, which has more information about the mistranslated word, as shown in Figure 6.5.

Figure 6.5: Arabic prepositions CALL output screen; Mistranslated items

Moreover, if the learner then clicks on the mistranslated word on this page, the tool will take them to the translation page that gives them a potential translation, which is
extracted from our bilingual dictionary.

On the other hand, if the user misuses certain prepositions, the system will notify them again by marking the incorrect preposition in red. Similarly, if the user clicks on the incorrectly used preposition, it will take them to the ‘Missing elements for using prepositions’ page, where there is full explanation about spatial prepositions and conceptualisation underlying the use of Arabic prepositions. This page, as shown in Figure 6.6, also contains diagnostic messages about the particular sentences, which tell the learner why their usage is incorrect.

Figure 6.6: Arabic prepositions CALL output screen: Missing elements for using prepositions

In addition, at every stage of using our system, we allow the learners to have a look at the model to see the full picture of the sentences they have constructed. This model, as shown in Figure 6.7, illustrates how the original sentence and the learner’s translation compare; the figure shows an example of identical models unlike the example discussed in Chapter 5 (Figure 5.1) showing a mistranslated model.
These models help the users find out the relation between the two sentences, and especially the properties of the items linked by prepositions. Finally, we asked the user to provide us with some feedback as seen in Figure 6.8 about their experience using the website; in this page, we provided them with a very short form to fill in to inform us about what they thought still needs improvement. We used this feedback in the evaluation and the pilot study, which are discussed below.

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**Figure 6.7:** Arabic prepositions CALL output screen: An example of identical models

**Figure 6.8:** Arabic prepositions CALL: The feedback page
6.2.1 Pilot Study

We performed a pilot study to assess the usability and suitability of our CALL tool. Pilot studies are normally used to assess ‘feasibility’ and therefore are an essential component in designing quality studies, as they serve the purpose of pre-testing a system before it is used. We conducted a pilot study because it offered the possibility of significantly reducing the number of unexpected problems, which allows redesigning different parts of our CALL tool in order to overcome difficulties, while serving as evidence of the efficacy of the non-problematic parts of the tool. To assess the usability of our tool, we contacted the University’s Language Centre and requested access to their Arabic Language students. Through the Centre’s coordination, each student applied the tool in an Arabic class in order to test its effectiveness. Due to the University’s regulations, direct contact with the students was not possible and therefore the management in the Language Centre provided assistance during this stage.

We provided full explanation about the tool and instructions about what is needed exactly. This assessment was considering the usefulness of diagnosing errors by offering a set of exercises that involve the use of prepositions. When the participants used the prepositions incorrectly, the system would provide immediate feedback through hints or explanations.

First, the users were informed that this tool was still under development. For it to work, it had to be able to provide useful feedback that students can learn from. It also had to be easy to use and to give the feedback in a form that was clear and helpful. Then we asked them to work through a fairly short set of exercises, imagining that this was a piece of homework. We explained to them that if they got something wrong, the system would show them the words where it identified a problem marked in red. They have two choices: they could either try to correct the problem, or they could click on the words marked in red to obtain more information about the incorrect use. They could always skip to the feedback form at any point without necessarily completing all the exercises. Filling in the form, such as the one in Figure 6.8, was the most important requirement for us at this stage since just completing the exercises would really tell us much about how usable the tool is.

Overall, we had only five Arabic students in total and these participants used the first version of our CALL tool. The exercises in the first version of our CALL tool featured the option ‘from English to Arabic’ only, which constituted full translation exercises. At
this stage, we just wanted some helpful comments from the participants to inform us about which components needed improvement, to make it the tool easier to use and more effective.

Due to the small number of participants, we did not collect exceptionally useful feedback. The most useful feedback was that we should make the exercises easier for beginners because the participants encountered many mistranslated words. Another useful feedback was focused on the design of the website and its presentation, such as the size of the virtual keyboard, adding the feature of informal equivalent and increasing the size of sentences. To take these and other comments into consideration, we added ‘fill in the gaps’ exercises to make it easier for beginner to use the tool in order to avoid the problem of high numbers of mistranslated items that can frustrate users and make them give up quickly. Additionally, we changed the size of the virtual keyboard and added an informal equivalent.

The most significant change we made after we conducted the pilot study was that we made our system compatible with both Arabic and English learners. Therefore, a learner could choose to do the exercises from English to Arabic or vice versa (see Figure 6.1). This change took very little time and effort as all the machinery for handling the two languages is identical. This feature enabled us to have more users for our more detailed evaluation.

At this point, our CALL tool was developed to a sufficient extent, and therefore we went on to evaluate its effectiveness. This evaluation is presented in the following sections.

6.3 Evaluation of the CALL tool

Generally, evaluating a CALL tool is an extremely complex process due to the complicated, long and slow nature of learning a language, which usually requires designing and conducting a large-scale longitudinal study with carefully considered variables. However, experiments with our CALL tool, which is intended to help learners to use prepositions correctly, showed that prepositions are not especially memorable for learners unless they understand what they mean and how they are used, which is facilitated by tools such as this one.

