Developing a Linguistically Motivated Avatar for Irish Sign Language Visualisation

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ABSTRACT

This paper is concerned with research work in progress in the development of a Role and Reference Grammar (RRG) parser/generator for sign language, in particular, Irish Sign Language (ISL). RRG is a functional model of grammar. It incorporates many of the viewpoints of current functional grammar theories. RRG takes language to be a system of communicative social action, and accordingly, analysing the communicative functions of grammatical structures plays a vital role in grammatical description and theory from this perspective. It is planned to use RRG as the linguistic 'engine' in this development. It is envisaged that the RRG parser/generator described in this paper will later be used as a tool or component in the development of a computational framework for an embodied conversational agent (ECA) for ISL. We discuss the development of a linguistically motivated ECA to encode gesture. It is envisaged that the ECA undergoing development in this research will later be employed for real-time sign language visualisation, in particular, ISL visualisation.

General Terms

Algorithms, Languages, Design, Human Factors, Standardisation.

Keywords

Irish Sign Language, Embodied Conversational Agent, Role and Reference Grammar, Sign Language Visualisation.

1. INTRODUCTION

Irish Sign Language (ISL), like all other sign languages, is a visual gestural language without any aural or written form. It is the indigenous language of the Irish Deaf Community and is the first language of Deaf people in Ireland. ISL is a visual, spatial language, with its own distinct grammar. [1] There are many misconceptions within the hearing community with regard to sign languages. Some of the misconceptions are: that all Deaf people are literate in a written national language e.g. English; there is only a single Sign Language; that a Sign Language is merely the visual-gestural representation of a spoken language; linguistic studies of verbal languages can easily be applied to Sign Languages; Sign Language sentences using can be easily written using spoken words.

Sign language, of particular relevance to this research ISL, is not only a language of the hands, but also of the face and body. In both speech act modality and linguistic terms, ISL is a completely different language to English or Irish. Unfortunately, even with today's technological advancements in both computer hardware and software, the Deaf community in Ireland is still overlooked with regard to the provision of public services in ISL [2]. Insufficient socio-economic opportunity occurs within the Deaf community as a result of lack of access to information and communication services [3]. Sign Language interpreters are used as a means of communication between the Deaf and hearing, however, in Ireland where the ratio of interpreters to Deaf people is about 1:250 [4][5], they are often difficult to come by.

Virtual reality human modeling and animation has the potential to alleviate the communication barrier for sign language users. To date research in this area has reached the point where it is possible to construct a human avatar that is articulate and responsive enough to perform Sign Language [6]. It is possible for Sign language users to view onscreen animations and successfully interpret the movements of an avatar to understand its meaning [7]. However, to date, there is no standard computational linguistic framework available to link the divide between the linguistic and the animation interface. This linguistic component would suffice as a tool for the development of a script with appropriate instructional content to "drive" the virtual avatar. At a minimum, this linguistic component or framework should be capable of communicating to the animated avatar what actions to carry out in order to convert from the first language (in this case English) to the target language (in this case ISL).

The aim of this paper is discuss research work in progress in the development of a linguistically motivated avatar for ISL. For the purpose of this research it is intended to use RRG, which is a theory of grammar that is concerned with the interaction of syntax, semantics and pragmatics across grammatical systems. RRG takes language to be a system of communicative social action, and accordingly, analysing the communicative functions of grammatical structures plays a vital role in grammatical description and theory from this perspective. RRG will be used in this research in the development of an RRG parser/generator which will later be used as a component in the development of a computational framework for an embodied conversational agent for ISL. This poses significant technical and theoretical difficulties within both RRG and for software [8], [9]. As ISL is a visual gestural language without any aural or written form, like all other sign languages, the challenge is to extend the RRG view of the lexicon and the layered structure of the word, indeed the model itself, to accommodate sign languages. In particular, the morphology of sign languages is concerned with manual and non-manual features, handshapes across the dominant and non-dominant hand in simultaneous signed constructions, head, eyebrows and mouth shape. These are the morphemes and lexemes of sign language. This work directly seeks to improve the communicative experience for those members of the Deaf Community through the innovative use of conversational avatar technology. Potentially, this will enrich the experience of these language users within society.

