CHAPTER 12

NATURAL LANGUAGE PROCESSING IN ARTIFICIAL INTELLIGENCE: A FUNCTIONAL LINGUISTIC PERSPECTIVE

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Abstract

This chapter encapsulates the multi-disciplinary nature that facilitates NLP in AI and reports on a linguistically orientated conversational software agent (CSA) (Panesar 2017) framework sensitive to natural language processing (NLP), language in the agent environment. We present a novel computational approach of using the functional linguistic theory of Role and Reference Grammar (RRG) as the linguistic engine. Viewing language as action, utterances change the state of the world, and hence speakers and hearer's mental state change as a result of these utterances. The plan-based method of discourse management (DM) using the BDI model architecture is deployed, to support a greater complexity of conversation. This CSA investigates the integration, intersection and interface of the language, knowledge, speech act constructions (SAC) as a grammatical object, and the sub-model of BDI and DM for NLP. We present an investigation into the intersection and interface between our linguistic and knowledge (belief base) models for both dialogue management and planning. The architecture has three phase models: (1) a linguistic model based on RRG; (2) Agent Cognitive Model (ACM) with (a) knowledge representation model employing conceptual graphs (CGs) serialised to Resource Description Framework (RDF); (b) a planning model underpinned by BDI concepts and intentionality and rational interaction; and (3) a dialogue model employing common ground. Use of RRG as a linguistic engine for the CSA was successful. We identify the complexity of the semantic gap of internal representations with details of a conceptual bridging solution.

1. Introduction to NLP in AI

A simple definition of artificial intelligence (AI) is '*the science of mimicking human mental faculties in a machine'*(Hopgood, 2014*).* Philosophers pose the question – how do minds work? This raises two hypotheses – one of weak AI – the assertion that machines could act as if they are intelligent or strong AI – the assertion that machines that do so are actually thinking. In most cases researchers comply with weak AI, as they are not concerned whether it simulated intelligence or real intelligence, but more importantly their program works (Russell and Norvig, 2016). However, for this chapter we will consider strong AI. In terms of the spectrum of intelligence (from reactive agents to expert systems), natural language (NL) sits midway depicting that the level of understanding required for computers is complex, fundamentally because NL is inherently ambiguous, complex and dynamic, compared to being the most easily understood knowledge representation for people. For example, 'he saw her duck' may mean he saw a waterfowl that belonged to her, or that he saw her move to evade something. Here we have a probability distribution over possible meanings.

Computational linguistics (CL) is an interdisciplinary field concerned with processing of language by computers, and sub-field of AI. NLP is defined by Liddy (2001) 'as a theoretically motivated range of computational techniques for analysing and representing natural occurring texts at one or more levels of linguistic analysis for the purpose of achieving human-like language processing for a range of tasks or application'. Real world applications are varied such as machine translation, question answering, text data mining, NL interfacing and generation, spoken dialogue systems, and multilingual online language processing (Mitkov, 2003). Our focus lies with NL interfaces, generation, understanding and processing – an engineering domain (Clark, Fox, and Lappin, 2013).

One explanatory approach to understanding the NLP system is the 'levels of language', from phonology to pragmatics, where the levels can interact in a 'variety of orders' and thus dynamic. Each level conveys meaning and knowledge, and humans tend to use all levels of language to gain understanding, subsequently, a potential for a more capable NLP system. The different forms of knowledge relevant to NLU exist at each level of language whereby there is the additional world knowledge (general knowledge, and knowledge of the other user's beliefs and goals). With knowledge of the possible ambiguities, we are confronted with ascertaining what something means by determining ‘‘WHO did WHAT to WHOM, WHERE, WHEN, HOW and WHY?” (Pradhan et al., 2004) which poses two problems. Firstly, WSD (word sense disambiguation) algorithms to deal with words with similar meanings (polysemy) and to extract their sense, for example the ambiguous word “dish” as either of three senses ‘plate’, ‘course of a meal’ or a ‘communication device’. Secondly, pronoun resolution, is a deeper kind of NLU to work out “Who did want to whom”, to detect the subjects and objects of the verb (Bird, Klein, and Loper, 2009). For instance, in the sentence “thieves stole the painting” may be followed by either one of these sentence - “They were subsequently sold” or “They were subsequently found”. Answering this question involves finding the antecedent of the pronoun, “they” either “thieves or paintings”. Computation techniques for tackling this problem are called anaphora resolution. This may include identifying what the pronoun or noun phrase refers to - and semantic role labelling – identifying how the noun phrase relates to the verb (as an agent, patient, instrument, and so on).

A practical NLP system must be good at making dis-ambiguous decisions of word sense, word category, syntactic structure and semantic scope. A technique of using selection restrictions e.g. a verb like “swallow” requires an animal being as its subject and physical object as its object. For example: 1) ‘I swallowed his story book, ink and ruler’; (2) ‘the supernova swallowed the planet’. This restriction will disallow common and straightforward metaphorical extensions of the usage of “swallow” as above. Our next question is – what do we want to achieve from NLP. Liddy (2001) states that full NLP system goals are: (1) Paraphrase an input text; (2) Translate the text into another language (not considered here); (3) Answer questions about the contents of the text; (4) Draw inferences from the text. NLP research has generally made progress on goals (a-c), but (d) refers to NLU – a more challenging goal, within this work. What computers find hard is processing an utterance which is implicit, high contextual, ambiguous and often imprecise (McCord, Murdock, and Boguraev, 2012) and hence which requires a deeper linguistically knowledge aware architecture.

To summarise the aim of this chapter is establish, explain, demonstrate and discuss future work for our use of a functional linguistic perspective for NLP in AI. The objective of this chapter include: (1) to establish the use of formal to functional linguistic phenomena; (2) to define the goals of linguistic theory; (3) to explain the basic concepts of our strong functional linguistic theory (4) to present an experimental case (5) to demonstrate a proof-of-concept (6) discuss future work.

2. NLP Models – Statiscal to Formal to Linguistic to Functional

2.1 NLP models – statistical to formal

Ordoñez-Salinas and Gelbukh (2010) highlights there are several statistical probabilistic computational structures (CS) used in NLP from limitation in syntax-driven processing to semantic-driven processing and using more complex structures such as vector-based, graph-based and tree-based models. To reiterate the goal of NLU defined by Winograd (1972) is "we can describe the process of understanding language as a conversion from a string of sounds or letters to an internal representation of 'meaning". Further, NLU is popular in linguistics, and cognitive science as well as NLP.

The first NLP related task was a machine translation (MT) – a computer-based application, derived in the late 1940s. This was followed by computer translation projects, using various techniques of dictionary-lookup, and word order tasks, but omitted lexical ambiguity. In the 1950s, researchers realised there was a need for an adequate theory of language, and in 1957 Chomsky published "syntactic structures". In the 1990's there was much acceleration in three areas as confirmed by (Lester, Branting, and Mott 2004), which include: (1) development of large corpora of tagged text, for instance, the Brown Corpus, the Penn Treebank and the British National Corpus (BNC); (2) using the tagged corpora influenced the development of statistical, machine-learning and empirical techniques for extracting grammars and ontologies; (3) rise of competitions such as Text Retrieval Conferences (TREC) since 1992 provide a driving force for NLP prototypes and automation.

A language-understanding system must have some formal way to express its knowledge to a subject, and must be able to represent the 'meaning' of a sentence in this formalism. The formalism must be structured so the system can use its knowledge in conjunction with a problem-solving system to make deductions, accept new information, answer questions, and interpret commands. Further Raskin and Nirenburg (1987) identify that NLP applications are easier to build, and deceptively intelligent as noted by Periñán-Pascual (2013) but controversially, without linguistic theories, semantic relevance is missing, and therefore dismisses the NLU. For instance, the first conversational agent was ELIZA, contrived for NLP, based on simple pattern matching technique ALICE (Artificial Linguistic Internet Computer Entity) ALICE (n.d) at the website - http://www.alicebot.org) programmed in a language called AIML (Artificial Intelligence Markup Language) that is based on XML (Weizenbaum, 1966). It could facilitate dialogue but the responses did not reflect the user's intentions, and not having any understanding of the language.