6.3.1 Study Procedure

We discussed using the CALL tool with the University’s Language Centre, where Arabic is taught, and some other institutions where English is taught to native Arabic speakers.
Both sets of students used the tool and we requested them to complete two sessions with identical content on the system, which were interspersed by one week in order to assess whether they benefited from using the system. Again, contacting students enrolled in the Language Centre was not possible, we however provided a full explanation of our tool and clear instructions in the home page as mentioned in Section 6.2. For the evaluation to work, we needed to track the performance of the users in the two sessions, so a means of identification was required. Therefore, each participant was requested to choose a unique username in the first session and to use the same identifier in the follow-up session. For the purpose of anonymity, the username did not have to be their real name and they could pick any name they liked. The strict requirement was to use the same username in both sessions in order to track their use and behaviour accurately. The students were provided with a number of translation tasks and they needed to do exercises where they started with English sentences and tried to insert the correct Arabic forms, and the other way round. In each option, they could either do 'fill in the gaps' type exercises or ones where they had to write the whole translation. In order to evaluate our CALL tool, we created a log file to track the participants’ usage of the system. The log file is discussed below.

6.3.2 Log File

In order to save the history of use by participants, a log file was created and maintained. Extensive information was saved on this file including the user, the date and time, requested pages, and system usage. The behaviour of students and their use of the tool could then be studied by analysing the data stored in the log file.

This file was stored in XML format, containing different types of text data, a format which allows easy extraction of information. One important type of data collected in the log file is the mistakes made by users, including mistranslation, misuse of prepositions, in addition to feedback by users at different stages of using the system. Information related to students’ performance can be used more effectively when we know what types of information are available, the most suitable ways of collecting and analysing them, and what can be learned from the collected information.

The highest level entry in the log file represents a set of ‘Actions’, which identify the users and their choices, with the first ‘ACTION’ type showing the log according to time and period of use. Events generated by the user, which are recorded on the log, result in creating queries to the Prolog. Some of the cases represent ‘dummy’ queries used to
make sure that the entries are maintained in the log file in an identical format. As the student uses the Parasite tool to submit a sentence, the event is recorded to keep a history of what happened. This action represents the ‘query’ mechanism that records both the time and result of the event. For actions with a target and a translation considered as submissions by the user, the ‘MARK’ will show if the submission was correct, and if incorrect, what type of mistake was made. For example, when the submitted translation contains a word which is unknown to the system, the word would be shown in red font and a feedback message would be provided to explain the issue with the selected word. Eventually, the text in the log file is assessed and analysed; it represents a track record of the behaviour of usage by the learners and their interactions with the system, offering an objective complement to the subjective user feedback.

6.4 Results of the Experiments

As the system exists on a website\(^3\), it could be easily accessed by our users. From the log file, around 30 students representing different levels of Arabic and English used the system. Unfortunately, not all of the participants managed to attend the two sessions, and not everyone who did both sessions managed to do five or more exercises in each session. Due to the low number of users who were available for performance assessment, only 10 students in total were used as our final sample. Generally, we measured the total number of users’ submissions in the two sessions as presented in Table 6.1. This table shows that the users performed 245 submissions in the first session and only 203 in the second.

<table>
<thead>
<tr>
<th>Users</th>
<th>Session1</th>
<th>Session2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
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<td>33</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>254</strong></td>
<td><strong>203</strong></td>
</tr>
</tbody>
</table>

\(^3\)http://ramapp.cs.man.ac.uk/cgi-bin/ARABCALL/index.py
Further analysis for the learners’ submissions showed that the majority of students did better in Session 1 than in Session 2. This could be because we did not provide sufficiently strict guidelines, such as setting a minimal number of exercises that needed to be done in each session. Figure 6.9 shows the average frequencies of the system outputs or the messages related to the users’ translations. It is clear that the learners submitted a correct translation significantly more frequently than mistranslated or missing submissions, and unknown or ‘no analysis’ outputs, where the system could not recognise or handle the input, were very rare. ‘No analysis’ cases were often ones where the students did not delete all the dots in a missing word exercise.

![Figure 6.9: The average frequency of system outputs](image)

However, in our assessment, we were more concerned about the students’ errors and if there was any improvement that may indicate whether or not our CALL tool was useful to the learners. Therefore, we needed to highlight the users’ mistakes, particularly in the use of prepositions.

### 6.4.1 Analysis of Users’ Errors

Our performance assessment is based on the proportion of incorrect usage of prepositions that the ten students made in the two sessions. We measured the learners’ performance on a set of translation tasks focusing on Arabic prepositions, and how often they performed them incorrectly. The performance of students was calculated at the end of each of the two sessions as representative scores. Although the learners made some mistranslation
mistakes, we only focused on misuse mistakes where the students used the prepositions incorrectly. The results are shown in Figure 6.10.