2. RELATED WORK

There are presently several on-going SL related research projects of note. One of these is Dicta-Sign [10], a three-year EU-funded research project that aims at making online communications more accessible to Deaf Sign Language users. This has been facilitated by the emergence of various Web 2.0 technologies that allow people to constantly interact with each other, by posting information (e.g. blogs, discussion forums), modifying and enhancing other people's contributions (e.g. Wikipedia), and sharing information. There is recognition that these technologies are not sign language user friendly because they require the use of written language. Therefore, Dicta-Sign's goal has been to develop the necessary technologies that make Web 2.0 interactions in sign language possible: Users sign to a webcam using a dictation style. The computer recognises the signed phrases, converts them into an internal representation of sign language, and then has an animated avatar sign them back to the users. Content on the Web is then contributed and disseminated via the signing avatars. Moreover, the internal representation also allows for the development of sign language-to-sign language translation services. Recent research by Morrissey [11] has been on the application of example based data-driven machine translation (MT) to sign languages (SLs) is concerned with the provision of a SL MT system that can facilitate communication between Deaf and hearing people by translating information into the native and preferred language of the individual. This work also focuses on Irish Sign Language - the native language of the Deaf community in Ireland. [12] eSIGN was an EU-funded project whose aim was to provide information in sign language using Avatar software technology. The project has produced software tools which allow website and other software developers to extend their applications with signed versions. The eSIGN project includes partners from the UK, Germany and the Netherlands. eSIGN uses Signing Gesture Markup Language (SiGML) which allows sign language sequences to be defined in a form suitable for performance by a virtual human, or avatar. SiGML is a form of Extensible Markup Language (XML), and the SiGMLSigning software system converts SiGML to a sequence of animation frames, each corresponding to a configuration of the avatars virtual skeleton. DIVA (DOM Integrated Virtual Agents) is a web-oriented software framework that provides capabilities for the development and deployment of conversational virtual agents that are completely integrated with the DOM (Document Object Model) tree structure of web pages. The DOM is a standard interface, independent from any language and platform which allows programs and scripts to dynamically access both in read or modify modes the content, structure and the style of HTML or XML-based documents. A sign language utterance is built by a concatenation of atomic *signs*. Each sign is displayed as a predefined animation, built using rotoscoping. In order to build animations that are as realistic as possible, each utterance contains prologue and epilogue postures, allowing the virtual signer to begin and to end the utterance in a rest posture.

3. AVATAR TECHNOLOGIES

[13] MakeHuman and [14] Blender are the core technologies used in this research. MakeHuman is an open source, innovative and professional software tool that can be utilised for the development of 3-Dimensional humanoid characters. MakeHuman provides for the creation of virtual humanoid characters through the manipulation of a base polygonal mesh. It is possible to sculpt and shape the mesh provided by MakeHuman, by manipulating various user interface parameters. The mesh can then be exported in various formats for further use and development. Blender is an open source, cross platform 3D graphics and animation application that provides capabilities for the development of images and animations through 3D modelling and rendering. Blender was chosen as a tool for this research as it provides extensive capabilities that will aid in the development of an embodied conversational agent. Blender provides its own internal games engine, which renders it particularly attractive for real time processing. Some of the more important features that Blender provides for this research include: 3D modelling, rigging, skinning, animation, non-linear animation, shape keys, simulation and rendering, UV mapping, texturing. It provides a powerful character animation toolkit, advanced simulation tools including cloth and softbody dynamics and most importantly it supports the use of Python for embedded scripting. This provides Python scripting access for custom and procedural animation effects. It is expected that this area in particular will be central to the development of my research in the future. Another important feature of Blender is its cross platform capabilities, enabling it to run on multiple computer platforms including Microsoft Windows, Mac OS X and Linux. The version of Blender used for development was version 2.49b as this was current at the time. Within the Blender environment, the initial stage of avatar development in character animation involves working with a skeleton referred to as an *armature*. An armature behaves in a similar fashion to the human skeleton. The bones of the armature can be connected by using an array of different approaches, resulting in a controllable, intuitively movable character rig. The process of building an armature is called rigging. Figure 1 below provides a front view of the armature taken from Blender 2.49b. The armature gives the avatar structure while also providing a mechanism for creating and holding poses. The process of attaching an armature to a mesh is called skinning. The mesh for the avatar was imported from MakeHuman and attached to the custom built armature is as seen in Figure 1. Figure 2 provides an image of the right hand showing different orientations to include the palm and the back of the right hand. It also provides an image of the right hand while in Blender 'edit' mode. In this case the base polygonal mesh is also visible.