The earliest language models were n-gram letter models proposed by (Markov, 1913) followed by n-gram word models in English based on the statistical methods and ideas from information theory (Shannon and Weaver, 1949). Duta (2014) notes the theoretical modern CLs started in the late 1950's, with the introduction of generative grammar by Noam Chomsky. This theory's aim was to produce a set of rules that could correctly predict which combination of word forms made up grammatical sentences. After this there were attempts at NLU by a first computer at Stanford and MIT called STUDENT which had the ability to input algebraic word problems.

Ovchinnikova (2012) asserts that most of the NLU programs in the 1970s were also called knowledge-based systems, and their development closely related to the AI research on knowledge representation (KR). The focus of these programs was world knowledge from large efforts into general-purpose knowledge base such as CYC to more most recent large-scale project attempting NLU with Watson – Deep QA project by Chaplot, Chhipa, and Kumar (2013). Here several models and algorithms were used such as machine learning techniques, semantic frames, shallow and deep parses logical forms, semantic role labels, co-reference, relations, named entities, probabilistic methods to name a few, for question answering. The challenge here was to build a computer system that could compete at the human champion level in real time (Ferrucci et al., 2010). The interesting elements here are the cognition approaches used. To date, this project has expanded, and the Watson API is invoked for various NLU related activities.

The challenge of NLP and NLU is due to the range of ambiguities from lexical to pragmatic as illustrated in Figure 1 with the NLP pipeline. Our next question is - what are the theoretical aspects of language, and further what are the non-statistical ways of processing natural language text.

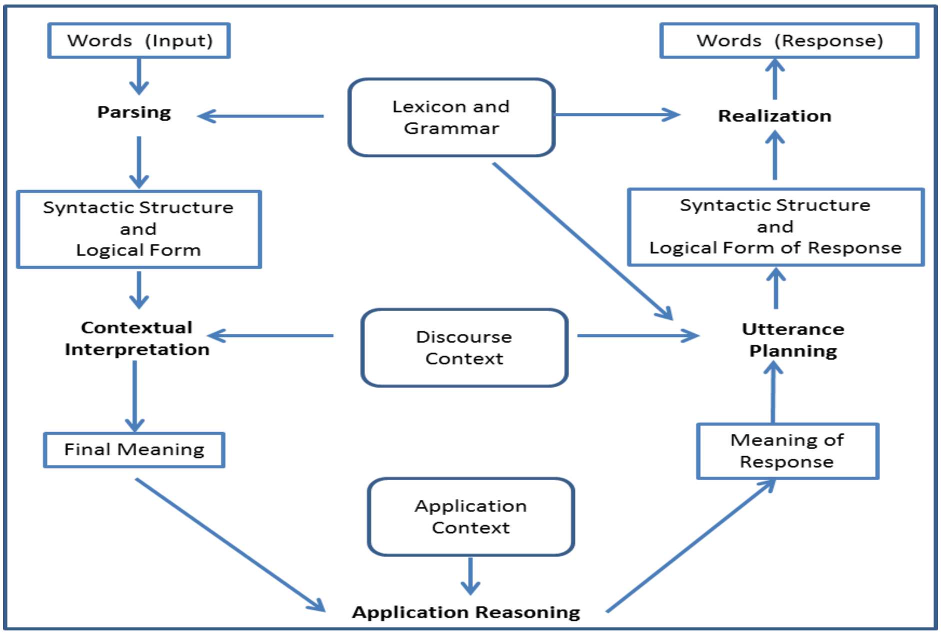


Figure 1: NLP Pipeline.

There are several popular linguistic based computational structures. One example is dependency grammar where a relation exists between the head word and the other words that depend on it, and where the order of the words and the positon in the sentence is not important (Tesnière, 2015). Comparatively link grammar developed undirected relations between pairs of words (Sleator and Temperley, 1995). Further, there is constituent-based grammar, whereby a group of words will form a constituent category, which maybe a noun phrase or a verb phrase. Here a tree has an iterative segmentation into a range of constituent categories based on their grammatical classification. There are formal language theories and varied grammars such as phrase structure grammars, and probabilistic context-free grammars which are also used for CL projects, and popularly used, for example in word processing packages. However, for our NLP focus, we will explore functional grammars in the next section.

2.2 NLP models – formal to functional grammars

Butler and Taverniers (2008) and Rezai (2003) in their discussions outline that over the last 40 years, several new approaches to "grammar theorising and description" have evolved under the different "functional(ist)" perspective of language as opposed to the "formalist" theories by Chomsky. The idea was that knowledge was acquired by the use of language, which Chomsky (1986) identifies relates to communication, syntax "rules of grammar", semantics "rules of meaning" and the communication of a spoken NL using syntax and semantics theoretically. Further to this, Chomsky discusses that there are problems with the behaviourist view, for example the badger will howl in danger, but humans do not need an environmental stimulus or the “occurrence of internal states”, in order for producing language. Key findings on human languages formulated by the Chomskyian approach (1986) is that the study of language is known as universal grammar (UT). Contrastingly, Rezai (2003) asserts that functionalists look at all aspects of the structural organization of language in the light of its role in human social interaction and that linguistic investigation is expansive. Hence, the guiding principle of functionalism is such that the form of a sentence is determined by its meaning with reference to pragmatic and social considerations. Butler and Taverniers (2008) notes the central claim of functionalism is that language should be seen first and foremost as a system for communication between human beings. They further add the forms that languages take are strongly conditioned by both the nature of human cognitive capacities, and the sociocultural contexts in which, and purposes for which, language is used.

A trait of most functionalism is that syntactic phenomena is being motivated by (and not simply correlating with) meaning, and to degrees which vary with the particular functional theory, and further to tackle everything that is systematic in language. Natural language (NL) is conceived of as a functional system (Francois, 2014). The functionalist continuum composes three groups which identify a reduction of grammatical structure to discourse from extreme (no relevance to formal aspect of language), to conservative noted by Yang (1994). Between these two extremes, there exists moderate functionalist known as structural-functional grammar (SFG) approaches - focus on both meaning and formal structure, and their inter-relationships, with generative qualities. They have an explicit framework of rules and principles, linked in specified ways, by means of which the structure and interpretation of linguistic expressions can, in principle, be exhaustively described’’ (Butler, 2009).

There are four periods of structural functional grammar (SFG) in which the theories were mostly developed in the realm of European structuralism starting with: (1) period of 1925- 1950; (2) period of 1950-1975; (3) period of 1975-2000; and (4) since 2000 (Francois 2014). The fourth era saw further work by (Halliday and Matthiessen 2004) on SFG, and the development of the Functional Discourse Grammar (FDG) in 2008, and the new formulation of Role and Reference Grammar (RRG) by Van Valin Jr (2005a) specifically on the syntax-semantic interface. A key feature of SFG is layering, that is the clause and other phrasal units can be analysed in terms of number of layers which are related to the functions which language serves in communication, and provide further interesting frameworks for syntax, semantics and pragmatics, compared to the traditional ways. Another important influence to layering was from the work by (Foley and Van Valin Jr., 1984) when working on RRG with its central tenet related to strong typological orientation, and the discovery of linguistic universals. This work further influences the present day RRG, the layered model of the clause structure.

With this in mind, RRG specifically will be pursued in our experiment of linguistically centred conversational software agent. The reasoning behind this is that RRG's major influence on layering and its ongoing developments such as detailed rules for mapping from semantic structures to syntactic structures (needed in modelling language production) and from syntactic structures to semantic structures (needed for comprehension), and its computational abilities and applications have provided some fruitful results (Salem, Hensman, and Nolan, 2008). This is discussed in the next section. Before focusing on an RRG implementation, it is important to understand the goals of linguistic theory.

2.3 Introduction to the goals of linguistic theory and NLP

Language 'is an immensely complex behaviour' requiring a mental lexicon consisting of knowledge of words in that language, together with knowledge of the grammatical use of those words in the sentence (Jones and Mewhort, 2007). This signifies that the mental lexicon has a rich history in psychology. This is deeply rooted with work of Van Valin and LaPolla (1997) state that there are a set of general goals that most linguists have agreed upon, which include: (1) description of the linguistic phenomena; (2) explanation of linguistic phenomena; (3) understanding of the cognitive basis of language.