Figure 6.10: Scores of mistakes in the use of prepositions

In this Figure 6.10, the blue and red bars show how often mistakes with prepositions were made in the first and second session, respectively. Logically, larger blue bars would provide an indication of the usefulness of the CALL tool in improving the students’ use of prepositions. However, mixed results were seen from the ten students, with only four participants showing notable improvement between the two sessions while five participants showed the opposite trend. The performance of the remaining student did not change. The results from these observations are evenly split and therefore we suggest that there is not enough evidence to show if the students have learnt from using our CALL tool. Therefore, a cautious conclusion, on the basis of the available evidence, suggests that more data need to be collected using a larger sample of students and a higher number of sessions to be able to provide proof of whether or not using the CALL tool can help students make a significant improvement in using Arabic prepositions. However, tracking and analysing user behaviour may still provide useful insights into how the students used the tool.
6.4.2 User Behaviours

Based on this analysis, we aimed to gain more insight into the behaviour of learners when using the CALL system. In particular, we wished to correlate user behaviour to our results by analysing the outcomes based on the log file. The log file contained information that identified the user and tracked what they did as explained in Section 6.3.1. The log file therefore provided an objective record of the actions of students while using the tool. The transition tables in Appendix C suggest that our tool did indeed produce beneficial effects when the learners made use of the diagnostic messages. A state transition diagram extracted from the transition tables was used to represent steps done by the learner during the two sessions. In the discussion below, we explore the users’ behaviours that were observed.

The initial approach was to extract different patterns of use from the data present in the log file. When viewing the log file from various perspectives, different student behavioural trends start to transpire; these can be useful for us as they help to show how the students view the system. Transition analysis shows a number of common paths; Table 6.2 shows the property represented by each action title.

<table>
<thead>
<tr>
<th>Actions’ title</th>
<th>Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>“checktrans”</td>
<td>Check incorrect answer (Mistranslated)</td>
</tr>
<tr>
<td>“checkmissing”</td>
<td>Check incorrect answer (Missing preposition element)</td>
</tr>
<tr>
<td>“NEXT”</td>
<td>GO to the next sentence</td>
</tr>
<tr>
<td>“PREV”</td>
<td>Go to the previous sentence</td>
</tr>
<tr>
<td>“showmodels”</td>
<td>Show the text models</td>
</tr>
</tbody>
</table>

Table 6.2: The representation of the actions path

Some common observations are made in relation to the path used throughout the procedure as exhibited by the users. Figure 6.11 represents all the possible transitions. Essentially, looking at the active moves made by an individual student will provide us with information about how they have used the tool.
From Figure 6.11 and Table 6.2 above, we can see very different behavioural trends related to the way the students used the system. This is shown by the numbers of the actions and the thickness of the arrows going from one node to the other. For example, the students who tended to move on to the next exercise, regardless of whether they performed well on the current one or not, did not seem to show satisfactory use of the system. This behaviour can be characterised by the series of 'Next' / 'Prev' as the aim of the system is to allow students to build on and practice what they already know.

Our expectation was that a student who looked at the model and used the diagnostic messages when they missed an element or mistranslated a sentence would consequently benefit the most from the system. Regarding this expectation, we can see that the most interesting action was ‘ShowModels’; this action can be used to trace and find out whether or not the students looked at the model and when exactly they looked at the model. Different behaviours of learners were recorded with the use of the ‘ShowModels’ action. It is apparent from the Figure 6.12 that the learners looked at the model differently when they made correct translations, when they had missing elements and when they mistranslated the sentences. Interestingly, the results show that the learners looked at the model more often when they received messages about mistakes with prepositions.
Surprisingly, only few people checked to find out the reason for their incorrect use of prepositions. This cannot just be attributed to lack of useful explanation as approximately half of the users never checked at all. We suggest that by telling the users that they would score better if they did not use the feedback, we may have discouraged them from using the feedback at all.

However, from the small number of users who looked at the diagnostic messages about misused prepositions, we believe that there is some evidence that students who did check what was missing did show an improvement. Of the people who may have improved between the two sessions (Users 1, 3, 4 and 7; see Figure 6.10), we can see that Users 1, 4 and 7 looked at the information about what was wrong with their use of prepositions,
and Users 1, 3 and 7 also looked at the model. This, however, is clearly not enough to provide solid evidence about the benefits of the tool but it is indicative. In other words, it seems that the users who looked at the feedback did improve, and those who improved were users who looked at the feedback. In addition, it is especially challenging to perform very reliable statistical analysis on data from this small sample size. However, the general observations show that if the learners used all the instruments provided to them by the tool, they stand a better chance of attaining the most benefit from the designed system. Therefore, analysing these trends can provide useful information about individual students’ behaviour and may be used as a guide for subsequent development of the system. Exploring ways of using these behaviour traces falls outside the scope of this thesis, but could form a useful avenue for further work.

6.5 Conclusion

This chapter presented the user interface of our system and how the learners could interact with the CALL tool, followed by discussion of the initial pilot study and the subsequent evaluation of the system performance. Analysing the trends of students’ use of the system indicated that there was no evidence of significant improvement in the follow-up session. Further analysis of user behaviour based on all expected paths of interaction showed relationships between improved learning outcomes and use of all available resources provided by the system. Unfortunately, we were only able to use a sample of 10 students who took the two sessions, which is a relatively small sample. It was therefore not possible to perform any reliable statistical analysis on the collected data. However, the presented evidence suggests that the tool can be useful if used as intended.
Chapter 7

Conclusions, Contributions and Future Work

7.1 Main Conclusions

In this thesis, we sought to investigate an effective way of assisting non-native Arabic learners with the correct usage of Arabic closed class items (CCIs), particularly spatial prepositions; an in-depth investigation of certain linguistic features of Arabic and English CCIs was conducted for this purpose. The main goal of the current study was to facilitate the use of Arabic prepositions by Arabic learners and providing them with a CALL system to be used as a diagnostic tool.