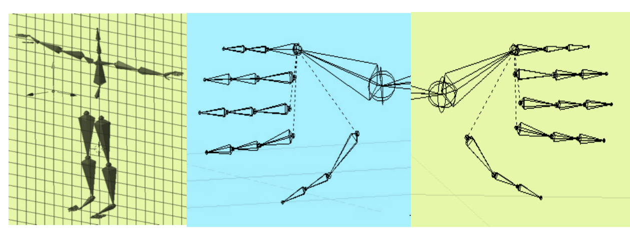

Figure 1: The Blender avatar rig and the armature of the left and the right hand respectively

Figure 2: Various orientations and views of the avatar right hand in Blender

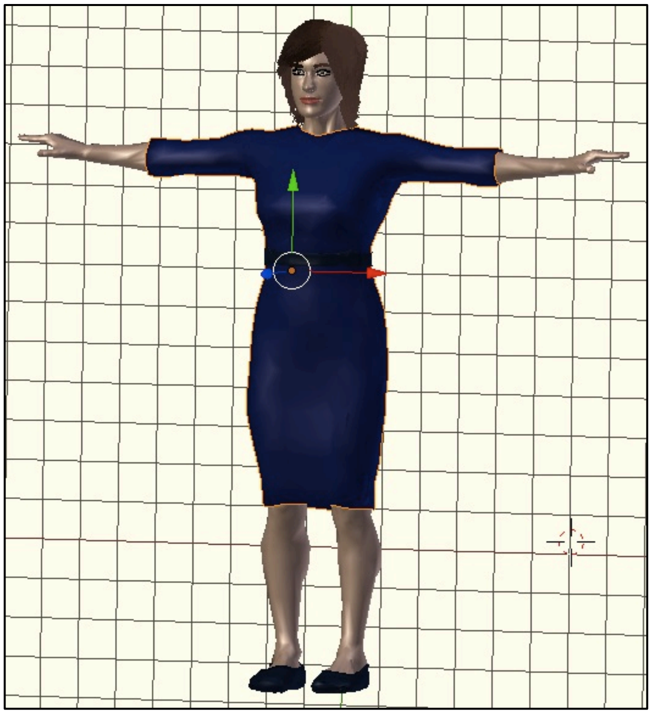

Figure 3: The avatar in Blender

Figure 3 provides a front view image of the completed avatar in Blender. The Blender particle system was used to add hair and eyebrows to the mesh. Vertex groups for the scalp and the eyebrows were created. Then Blenders particle system was used to allocate hair particles the designated groups. The clothing and footwear were developed by using a 'plane' mesh. This mesh was edited and sculpted into clothing and footwear using many of the tools and modifiers supplied by Blender. Blender utilises the Python programming language as a scripting language. Python scripts are used to extend Blender's functionality allowing for the development of custom made or procedural animation effects. It is intended that this functionality will be used to help bridge the linguistic/animation interface during the next phase of research.