Describing the linguistic phenomena demands: (1a) describing an individual language (1b) describing the commonality between languages (language universals); (1c) describing the differences between languages (language topology). The demands are crucial for the evolution of the language itself, and presupposes the other goals, in that, one cannot explain a language if you cannot describe it first, alternatively one cannot understand the cognitive basis of a language without its description.

Explaining the linguistics phenomena involves the use of criteria and standards to explain (2a) how speakers use language in different social situations; (2b) why human languages have the structure they do? (2c) what is common to all human languages; 2(d) use of inductive or deductive theories; (2e) theory-internal explanatory criteria related to phonology, semantics, pragmatics and processing; (2f) theory-external criteria related to reasoning, categorisation and perception.

Understanding the cognitive basis of language outlined by Van Valin and LaPolla (1997, 4) present three facets of the psychology of language in (1):

(1)

a) Processing: What cognitive processes are involved when human beings produce and understand language on line in real time, assist our understanding of the cognitive basis of language? How specialised to languages are these processes?
b) Knowledge: What constitutes knowledge of language? How is it organised? How is it represented? How is it employed in language processing? How does knowledge of language relate to knowledge in other cognitive domains?
c) Acquisition: How do human beings come to have knowledge of language? What is the nature of the acquisition process? Is coming to know language similar to or different from acquiring knowledge in other cognitive domain? Does it involve knowledge form other cognitive domains?

Our focus in this chapter is processing and knowledge of language. Chomsky (1965) in his book - *Aspects of the theory of syntax*, proposed levels of adequacy that grammar must meet, and align with the goals mentioned above. These include: (1) observational adequacy - determines and predicts which sentences (grammatically) are well-formed, and those which are not; (2) descriptive adequacy – presupposing it is observationally adequate in native speaking, and assigns structural description for sentences -both in terms of the structure and meaning; (3) explanatory adequacy - presupposes it is descriptively adequate and part of the theory that informs about the "how these facts arise in the mind of the hearer and speaker, theory-internal. Both observational and descriptive adequacy are empirical accuracies. The latter two types of adequacy are explicitly cognitive in nature, as they make reference to native speaker intuition and to language acquisition. Van Valin and LaPolla (1997) discuss the communication-and cognition perspective. This describes the link between a human language's role as a means of communication and the broader cognitive processes such as reasoning and conceptualisations, and further cognitive systems such as perception and knowledge.

The knowledge and processing of language is critical under the computational adequacy of the linguistic theory, and RRG, which from the above discussions presents credentials for the exploration of a NLP language model for a text-based conversational software agent (CSA).

3. Functional Linguistic Theory – Role and Reference Grammar (RRG)

NL is conceived of as a functional system (Francois, 2014), and RRG is a mature, functional, linguistic theory that involves the interaction of syntax, semantics and pragmatics across grammatical systems (Van Valin Jr., 2005a). This is essential for NLU and a computational model addressed on three points. Firstly, RRG's functional view encapsulates the syntax-semantic generalisations which are prominent to explain the semantic motivation of grammatical phenomena. Secondly, RRG has a system and linking algorithm which will allow for comprehension and production of linguistic expressions. Thirdly, RRG looks at language as a means of communication, and aims to be "typologically adequate" to address fairly the analysis of all languages, as languages have varying arbitraries such as the position of the verb, and hence RRG provides added value. The following outlines its basic concepts.

3.1 Basic theory and organisation of RRG

RRG uses a single syntactic description which is semantically motivated. RRG looks at language as a means of communication, and aims to be "typologically adequate" to address fairly the analysis of all languages, as languages have varying arbitraries such as the position of the verb. The organisation of RRG includes a parser and syntactic inventory that link to the syntactic representation, and a lexicon that links to the semantic representation. The linking system is a set of rules that relates the syntactic representation and semantic representation to each other and the discourse-pragmatics plays a role in the linking system, with an input from constructional schemas. A point to note here is that languages will differ from each due to the manner in which the discourse-pragmatics interacts with the linking between syntax and semantics (Van Valin Jr., 2005a: 1).

It further illustrates RRG is a language processing model with mappings of the semantics-to-syntax (production process) and from syntax–to-semantics (comprehension process), and further how the pragmatics interface supports the generation of output responses for example for a NLP example such as a text-based conversational agent (LING-CSA) using dialogue management. Figure 2 represents a view of is the RRG linking system (Van Valin Jr., 2009) where the syntax links to semantics. There are some universal and language specific traits. The semantic macroroles, logical structures, and hierarchy linking them are universal and represent the domain of lexical processes.

This encompasses limited cross-linguistic variations; alternatively it is the linking to the syntactic functions of the macrorole and arguments that languages differ substantially.

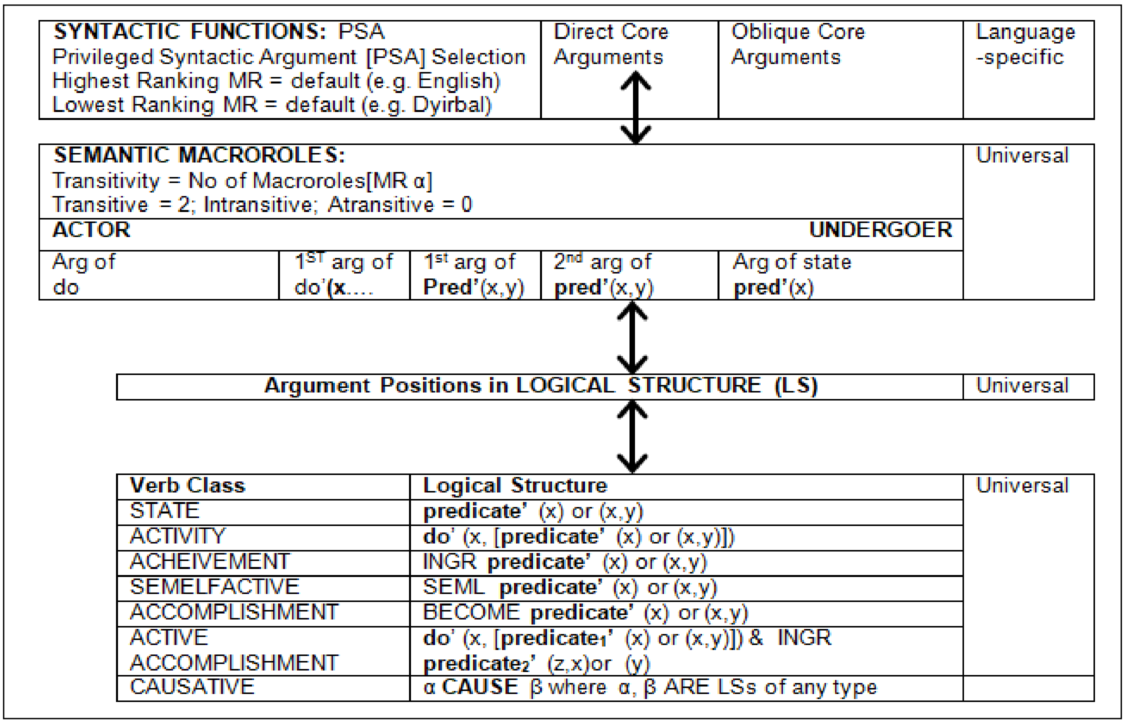


Figure 2: RRG Linking System (Based on Van Valin Jr., 2005b).

The arrows are double-headed representing a bi-directional linking system and facilitate the working of the syntactic-semantic pragmatic interface for simple and complex sentences. The logistics of the comprehension process is that the parser would take the input and produced a structured syntactic representation of the clause (Van Valin Jr., 2005a: 129) asserts that all grammatically relevant elements of LSc (layered structure of the clause), cases, adposition and other elements will be identified in this representation. Next it is the task of the grammar to map the LSc and operator projection into the semantical representation of the clause. This interpretation of this mapping is achieved by the syntax-to-semantic linking algorithm. In the semantic-to-syntax linking, Gottschalk (2011) notes that an inheritance process within the lexicon maps the lexical elements in to the LS (logical structure), thus producing an output. Having produced the LSs, it is the task of the grammar to project the LSc and all other grammatically elements from the LS in question.