The thesis started by introducing the research aims and objectives and outlining the thesis structure, as presented in Chapter 1. Chapter 2 provided a general overview of the theoretical dimensions of the research and looked at language acquisition and learning theories related to CALL. The concept of CALL and a number of atheoretical systems were also discussed in this chapter. The linguistic and computational description of English and Arabic closed-class items (CCIs); in particular, spatial prepositions, were outlined in Chapter 3. It examined the properties of CCIs and the characteristics that make English and Arabic CCIs difficult to learn.

Chapter 4 outlined the machinery of the system and described the development of the CALL tool. Chapter 5 introduced the work performed in model building and abductive reasoning, showing how the theorem prover can be adapted to work abductively to try to fill in the gaps in the use of prepositions. Finally, Chapter 6 described the experiments carried out to investigate and evaluate the effectiveness of the CALL tool. This chapter
revisits the research questions and research objectives that were set in Chapter 1, pointing out the main findings and contributions of the thesis. The chapter also summarises the research outcomes and makes potential suggestions for future work. The research objectives for this study presented in Chapter 1 are outlined below:

- To represent the meaning of English and Arabic prepositions in an appropriate formal framework.
- To design and implement an architecture for identifying mismatches between models of English and Arabic sentences.
- To design and implement presentation tools for target exercises.
- To evaluate these tools in a classroom setting.

In order to achieve these objectives, we raised and set out to address two research questions, which were posed at the beginning of this study as follows:

**RQ1:** Can the differences between English and Arabic prepositions be accounted for by treating all prepositions as spatial and looking at the different spatial metaphors that each language associates with various words?

**RQ2:** Can this be used to help people learn how to use the right prepositions?

In order to answer these questions, we had to carry out certain investigations of the linguistic and computational description of English and Arabic CCIs, and we linked between image schemas and notions of prepositions. As we noted previously, schemas tend to appeal to a common intuitive notion of space without actually explaining what the notion is. Therefore, although schemas are helpful for understanding certain concepts, they cannot actually be used as a basis for any kind of automated reasoning, but if the notions that they exemplify can be formalized then they can be used as a basis for writing meaning postulates (MPs). We, subsequently, used the established meaning postulates abductively in order to identify the differences between English and Arabic prepositions.

Therefore, the answer to **RQ 1** “can the differences between English and Arabic prepositions be accounted for by treating all prepositions as spatial and looking at the different spatial metaphors that each language associates with various words?” can be affirmative to very large extent as supported by this study. Unfortunately, we could not answer **RQ 2** “can this be used to help people learn how to use the right prepositions?”
in adequate detail because we did not manage to collect sufficient data to assess this question reliably. Despite having some indicative answers from the log file results, it would be desirable to have more comprehensive data. We believe that if we had a larger sample of participants and more sessions, the outcome would have been assessed more clearly leading to more conclusive evidence of the extent of students' learning from such a tool.

7.2 Contributions of the Thesis

In this study, we have made several noteworthy contributions to the field:

C.1 A precise, formal description of the ways that English and Arabic spatial prepositions are used to locate a figure with respect to a ground. In Section 4.5.2, we have discussed how we formalised the notion of the meanings of Arabic and English spatial and temporal prepositions as a set of MPs in order to reason about the consequences of such utterances.

C.2 Implementation of an abductive inference engine for finding missing information in the use of prepositions. As described in Section 5.2.2, we used the ‘abductive’ inference by adapting a theorem prover (TP) to work abductively to find out errors in the way that someone uses a preposition.

C.3 Development of a tool for displaying this information to a learner. This is demonstrated in Section 6.2.

C.4 Evaluation of the effectiveness of the developed tool. See Section 6.3 for more detail.

We were unable to demonstrate a significant improvement in learning the correct use of prepositions. As noted previously, CALL tools are very difficult to evaluate because learning a language is a long, slow process and measuring the effect of such tools requires a large number of students and an extended number of sessions. The transition tables in (Appendix C) suggest that learners did not make as much use of the diagnostic messages as expected: it would be particularly interesting to see whether learners who did make more use of these messages showed a greater level of improvement, but this would require a larger study that was feasible within the constraints of this project.
7.3 Future Work

There are a number of possible directions for future research and also some remaining questions related to the field that are worth further investigation. Although we did a reasonable amount of work with this tool by turning a formal description of the ways that English and Arabic spatial prepositions could be used into a set of meaning postulates to perform two tasks; diagnosing misuse of prepositions abductively, and diagnosing other mistranslations by comparing models, our CALL tool would benefit from further work by developing extensions of the meaning postulates and adding a large number of open class words. In addition, it would be advantageous to examine how the system affects the development of learning of a larger number of students over a longer period of time in order to form more comprehensive conclusions. Moreover, it would be useful to investigate whether there is a significant and meaningful link between patterns of students’ behaviour reflected on the log file and the extent of academic achievement.

Another useful future work can be adopting the developed CALL tool to a MALL (mobile-assisted learning language) tool, also know as MALU (mobile-assisted language use). However, Yamaguchi (2005, p. 57) argued that “a computer is better than a mobile phone for handling various types of information such as visual, sound, and textual information, but mobile phone is superior to a computer in portability. And some students don’t have their own computer”. Huw and Marianna(2013) provided a definition of MALU as “non-native speakers using of a variety of mobile devices in order to access and/or communicate information on an anywhere/anytime basis and for a range of social and/or academic purposes in an L2”.

The recent widespread of personal mobile devices with access to wireless networks has resulted in surging popularity of these devices, a trend which can be utilised in order to enhance language learning anytime and anywhere. This means that learners have increasing control and choice over activities that can be motivated by their personal requirements and specific leaning situation (Kukulska-Hulme et al., 2007). MALL is different from CALL affording portability and personal choice, which offers new ways of learning a second language based on continuous access and interaction.

Mobile technology can encourage independence and control over one’s personal learning. This led to the recent surge in the number of apps targeted at assisting language learning. Because of the large number of available mobile platforms, including iPhones,
iPads, MP3/MP4 players, PDAs (personal digital assistants), palmtop computers, this can afford more effective ways to promote language learning skills. A study on mobile learning projects showed that mobile phones represent the most popular platform used in such projects (Pecherzewska and Knot, 2007). This growing trend has the potential to change the dynamics of the classroom by providing a more comprehensive range of learning activities, offering alternative types of homework, providing evaluation and feedback, and promoting communication, cooperation and creative expression (Burden et al., 2012)
Bibliography


DeVries R (2002). What is constructivist about constructivist education, *in Keynote address at the annual meeting of the Association for Constructivist Teaching, Houston, TX*.


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Mark J (1987), ‘The body in the mind: The bodily basis of meaning, imagination, and reason’.


Piaget J (1973). To understand is to invent: The future of education.


Ramsay A and Seville H (2001), ‘What Situational and Discourse Relations Entail’, @in-proceedings,ramsaysituational.


Smith C S (1991), ‘The parameter of aspect (Studies in Linguistics and Philosophy, 43)’.
Snider T (2010). The Semantics of Prepositions: An exploration into the uses of “at” and “to”.


STEVENS S (2009). When to Use On, Onto, and On to, Grammatically Correct is a grammar tip of the week created by Academic Center Peer Writing Tutors.


Talmy L (1972). Semantic structures in English and Atsugewi.


Yamaguchi T (2005), ‘Vocabulary learning with a mobile phone (Program of the 10th Anniversary Conference of Pan-Pacific Association of Applied Linguistics, Edinburgh, UK. ed.).’


Appendix A: Ethical Approval

Prior to commencing our experiments and collecting data or involving our human participants to use in our research, we must obtain ethical approval which is included in this appendix.
Re: Hayat Mohamed a Alrefaie

Project Title: Supporting language learners with the meanings of closed class items

Abstract: I need to evaluate my tool by getting students to use it, and assess whether it helps them or not. I have two standard strategies for this kind of evaluation. (i) get two groups of students, one who are going to use it and one who are not. Give them a test on the relevant task. Get the active subjects to use the tool. Give them all a follow-up test. See if the ones who used the tool have improved more on the task than the ones who didn’t. All properly anonymised. (ii) the tool can be used in different ways. (a) It can just tell you whether you got it right or not. It can give you summary information about what you did wrong. It can give you detailed information about what you got wrong. (b) You can go through the examples in any order you like. You can have repeated goes at something that you got wrong or you can skip straight to the next thing. We gather behaviour traces and try to interpret them (to see what students like and don’t like about the tool) and to link them to changes in performance. All again anonymised.

To whom it may concern:

This is to confirm that the above project was submitted to the Ethics Committee of the School of Computer Science in February 2016, and approved on the 26th of February 2016. The approval number is CS228, and the study has now been recorded on the system as being completed.

Yours Sincerely,

Dr Carole Twining, Computer Science Ethics Review Panel

Room G21, Kilburn Building, School of Computer Science
University of Manchester, Oxford Road, Manchester M13 9PL

Room G539B, Stopford Building, Faculty of Medical and Human Sciences

Email: carole.twining@manchester.ac.uk
Appendix B: Requirements
Analysis Questionnaire Template

This appendix contains the Requirements analysis Questionnaire Template, that we used as a structured questionnaire have been done with an experienced Arabic teachers.
Computational support for the learning of Arabic prepositions

Hayat M. Alrefaie
Project abstract

The aim of this study is to help learners of the Arabic language to correctly learn the Arabic prepositions and temporal marks. This will be conducted through the implementation of a tool that uses a CALL model to support language learners in managing linguistic features like closed class items (CCIs) (Prepositions and Temporal markers). This aspect of Arabic language has been chosen because it represents one of the most difficult areas of the target language for learners and yet has not been investigated in any previous research. We are preparing in the future to providing learners of Arabic language with feedback based on the semantic content of their input to the system.