Van Valin Jr. (2009) states that RRG posits three main representations as identified in Figure 3 detailed as: (1) A representation of the syntactic structure of the sentence, which corresponds closely to the actual structural form of the utterance. (2) A semantic representation depicting important facets of the meaning of the linguistic expression. (3) A representation of the information (focus) structure of the utterance is focused to the communicative function in particular, its speech act (SA).

As in Figure 3: Gareth ate everything fast (BNC ADY 1079). (Butler and Taverniers 2008) a syntactic and semantic representation is defined in (2):

(2)

SYNTACTIC: SENTENCE (CLAUSE (<CORE> <NP> Gareth (<NUC> (<PRED> <V> ate)) (<NP> (everything))) (PERIPHERY fast)

SEMANTIC: [<IF> ASS <TNS> PT, do'(ACT: Gareth, (eat'(Gareth <NOM>, pizza <ACC>)])] & INGR consumed' (UND:pizza)]

Here we have an assertive speech act; 'ate' is the predicating element, and *'fast'* is the non-argument, as the semantic core meaning is intact with 'Gareth ate everything', but still pragmatically motivated by 'fast'.

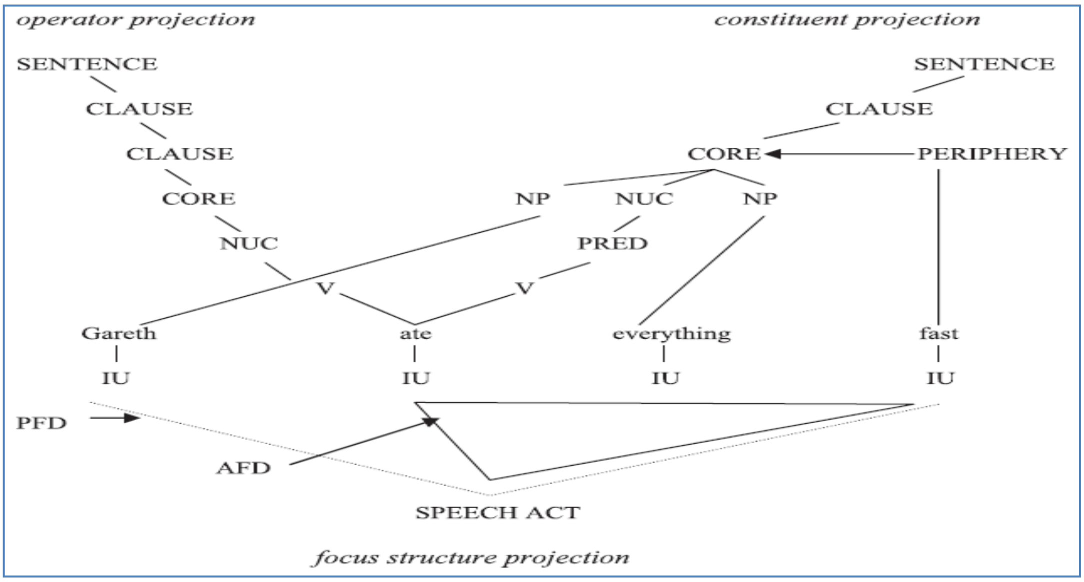


Figure 3: Layered Structure of the Clause (LSC) (Based on Van Valin Jr., 2005b).

Another interesting principle of the linking algorithm relates to the ‘completeness constraint’ as stated by Van Valin Jr. (2005a) ‘all the specified arguments in the semantic representation must be realised in the syntax in some way, and conversely that all the expressions in the syntax must be linked to something in the semantic representations of a sentence, in order to be interpreted’. This principle is an important formalistic, computational test in the implementation phase, and as part of the proof of concept.

Constructional schemes (CSs) play a crucial role in the linking system. For the semantics-to-syntax linking algorithm they supply the language-specific and construction specific details necessary for the correct encoding of the meaning in the morphosyntax (Van Valin Jr., 2005a: 134).

Similarly, CSs are important for the syntax-to-semantic linking for languages which have different privileged syntactic arguments (PSA) for different constructions such as Jakaltek and Sama. CSs invoke the syntactic inventory for the appropriate syntactic template (combination of lexical entries), as illustrated in the original RRG

4. Experiment – Text-Basd Conversational Software Agent (CSA)

An experiment is conducted to explore NLP in AI using a functional linguistic perspective (that is RRG) - as a linguistic engine for a linguistically centred CSA (LING-CSA).

4.1 Introduction to Conversational software agents

A CSA is a program that engages in conversation using NL dialogue with a human user. The challenge here is for the system to encapsulate sufficient knowledge from the user’s question to present a grammatically correct response. Here a discussion of knowledge and its role is very important. When a person hears or sees a sentence, an individual will make full use of their knowledge and intelligence to understand it; additionally, besides the grammar, knowledge about the words, the sentence context, and an understanding of the subject matter is necessary. Here the computational model, must model this language understanding and the interactions that combine grammar, semantics and reasoning.

Two main requirements for a CSA specified by Mao, Sansonnet, and Li (2012) and Lester, Branting, and Mott (2004) are the ability of accurate NLU and the technical integration with an application. A CSA must respond appropriately to the user’s utterance via three phases: (1) interpret the utterance, (2) determine the actions (logic) that should be taken in response to the utterance (3) and perform actions replying with text. In the last decades, there has been a great evolution in the field of CSA enfolding three emerging trends of more sophisticated NLP via improved parsing techniques, humanising of agents through language and their pervasiveness (Perez-Marin and Pascual-Nieto, 2011).

CSAs are becoming prominent in the marketplace where the consumer's use and familiarisation of the smartphone technology and consumer support agents, human-computer interaction, and ubiquitous computing is maturing, and is of great value. A long-standing issue within NLP CSA systems is refining the accuracy of the interpretation of meaning to provide a realistic dialogue to support the human-to-computer communication.

Historically, CSA systems link to the concept of intelligent machines originated by British mathematician and code breaker Alan Turing who addressed the question 'can machines think' (Turing, 1950). He worked on a proposal of how to test this using the imitation game (also known as the Turing Test) and used dialogue testing, as means to work out whether or not the computer program was intelligent. This question has inspired much exciting CSA research and commercial undertakings as the yearly Loebner competition to demonstrate human-like conversation ("loebner.net", 2015) as in the Chatbot 'Mitzuki' in 2013, 2016, 2017 and 2018, built on Pandorabots: the world's leading conversational (AI) Chatbot platform. As a thought to the foundations of AI, cognitive science, investigations into 'can machines think' and to challenge the concepts of strong AI, Searle (1980) introduces the Chinese room argument (experiment).

This experiment demonstrates that the computer program may very well look like it understands Chinese, but it only simulates that knowledge which is not a form of intelligence. Subsequently, there is a need to address the differences between a human brain and computer program and being able to think and understand. This “understanding" implies both the possession of mental (intentional) states and the truth (validity and success) of these states (Searle, 1980). In other words, a dialogue system is a more refined “intelligent” version of a Chatbot, where the NL input must be constrained and is unexpected, thus requiring a robust complex framework, with an integrated knowledge base (KB) which may take the form of ontologies for recognition, interpretation and generation, and deploying computational linguistically technologies.

A main distinction between an applied Chatbot and CSA is that the CSA has a deep strategic role to hold a conversation and enable the mechanisms to focus the conversation on achieving a goal, via NL dialogue (O'Shea, Bandar, and Crockett, 2010). There is a need to plan, and to decide what do next, and manage the conversation - this is the work of the dialogue manager (DM) (Treumuth, 2011). The CSA's role is that of a linguistic aware knowledge aware process simulating an empowered human to take part in the conversation and ask questions.

4.2 Requirements of a conversational software agent (CSA)

As noted previously, the two main requirements for a CSA are the ability of accurate NLU and the technical integration with an application. To enable cognitive manipulations as part of conversation, a CSA will have the architectural components of an interpreter, dialogue management (DM) and response generator (RG) with three models - internal state, external interaction and language feature Nolan (2014b). The internal model and state is reflected by the agent's BDI. The external model of the agent is reflected by the interacting participants (human and other agents) in its world. The language model is related to the interaction model to support dialogue via speech acts – the linguistic act of uttering a sentence (Searle, 1969). Further the CSA must have robust functional capabilities for parsing and generating utterances, as well as dealing with tricky grammatical rules and structures, and handle conversational behaviour. Key facets noted by Nolan (2014b) in (3):

(3)

a) The set of beliefs that the agent has at a given time
b) The goals that agent will try to achieve;
c) The actions that the agent performs and
d) The knowledge of the effects of these actions;
e) The environment information the agent has (not necessarily complete or correct);
f) The ongoing discourse interaction that the agent participates in the environment over time;
g) Human language understanding and conversation tracking over a discourse.

4.3 Additional requirements of LING- CSA

The CSA must respond appropriately to the user's utterance via three phases – (1) interpret the utterance, (2) determine the actions (logic) that should be taken in response to the utterance, and (3) generation of a grammatical correct dialogue response in the target human language, English.

To achieve these phases speech act theory (SAT) comes into play based on work from Austin (1962) to Searle's work to address the issues of meaning and expression of NL. Searle (1969: 22) states "speaking a language is engaging in a rule governed form of behaviour" and that 'illocutions are intentional acts'. Further, SAT provides the basis for interpretation of the utterance in terms of a speaker's intention and the effect it has on a listener. These intentions are composed of speech acts (SAs) involving a range of functions (actions) denoted as illocutionary acts for example – John says to Mary '*pass me the glasses please*' – involves the illocutionary act (point of the speech act) of requesting or ordering – '*Mary to hand the glasses over to him*'. As highlighted previously, the constructional schemas (CSs) are enhanced into speech act constructions (SAC) based on grammatical objects, providing a richer and better-motivated understanding of constructions in a lexically orientated functional model of grammar (Nolan, 2014a).

The next question is how this goal is achieved and able to conduct conversational behaviour. The Belief-Desires-Intentions (BDI) model was based on a model of human behaviour from the theory of human practical reasoning developed by the philosopher (Bratman, 1987). Put simply, the BDI model reflects a change of 'mental' states. Beliefs refer to the facts representing what an agent believes about the world. Desires are all the possible state of affairs (goals) that the agent potentially may accomplish. Intentions are the agent's commitment to its desire (goals) and its commitment to the plans selected to achieve these goals. Therefore, practical reasoning consists of two key processes: deciding what goal we wish to achieve known as deliberation, and secondly how will we achieve our goals is called means-end reasoning. Searle (1985, 4) identifies that SAs differ due to differences in psychological states. For instance, as in the BDI model, a SA reflects beliefs, desire, wants and intentions. For instance, a speaker states, claims, explains, asserts or claims P is a representation that the speaker expresses the belief of P; a speaker who promises, vows, threatens or pledges to do A**,** is a representation that the speaker expresses an intention to do A; a speaker who orders, commands, requests the hearers to do A is a representation of the desire (want, wish) that hearer do Action A.

From a knowledge perspective, Ramirez and Valdes (2012) note that knowledge has several facets, with some static components called concepts or facts, and some dynamic components such as skills, abilities, procedures, actions which collectively enable general cognition.

This cognition is associated with several different processes, for instance, perceiving, distinguishing, abstracting, modelling, storing, recalling, and remembering which constitute three primary cognitive processes: learning, understanding and reasoning (Ramirez and Cooley, 1997). Knowledge representation and reasoning (KRR) is a central issue in AI. Chein and Mugnier (2008) affirm that a knowledge base (KB) collates symbolic knowledge representation about an application domain, containing different kinds of knowledge such as ontology (symbolic representation of objects and relations), facts, rules and constraints, and a reasoning engine.

To recap RRG is deployed as a linguistic theory that can adequately explain, describe and embed the communication-cognitive thinking in conversation, in a computational form. With this in mind, we propose a language model, knowledge model, speech act constructions (SAC) and belief, desires, and intentions (BDI) framework for LING-CSA. It will further investigate how language can be comprehended and produced, to gain a deep understanding, and how it interfaces with knowledge. In order to use the RRG linking system and to create an effective parser, RRG is re-organised to facilitate the innovative use of SAC as grammatical objects (Nolan 2014a) and a rich lexicon, as illustrated in Figure 4.

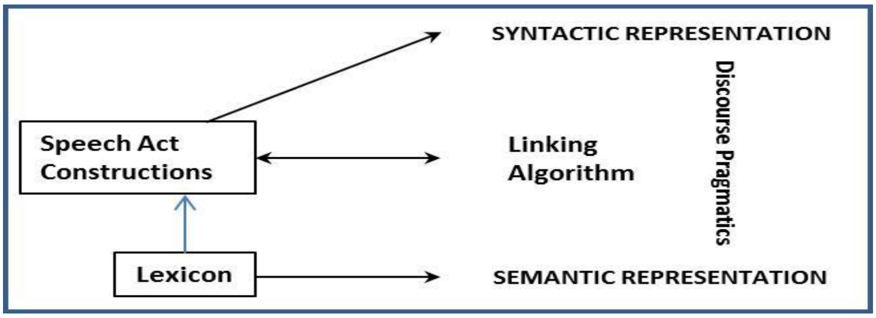


Figure 4: Re-organisation of RRG for Ling-CSA.

5. Methodology

The architecture of LING-CSA (diagrammed in Figure 5) constitutes three phase models.

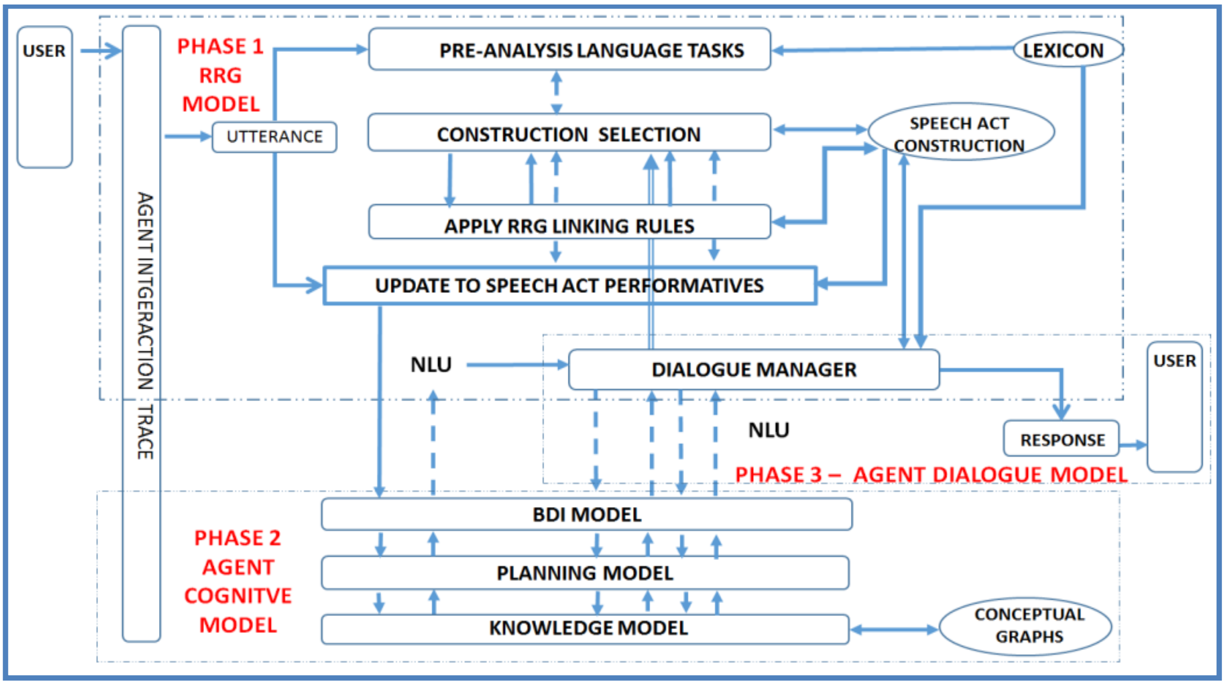


Figure 5: Conceptual Architecture of the Ling-CSA (Panesar, 2017).