Please try to respond to all the items, and explain as much as you can.

Questions:

• How long have you been teaching Arabic language as a foreign language?

• What are the most difficulties that students face while they are learning Arabic prepositions?
In your opinion what items cause the most difficulties and problems?

في رأيك ما هي البنود التي تسبب معظم الصعوبات والمشاكل؟
- Suppose each student had a 24hr-teaching assistant (TA) to help them with their work. This TA can mark simple translation exercises, and can give feedback at various levels about what students have done wrong. If your students had someone like that to help them, how would you use that person?

- What kinds of exercises would you set? What kinds of exercises don’t you set?
• What kinds of feedback would you want the TA to provide? How many levels? How much detail?

ماهي أنواع الملاحظات التي ترغب بأن يقدمها المساعد التعليمي؟ وعلى كم مستوى؟ والي أي مدى هي تفصيلية؟
If a student mistranslates a preposition, what do you do? Do you just mark it as wrong? Do you tell them what it should be? Do you try to explain to them why it should be that? How do you express such an explanation?

What would you like the TA to tell you about the student? How many mistakes they made? What kinds of mistakes they made (what kinds of mistakes are there? Is it just “mistakes with ‘fy’” or is it subtler than that?) What else would you like to know?
If your students each had a 24-hour TA, would that affect your lesson planning? Would you want them to use it during lessons or just for homework?
Thank you so much for your time.

Sincerely,
Hayat Alrefaie

شاكرا لكم سلما تعاونكم

حياة الرفاعي
Appendix C: The Transition Tables

This appendix contains the transition tables which we extracted from the log file that contains a record of what the student has done. It is shown both the “ACTION” which represents the user’s log in time and period and the “MARK” that says something about the user output.
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**Maha, 2016-07-10**

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Maha, 2016-07-17

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Appendix D: Meaning Postulates

This appendix contains a Prolog script which we wrote as the Meaning postulates (MPs) or Background Knowledge rules. These MPs are embodied in English and Arabic BK, some shared BK, and translation rules.
dialogueTestSet(translationRules,
    forall(X :: {'mktb_desk;office'(X)},
        forall(Y :: {office(Y)},
            mktb_office(X)))
    &
    forall(X :: {'mktb_desk;office'(X)},
        forall(Y :: {desk(Y)},
            mktb_desk(X)))
    &
    forall(X :: {event(X, 'wqf_stop;stand')},
        forall(Y :: {event(Y, 'stand')},
            event(X, 'wqf_stand'))
    &
    forall(X :: {event(X, 'wqf_stop;stand')},
        forall(Y :: {event(Y, 'stop')},
            event(X, 'wqf_stop'))
    &
    forall(X::{'byt_home;house'(X)},
        forall(Y :: {home(Y)},
            byt_home(X)))
    &
    forall(X :: {'byt_home;house'(X)},
        forall(Y :: {house(Y)},
            byt_house(X)))
).

dialogueTestSet(shared,
    forall(_A :: {event(_A, _B)},
        type(_A, temporalObj) & dim(_A, 2))
    & forall(_A::{speaker(_A)}, human(_A))
    & forall(_A, _B : : {event(_B, live) & theta(_B, agent, _A)},
        forall(_C :: {in(_B, _C)},
            start(_C) & of(_C, _A)))
    & forall(_A, _B : : {alternateView(_A, _B)}, view(_A, _B))
    & forall(_A::{animal(_A)}, type(_A, physObj))
    & forall(_A :: {back(_A)},
        forall(_B :: {of(_A, _B)},
            properPartOf(_A, _B)
        & (animal(_B) => surface(_A))))
    & forall(_A :: {compassPoint(_A)},
        ...)