These are: (1) a linguistic model based on RRG; (2) Agent Cognitive Model (ACM) with two inner models: (a) knowledge representation model employing conceptual graphs (CGs) serialised to Resource Description Framework (RDF) (Chein, Mugnier, and Croitoru, 2013); (b) a planning model underpinned by BDI concepts (Wooldridge, 2013) and intentionality (Searle, 1983) and rational interaction (Cohen and Levesque 1990); and (3) Phase 3 – Agent Dialogue Model (ADM) where the DM is a common component of Phases 1 and Phase 3 – due to the discourse referents of an utterance, and the need to create a grammatically correct response. It employs common ground (Stalnaker, 2002).

The CSA's goals are to achieve: (1) present a mapping of the syntactic representation to a semantic representation; (2) an adequate explanation and representation of the NLU of the utterance; (3) present a range of SAC manipulations based on the utterance; (4) evidence the dialogue processes and manipulation interfacing with the language model; (5) present the agent's knowledge and its BDI states; (6) present the user's BDI states; (7) query the knowledge base for a fact based on the utterance the agent has perceived; (8) devise an appropriate plan based on the BDI states to support the response generator; (9) generate a grammatically correct response in RRG based on the agent's knowledge.

The CSA utilises a set of data sets, as highlighted in Table 2 – RRG steps. Firstly, the RRG lexicon, semantically motivated, with lexical entries that have features: (a) part-of-speech (POS); (b) tense/aspect, (c) definiteness, (d) person, (e) number, (f) gender, (g) case, (h) humanness, (i) animacy and (j) logical structure (LS), as identified in Table 1. Secondly, a lexical words list. Thirdly, SAC – a grammatical object based on SA types (assertive, and interrogative (Searle, 1969)) forms an updateable object, selected initially for processing the utterance and later for the agent response via the dialogue management processes and illustrated in Table 3. SAC template elements includes: (a) SA type, (b) signature list, (c) input, (d) workspace, (e) syntax, (f) semantic, (g) morphology, (h) pragmatic, (i) illocutionary force, (j) focus structure and (k) output LS (logical structure). Element manipulations are performed to create a completed SAC, which is extended by performative information to a form message perceived by the agent environment. Fifth data set is the agent's belief (knowledge) represented initially as a CG vocabulary as facts, due to their effective representation of natural language (Sowa 2009) in COGUI (COnceptual Graphs User Interface) (GraphIK, 2012). This is further serialised into RDF/XML (GraphIk, 2017) as there is no loss of meaning, forming a set of RDF triples and an opportunity of Semantic Web manipulations. Finally, the CSA's input are utterances constrained to single clause.

5.1 RRG Language Model (Phase 1)

The LING-CSA will constitute a closed domain - dialogue on food and cooking, for its richness and universality. A range of NLP tasks manipulated via the language model will include tokenisation, sentence splitting, part-of-speech-tagging, morphological analysis, syntactic and semantic parsing.

It is the dialogue manager (DM) that will assist with the SA dialogue working with the syntactic parser to work effectively with the data sources (word list, lexicon, empty speech acts constructions (SACs)). RRG manipulations exist for both simple and complex sentences, but the LING-CSA is limited to the manipulation of the linking system of simple sentences (active or passive) using transitive, intransitive and ditransitive verbs/auxiliary verbs with variable word order flexibility with SVO (subject-verb-object), and modelled via speech acts (Searle, 1969) applied to cognitive and rational interaction analysis. RRG’s bi-directional linking algorithm and discourse-pragmatics interface will be mapped into completed SACs, invoking the lexicon (Table 1) to supports all three LING-CSA phases, and internal BDI manipulations (Panesar, 2017) as shown in Table 2.

Lexical entry 1: ate								
POS TYPE	**VERB TENSE - ASPECT**	**DEF**	**PERSON TYPE**	**NO**	**GENDER**	**CASE**	**ANIM**	**HUM**
Verb	PST	DEF +/-	3	SG	M/F	DNA	ANIM	HUM
LOGICAL STRUCTURE (LS) : <tns:pst <do’(x, [eat’(x, y)]) & BECOME consumed’ (y) >>								

Lexical entry 2: eat								
POS TYPE	**VERB TENSE - ASPECT**	**DEF**	**PERSON TYPE**	**NO**	**GENDER**	**CASE**	**ANIM**	**HUM**
VERB	PRS/ FUT	DEF+/-	3	SG	M/F	DNA	ANIM	HUM
LOGICAL STRUCTURE (LS) : <tns:prs <do’(x, [eat’(x,y)]) & BECOME consumed’(y) >> <tns:fut <do’(x, [eat’(x,y)]) & BECOME consumed’(y)>>								

Lexical entry 3: eating								
POS TYPE	**VERB TENSE - ASPECT**	**DEF**	**PERSON TYPE**	**NO**	**GENDER**	**CASE**	**ANIM**	**HUM**
VERBAL NOUN	PROG	DEF+/-	3	SG	M/F	DNA	ANIM	HUM
LOGICAL STRUCTURE (LS) : <tns:prs <asp:prog <do’(x, [eat’(x, y)]) & BECOME consumed’ (y) >>								

Lexical entry 4: is								
POS TYPE	**VERB TENSE - ASPECT**	**DEF**	**PERSON TYPE**	**NO**	**GENDER**	**CASE**	**ANIM**	**HUM**
VERB BE	DNA	DEF+	DNA	DNA	DNA	DNA	DNA	DNA
LOGICAL STRUCTURE (LS) : be'(x,[pred'])								

Lexical entry 5: hungry								
POS TYPE	**VERB TENSE - ASPECT**	**DEF**	**PERSON TYPE**	**NO**	**GENDER**	**CASE**	**ANIM**	**HUM**
ADJECTIVE	DNA	DNA	DNA	DNA	M/F	DNA	ANIM	HUM
LOGICAL STRUCTURE (LS) : DNA								

Lexical entry 6: restaurant								
POS TYPE	**VERB TENSE - ASPECT**	**DEF**	**PERSON TYPE**	**NO**	**GENDER**	**CASE**	**ANIM**	**HUM**
NOUN	DNA	DEF+/-	DNA	SG/PL	DNA	DNA	DNA	DNA
LOGICAL STRUCTURE (LS) : DNA								

Table 1: Snapshot of the Lexicon – Lexical entries and Lexemes (Panesar, 2017).

Note: Logical structures have been partially expanded for readability.

PHASE 1 - RRG LANGUAGE MODEL			
Step	PHASE		(TRACKING) DISPLAY
1	PHASE 1A - PRE-ANALYSIS	Parsing, Sentence and word tokenisation, check against the lexicon.	Display the utterance and various internal representations.
2	PHASE 1B – SAC SELECTION	Construction selection computations	Display construction selected
3	PHASE 1C – SYNTAX-TO-SEMANTICS	• Verb selection and voice • Retrieve the LS and verb from the lexicon • Assignment of arguments to the LS arguments • Semantic representation • Update the LS • Map the operator projection and focus projections • Actor and undergoer assignment • Select the morphosyntactic properties of the argument	Display the verb selection and voice topics Display the LS and verb from the lexicon Display the argument value Display the semantic representation Map the operators to the Tense and illocutionary force Display the actor and undergoer as part of the LS. Display the additional information
4	PHASE 1E - SEMANTICS-TO-SYNTAX	• Verb selection and voice • Retrieve the LS and verb from the lexicon • Assignment of arguments to the LS arguments	Display the verb selection and voice topics Display the LS and verb from the lexicon Display the argument values
5	PHASE 1F – DIALOGUE MANAGER	• Ascertain whether there is any missing information • Refer to the stored discourse referents – if any, and process with the earlier Phase 1 steps	Display the specific elements that missing Display appropriately any saved discourse referents
6	PHASE 1G – CREATE SAP	• Attach the performative information to the Speech Act Construction	Display the performative type information

Table 2: Overview of the Phase 1 – RRG Model Steps (Panesar, 2017).