\[ \text{point}(\_A) \]
\[ & \text{type}(\_A, \text{physObj}) \]
\[ & \text{forall}(\_B :: \{ \text{of}(\_A, \_B) \} \& \text{region}(\_B), \]
\[ & \text{region}(\_A) \& \text{properPartOf}(\_B, \_A)) \]
\[ & \text{forall}(\_A :: \{ \text{day}(\_A) \}, \]
\[ & \text{type}(\_A, \text{temporalObj}) \& \text{circle}(\_A) \]
\[ & \text{forall}(\_A, \]
\[ & \text{forall}(\_B :: \{ \text{end}(\_A) \& \text{of}(\_A, \_B) \}, \]
\[ & \text{forall}(\_C :: \{ \text{alternateView}(\_B, \_C) \}, \]
\[ & \exists(\_D, \text{of}(\_D, \_C) \& \text{end}(\_D))) \]
\[ & \text{forall}(\_A :: \{ \text{end}(\_A) \}, \text{point}(\_A) \]
\[ & \text{forall}(\_A :: \{ \text{end}(\_A) \}, \]
\[ & \text{forall}(\_B :: \{ \text{of}(\_A, \_B) \}, \]
\[ & \text{forall}(\_C :: \{ \text{type}(\_B, \_C) \}, \text{type}(\_A, \_C))) \]
\[ & \text{forall}(\_A :: \{ \text{end}(\_A) \}, \]
\[ & \text{forall}(\_B :: \{ \text{of}(\_A, \_B) \}, \]
\[ & \text{properPartOf}(\_B, \_A)) \]
\[ & \text{forall}(\_A :: \{ \text{floor}(\_A) \}, \]
\[ & \text{type}(\_A, \text{physObj}) \& \text{surface}(\_A) \]
\[ & \text{forall}(\_A, \]
\[ & \text{forall}(\_B :: \{ \text{floor}(\_A, \_B) \}, \]
\[ & \text{floor}(\_B) \& \text{partOf}(\_A, \_B)) \]
\[ & \text{forall}(\_A :: \{ \text{hearer}(\_A) \}, \text{human}(\_A)) \]
\[ & \text{forall}(\_A :: \{ \text{human}(\_A) \}, \]
\[ & \exists(\_B, \]
\[ & \text{properPartOf}(\_A, \_B) \]
\[ & \& \text{foot}(\_B) \& \text{lowestPoint}(\_A, \_B) \]
\[ & \& \text{forall}(\_D :: \{ \text{place}(\_D) \& \{ \text{from}(\_A, \_D) \text{ or } \text{mn}(\_A, \_D) \} \}, \]
\[ & \exists(\_C, \]
\[ & \text{event}(\_C, \text{live}) \]
\[ & \& \text{theta}(\_C, \text{agent}, \_A) \& \text{in}(\_C, \_D))) \]
\[ & \& \text{forall}(\_A, \]
\[ & \text{forall}(\_B :: \{ \text{interior}(\_A, \_B) \}, \]
\[ & \text{interior}(\_B) \& \text{properPartOf}(\_A, \_B)) \]
\[ & \& \text{forall}(\_A :: \{ \text{interior}(\_A) \}, \text{region}(\_A)) \]
\[ & \& \text{forall}(\_A :: \{ \text{interval}(\_A) \}, \]
\[ & \text{type}(\_A, \text{temporalObj}) \& \text{region}(\_A) \& \text{dim}(\_A, 1)) \]
\[ & \& \text{forall}(\_A :: \{ \text{lowestPoint}(\_A) \}, \text{surface}(\_A)) \]
\[ & \& \text{forall}(\_A :: \{ \text{human}(\_A) \text{ or } \text{horse}(\_A) \}, \text{animal}(\_A)) \]
\[ & \& \text{forall}(\_A :: \{ \text{man}(\_A) \text{ or } \text{woman}(\_A) \}, \text{human}(\_A)) \]
\[ & \& \text{forall}(\_A :: \{ \text{name}(\_A, '\text{January}') \text{ or } \text{name}(\_A, '\text{February}') \text{ or } \text{name}(\_A, '\text{March}') \text{ or } \text{name}(\_A, '\text{April}') \text{ or } \text{name}(\_A, '\text{May}') \text{ or } \text{name}(\_A, '\text{June}') \text{ or } \text{name}(\_A, '\text{July}') \text{ or } \text{name}(\_A, '\text{August}')) \]
or named(_A, 'September')
or named(_A, 'October')
or named(_A, 'November')
or named(_A, 'December'),
month(_A))
& forall(_A :: {localised(_A)},
  forall(_B :: {view(_A, _B)},
    forall(_C :: {theta(_A, _, _C)},
      forall(_D :: {type(_B, _D) & type(_C, _D)},
        forall(_E :: {(_E > _C)}, (_E > _B))))))
& forall(_A :: {month(_A)},
 forall(_B :: {day(_B)},
    (_A > _B))
& forall(_A, partOf(_A, _A))
& forall(_A,
  forall(_B :: {partOf(_A, _B) & interior(_B)},
    interior(_A, _B))
& forall(_A :: {path(_A)},
  exists(_B,start(_B) & of(_B, _A))
  & exists(_C,end(_C) & of(_C, _A))
& forall(_A :: {place(_A)}, region(_A))
& forall(_A::{point(_A)}, referencePoint(_A, _A))
& forall(_A :: {instant(_A)},
  forall(_C :: {type(_A, _C)},
    forall(_B :: {region(_B) & type(_B, _C)},
      (_B > _A))))
& forall(_A,
  forall(_B::{properPartOf(_A, _B)}, partOf(_A, _B) & (_A > _B))
& forall(_A,
  forall(_B :: {properPartOf(_A, _B)},
    forall(_C::{type(_A, _C)}, type(_B, _C))))
& forall(_A,
  forall(_B :: {referencePoint(_A, _B)},
    point(_B)
  & forall(_C::{type(_A, _C)}, type(_B, _C))))
& forall(_A::{screen(_A)}, surface(_A))
& forall(_A,
  forall(_B :: {(_B > _A)},
    forall(_C :: {(_C > _B)},
      (_C > _A))))
& forall(_A :: {start(_A)},
  forall(_B::{of(_A, _B)}, properPartOf(_B, _A))
& forall(_A,
  forall(_B :: {start(_A) & of(_A, _B)},
    forall(_C :: {alternateView(_B, _C)},
      exists(_D,of(_D, _C) & start(_D))))

3
forall(_A: {start(_A)}, point(_A))
forall(_A: {start(_A)},
    forall(_B: {of(_A, _B)},
        forall(_C: {type(_B, _C)}, type(_A, _C))))
forall(_A,
    forall(_B: {surface(_B) & of(_B, _A)},
        properPartOf(_A, _B)))
forall(_A: {telic(_A)}, event(_A) & path(_A))
forall(_A,
    forall(_B: {top(_A) & of(_A, _B)},
        forall(_C: {alternateView(_B, _C)},
            exists(_D, top(_D) & of(_D, _C))))
    & forall(_A: {top(_A)},
        forall(_B: {of(_A, _B)}, properPartOf(_B, _A)))
    & forall(_A, view(_A, _A))).
dialogueTestSet(englishRules,
    forall(_A,
        forall(_B: {at(_A, _B)},
            forall(_C,
                forall(_D: {view(_A, _D) & type(_D, _C)},
                    forall(_E: {view(_B, _E) & type(_E, _C)},
                        forall(_F: {referencePoint(_E, _F)},
                            dist(_F, _D, 0)
                            & located(_A, _B)))))))
forall(_A,
    forall(_B: {from(_A, _B)},
        forall(_C,
            forall(_D: {view(_A, _D) & type(_D, _C)},
                forall(_E: {view(_B, _E) & type(_E, _C)},
                    forall(_F: {partOf(_D, _F) & start(_F)},
                        dist(_E, _F, 0)
                        & located(_A, _B)))))))
forall(_A,
    forall(_B: {in(_A, _B)},
        forall(_C,
            forall(_D: {view(_B, _E) & type(_E, _C)},
                forall(_F: {view(_A, _F)}
                    & type(_F, _C) & (_E > _F)},
                forall(_G: {partOf(_E, _G)
                    & region(_G)},
                    located(_A, _B)))))))
forall(_A,
    forall(_B: {on(_A, _B)}),
    forall(_C,
forall(_D,
forall(_E :: {view(_A, _E) & type(_E, _C)},
forall(_F :: {view(_B, _F) & type(_F, _C) & (_F > _E)},
forall(_G :: {partOf(_F, _G) & surface(_G)},
touching(_E, _G)
& located(_A, _B))))
& forall(_A,
forall(_B :: {to(_A, _B)},
forall(_C,
forall(_D :: {view(_A, _D) & type(_D, _C)},
forall(_E :: {view(_B, _E) & type(_E, _C)},
forall(_F :: {partOf(_D, _F) & end(_F)},
dist(_D, _F, 0)
& located(_A, _B))))))
dialogueTestSet(arabicRules,
forall(_A,
forall(_B :: {'ElY'(_A, _B)},
forall(_C,
forall(_D :: {view(_A, _D) & type(_D, _C)},
forall(_E :: {view(_B, _E) & type(_E, _C)},
forall(_F :: {partOf(_D, _F) & surface(_G)},
touching(_E, _G)
& located(_A, _B))))
& forall(_A,
forall(_B :: {'IlY'(_A, _B)},
forall(_C,
forall(_D :: {view(_A, _D) & type(_D, _C)},
forall(_E :: {view(_B, _E) & type(_E, _C)},
forall(_F :: {of(_F, _D) & end(_F)},
dist(_D, _F, 0)
& located(_A, _B))))
& forall(_A,
forall(_B :: {'End'(_A, _B)},
forall(_C,
forall(_D :: {view(_A, _D) & type(_D, _C)},
forall(_E :: {view(_B, _E) & type(_E, _C)},
forall(_F :: {referencePoint(_E, _F)},
dist(_F, _D, 0)
& located(_A, _B))))
& forall(_A,
forall(_B :: {b(_A, _B)},
forall(_C,
forall(_D, 
forall(_E :: {view(_B, _E) & type(_E, _C)},
...)
forall(_F :: {view(_A, _F) & type(_F, _C)}
forall(_G :: {partOf(_E, _G)
  & region(_G),
  located(_A, _B))))
&forall(_A,
  forall(_B :: {fy(_A, _B)},
    forall(_C, 
      forall(_D, 
        forall(_E :: {view(_B, _E) & type(_E, _C)}, 
          forall(_F :: {view(_A, _F) & type(_F, _C) & (_E > _F)}, 
            forall(_G :: {partOf(_E, _G)
             & region(_G)),
             located(_A, _B))))))
    &forall(_A, 
      forall(_B :: {mn(_A, _B)},
        forall(_C, 
          forall(_D :: {view(_A, _D) & type(_D, _C)}, 
            forall(_E :: {view(_B, _E) & type(_E, _C)}, 
              forall(_F :: {of(_F, _D) & start(_F)},
                dist(_E, _F, 0)
                & located(_A, _B)))))))
  &forall(_A,
    forall(_B :: {'l'(_A, _B)},
      forall(_C, 
        forall(_D :: {view(_A, _D) & type(_D, _C)}, 
          forall(_E :: {view(_B, _E) & type(_E, _C)}, 
            forall(_F :: {of(_F, _D) & end(_F)},
              dist(_D, _F, 0)
              & located(_A, _B))))))))