The analysis of utterance/responses will be constrained to assertive and interrogative (WH-word) SAs. SAC example shown in Table 3 include: - ‘assertive: ATE’, taken from a sample collection of 34 – created originally by the researcher. The selected SAC is updated with all the grammatical information. These include: voice opposition; macrorole; pragmatic; semantic; lexical; the PSA (privileged syntactic argument)-similar to the ‘subject’ of S-V-O; matching signature; syntactic morphology (rules); focus; semantic information such as tense and aspect.

PERFORMATIVE: <ASSERTIVE:ATE>
:SENDER <USER>
:RECEIVER <AGENT-1>
:ONTOLOGY <FoodAndCookKB>
:CONTENT <do’(Gareth, (eat’(Gareth, pizza)])] & INGR consumed’ (pizza)] everything>
SIGNATURE: [PN V NP ADJ]
CONSTRAINT: Default
INPUT: Gareth ate everything fast
WORKSPACE: (Gareth, PN), (ate, VERB), (everything N), (fast, ADJ)
SEMANTICS: Contains a noun phase before and after the verb
CONSTRUCTION BODY
SYNTAX: SENTENCE (CLAUSE (<CORE> <NP> gareth (<NUC> (<PRED> <V> ate)) (<NP> (everything))) (PERIPHERY fast)
PSA: gareth
SEMANTICS
Linking:
MORPHOLOGY:Default
PRAGMATICS
Illocutionary force: ASSERTIVE
Focus structure: narrow focus on the element
OUTPUT [LS]: [<IF> ASS <TNS> PST, do’(ACT:Gareth, (eat’(Gareth <NOM>, pizza <ACC>)])] & INGR consumed’ (UND:pizza)]

Table 3: Speech act construction performative “ate” used as a message to the agent environment (Panesar, 2017)

Here the updated SAC will use the generalised lexicon and computationally work with the surface syntax to the underlying semantic forms. Any discourse referents that are generated are also checked and updated accordingly. The updated SAC will store each text and the associated complete logical structure (LS) based on the working semantic predicating element. The linking system will facilitate the syntactic parse to enable fixed word order for English (SVO), and to unpack the agreement features between elements of the sentence into a semantic representation (the logical structure) and a representation of the Layered Structure of the Clause (LSC). The linking system will facilitate procedures for semantic-to-syntax and syntax-to-semantics, parsing and in the process of formulating a grammatical correct response.

5.2 Design framework - Agent Cognitive Model (Phase 2)

Cohen and Levesque (1988) take the viewpoint of language as action, and view utterances as events (updated to speech act performatives (SAP) messages) that change the state of the world, and hence speakers and hearer's mental state change as a result of these utterances. Further it is necessary for a computer program to recognise the illocutionary act (IA) of a SA, for both the speaker (USER) utterance and hearer (AGENT) and a response. The agent environment will constitute a language model, mental model to work the BDI states, planning model (to reason with states based on current knowledge), knowledge model (world knowledge – made up of shared and individual beliefs) and dialogue model (to provide a response back to the user).

The next question is how will this integrate and function; this is achieved in the Phase 2 – Agent Cognitive Model (ACM) with an input of the Phase 1 RRG Language Model in the form of a message as a speech act performative (SAP). The ACM contains two inner models namely the Agent Knowledge Model (AKM) and Agent Dialogue Model (ADM). The ACM Phase 2 model has a series of pre-agent steps and main agent steps illustrated in Figure 6 (Panesar 2017). The behaviour of agent is identified by the following basic loop where agent iterates the following two steps at regular intervals: (1) Read the current message, and update the mental state including the beliefs and commitments; (2) Execute the commitments for the current time, possibly resulting in a further belief change.

The user instigates the utterance into the CSA framework, and it is the agent which decides on the appropriate dialogue and grammatical response. The sentence pair and sub dialogue internal representations will be stored – based on theories and models such as the discourse representation theory (DRT) (Kamp, Van Genabith, and Reyle 2011). To facilitate conversation, the DM is invoked, and discourse referents in the previous utterance of the sub-dialogue are resolved. This will serve two purposes: 1) to establish the NLU of the utterance; (2) and to forward to the dialogue model to ascertain a response. This response generator here will further make use of the language model, and SAC model, to formulate a grammatically correct response.

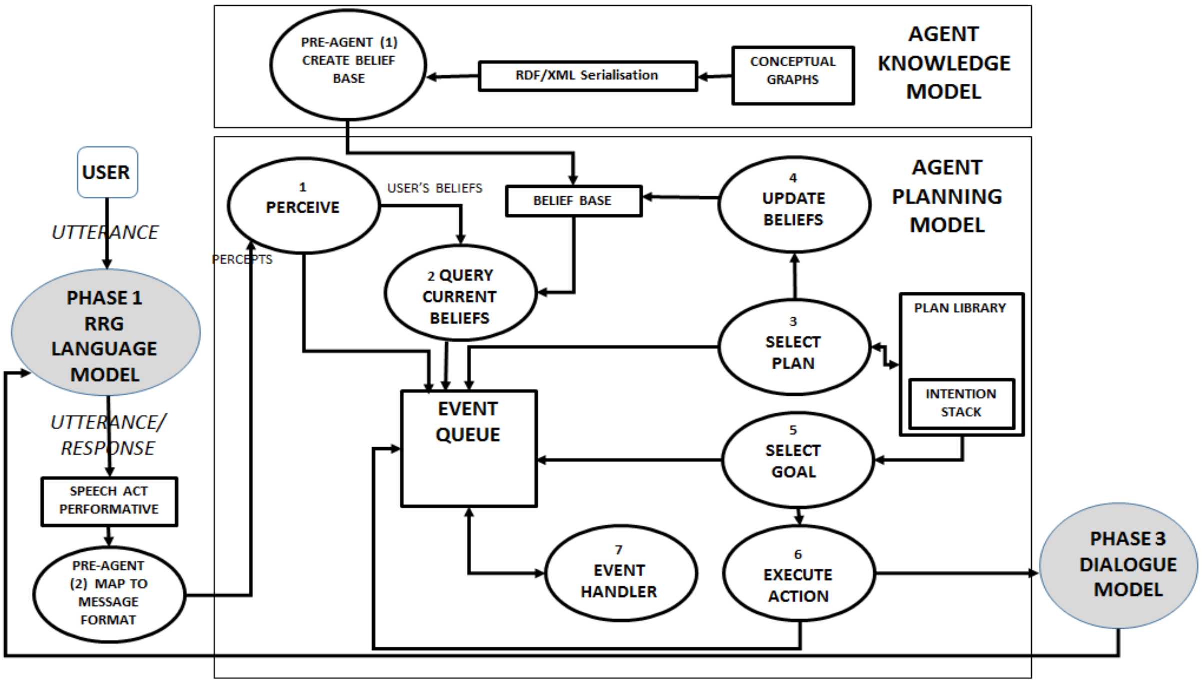


Figure 6: Design framework: Ling-CSA agent cognitive model.

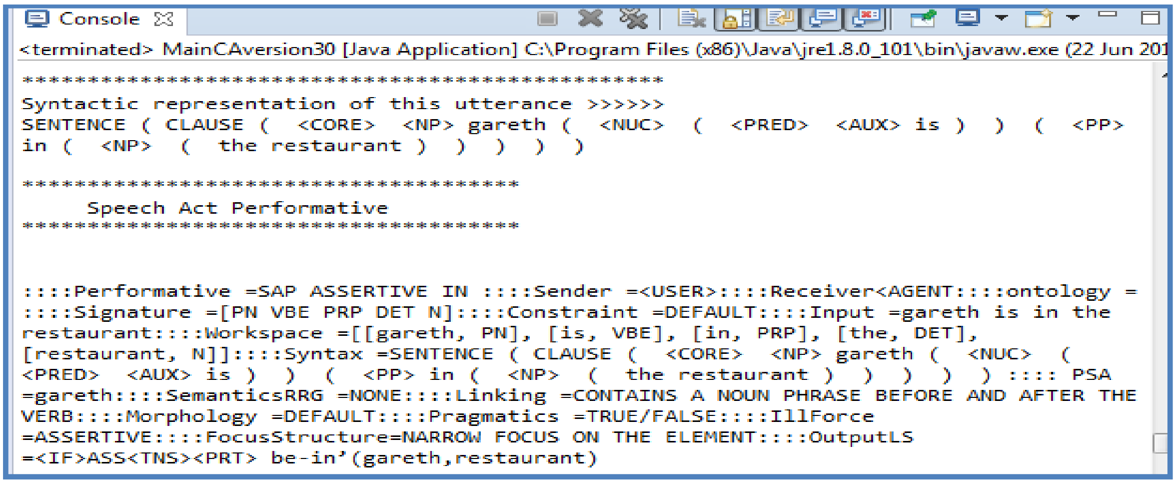
6. Implementation Details

Figures 5 and 6, and Tables 1 to 3 are mapped and configured to an operational framework, and implemented as a Java prototype, developed in Eclipse IDE platform, predominantly as POJO (plain old java objects) with some API support, based on a food and cooking domain.

7. Evaluation Conclusions and Recommendations

To iterate, our experiment was to present empirical evidence (proof-of-concept) of the use of functional linguistic theory via a linguistically centred CSA (LING-CSA). Its goal was to investigate the accuracy of the interpretation of meaning to provide a realistic dialogue to support the human-to-computer communication. LING-CSA was multi-disciplinary invoking NLP, computational linguistics, knowledge representation, functional linguistics, agent thinking and AI, as demonstrated in the conceptual and operational framework of LING-CSA. A set of evaluation criteria were grouped per phase model, and the testing framework aims to assess the interface, intersection and integration of all phase models and their inner models. The validation and verification (VV) approach deployed is based on the phase models and thus is a multi-approach. It is driven by: (1) grammatical testing (English language utterances) and NLP tasks; (2) software engineering (UML modelling, architecture centric, data structures and algorithms); (3) knowledge representation logics (first order logics and graph theory) and (d) agent practice (message passing, planning and cognitive responses and conforming to its appropriate inputs, environment, actions, performance measures (IEAP) (Russell and Norvig, 2016); (e) A range of RRG tests applied at various internal representations to address the goals of RRG - explanatory, descriptive, cognitive and computational adequacies (Panesar, 2017).

In Phase 1 – RRG model, the analysis of a SAC for each specific construal (either an utterance or response) – has two steps (Panesar, 2017). The RRG phase model evaluations identify that RRG is fit-for-purpose as the linguistic engine for LING-CSA as illustrated in Figure 7, demonstrating a syntactic representation that maps to semantic representation, and together are embedded in a speech act performative (SAP) message to the agent environment.



```
Console
<terminated> MainCAversion30 [Java Application] C:\Program Files (x86)\Java\jre1.8.0_101\bin\javaw.exe (22 Jun 201
*************************************************
Syntactic representation of this utterance >>>>>>
SENTENCE ( CLAUSE (  <CORE>  <NP> gareth (  <NUC>  (  <PRED>  <AUX> is )  )  (  <PP>
in (  <NP>  (  the restaurant )  )  )  )  )

**************************************
     Speech Act Performative
**************************************


::::Performative =SAP ASSERTIVE IN ::::Sender =<USER>::::Receiver<AGENT::::ontology =
::::Signature =[PN VBE PRP DET N]::::Constraint =DEFAULT::::Input =gareth is in the
restaurant::::Workspace =[[gareth, PN], [is, VBE], [in, PRP], [the, DET],
[restaurant, N]]::::Syntax =SENTENCE ( CLAUSE (  <CORE>  <NP> gareth (  <NUC>  (
<PRED>  <AUX> is )  )  (  <PP> in (  <NP>  (  the restaurant )  )  )  )  ) :::: PSA
=gareth::::SemanticsRRG =NONE::::Linking =CONTAINS A NOUN PHRASE BEFORE AND AFTER THE
VERB::::Morphology =DEFAULT::::Pragmatics =TRUE/FALSE::::IllForce
=ASSERTIVE::::FocusStructure=NARROW FOCUS ON THE ELEMENT::::OutputLS
=<IF>ASS<TNS><PRT> be-in'(gareth,restaurant)
```

Figure 7: Syntactic & semantic representation, speech act performative (SAP) – message to the agente environment (Panesar, 2017).

A snapshot of key recommendations are included: (1) consider the requirements for complex sentences (more than one clause) with the extended use of procedures for the linking system; (2) support for multi-lingual (additional lexicons) such as the Spanish,

(3) consideration of other SA categories such as commissives and emotives, such as, for the automatic analysis of social media tweets; (4) to include superlative adjectives and adverbs RRG lexicon to enforce greater coverage.

For Phase 2 the ACM – we can recall BDI architecture is based on the 'intentional stance' which is the highest level of abstraction of human reasoning where the agent will do what it believes are its goals. There are two main areas for future research, based on this evaluation. Firstly, is to reduce the gap between knowledge and language, in the agent space. Here, language is in the context of a rich RRG linguistic representation against the belief base as RDF Triples posed the key obstacle of interoperability between two different low level mappings, and hence a semantic gap. The solution is a 'lexical bridge' (LB), as illustrated in Figure 8.

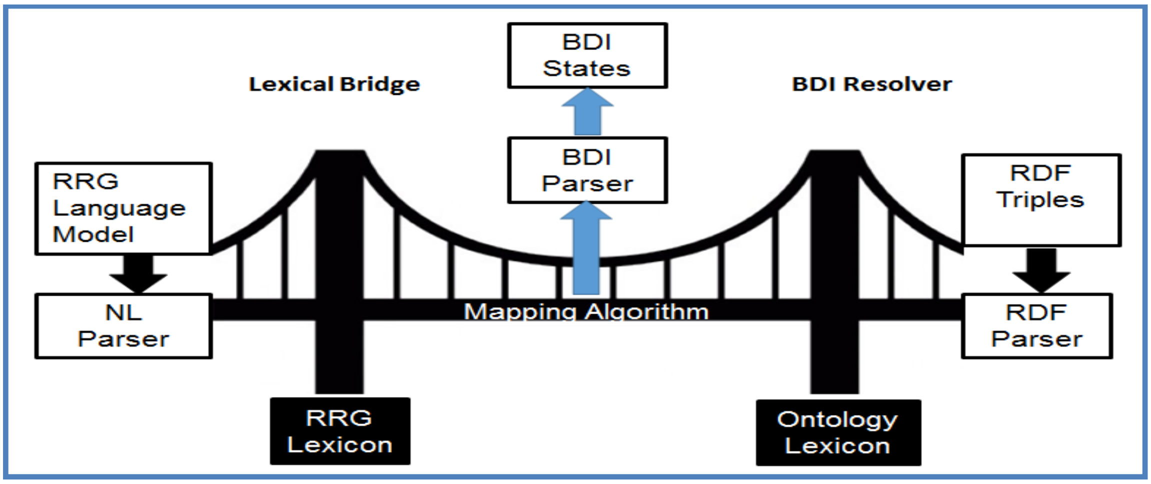


Figure 8: Lexical Bridge for the CSA'S belief base + BDI Parser to resolve the agent's BDI States (Panesar, 2017)

Central to this LB is the re-use of the RRG lexicon and NL parser. The derivation of a mapping algorithm from OWL to a NLP representation is recommended, specifically invoking the RRG lexicon and RDF parser. This mapping algorithm will be interfaced with a further model known as the BDI Resolution composing a BDI parser motivated by description logics (DL) to derive the BDI states of the agent.

This step will form an extra step to the pre-agent steps of ACM. The algorithm's output representation, will further invoke the rest of the ACM steps of querying the knowledge base for a specific belief, creating planning schemes, selecting a plan, manipulation of the appropriate intention, to create a grammatical correct response using the RRG language model and the extended SACs.

To summarise, our experiment of the use of a functional linguistic theory namely RRG for a linguistically centred conversational agent (LING-CSA) presented a proof-of concept that is adequate for NLP and NLU, and presents an accurate representation of meaning. Looking forward, companies with a strong base in core digital technologies and big data analytics and see profitability are more likely to adopt an AI tools such as natural language generation and NLP. However, laggard companies are subject to the risk of digital competition and digital hacking (van Zeebroeck, 2018).

Further, as more companies are adopting, there will be an increased commercial interest in NLP in AI, and greater human-to-computer communications, and more use of linguistic based manipulations.

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