4. GESTURE IN HUMAN COMMUNICATION AND LANGUAGE

Human conversation is known to encompass a myriad of complex behaviours. Further to using our vocal organs to produce a speech signal, there are a wide range of complex bodily behaviours underlying human communication [15]. It is important to realise that, even though speech is prominent in conveying content in face-to-face conversation, spontaneous gesture is also integral to conveying propositional content. In fact 50% of gestures add non-redundant information to the common ground of the conversation [16]. In face-to-face dialogue, utterances consist of co-ordinated ensembles of coherent verbal and non-verbal actions [17] [18] [19]. With regard to sign language, signs use visual imagery to convey ideas instead of single words. Sign language is used worldwide by the hearing-impaired as a form of communication with each other and with those that hear. It is a visual, spatial language, which utilises a combination of body and facial expression, lip formation and hand signs. Sign languages are fully developed natural languages and are used by Deaf communities all over the world [20]. Sign language is heavily reliant on gesture and facial expression, which play a very important role in the expression of meaning. It can be described as a natural language. It was not consciously invented by anyone, but was developed spontaneously by Deaf people and passed down without instruction from one Deaf generation to the next [21]. In terms of production, signed languages are articulated in three dimensional space, using not only the hands and arms, but also the head, shoulders, torso, eyes, eye-brows, nose, mouth and chin to express meaning [22]. Communication occurs using a visual-gestural modality, encompassing manual and non-manual gestures. Manual gestures make use of hand forms, hand locations, hand movements and orientations of the palm. Non-manual gestures include the use of eye gaze, facial expression, head and upper body movements. Both manual and non-manual gestures must be performed to produce a valid understanding and interpretation of the sign language [23].

5. IRISH SIGN LANGUAGE (ISL)

ISL is the indigenous language of the Irish Deaf community and is the first language of Deaf people in Ireland. It is a visual, spatial language, with its own distinct grammar. ISL is not only a language of the hands, but also of the face and body. In both modality and linguistic terms, ISL is very different to spoken English or Irish. "While ISL is used by approximately 5,000 Irish Deaf people, it is estimated that some 50,000 people also know and use the language, to a greater or lesser extent" [24]. ISL can be described as a minority language and therefore there is currently no real framework in place to describe its architecture. We propose to use RRG as a theory of grammar that will allow for the development of a lexicon architecture that is sufficiently universal with regard to content to accommodate ISL. We discuss RRG as a model of grammar in a later section.

6. POTENTIAL OF AVATAR FOR SIGN LANGUAGE COMMUNICATION IN ISL

ISL is a fully developed natural language used by the Irish Deaf community, however, ISL can be described as a minority language and therefore it is not currently recognised as a language in the Republic of Ireland. As a consequence, access to important information in relation to education, employment and a myriad of other resources are not available to members of the Deaf community in Ireland. Currently in Ireland, highly skilled interpreters must be employed to facilitate the communication between the Deaf or hearing impaired and the hearing. The use of an interpreter may not always be appropriate or even possible. The development of a three dimensional (3D) computer generated conversational avatar to deploy sign language communication could help to solve this problem through communication by the articulation of Irish Sign Language.

7. ROLE AND REFERENCE GRAMMAR

The value that RRG contributes to this is that it is a theory of grammar that is concerned with the interaction of syntax, semantics and pragmatics across grammatical systems. RRG can be characterised as a descriptive framework for the analysis of languages and also an explanatory framework for the analysis of language acquisition [25]. As a lexicalist theory of grammar, RRG can be described as being well motivated cross-linguistically. The grammar model links the syntactic structure of a sentence to the semantic structure by means of a linking algorithm, which is bi-directional in nature. RRG is a monostratal theory positing only one level of syntactic representation, the actual form of the sentence. Therefore there is only one syntactic representation for a sentence. This representation corresponds to the actual form of the sentence. RRG does not allow any phonologically null elements in the syntax; if there's nothing there, there's nothing there. Within RRG theory, non-relational clause structure is referred to as the layered structure of the clause. The layered structure of the clause is based on two fundamental contrasts. Between the predicate and non-predicating elements, on one hand, and among the non-predicating elements, between arguments and non-arguments on the other [26]. Since these contrasts are found within all languages, RRG describes the primary constituent units of the clause as the 'nucleus', the 'core' and a 'periphery', where the 'nucleus' contains the predicate (usually a verb), the 'core' contains the nucleus and the arguments of the predicate and the 'periphery' subsumes non-arguments of the predicate. This is informally represented in the figure following. Each of the major layers (nucleus, core and clause) is modified by one or more operators, which are closed-class grammatical categories including tense, aspect, negation, illocutionary force, modality and evidentiality. Operators are another important component of the RRG theory of clause structure. An important property of operators is that they modify specific layers of the clause. This is summarized in Table 1.

Table 1: Operators in the layered structure of the clause [26]

Nuclear operators: Aspect Negation Directionals (only those modifying orientation of action or event without reference to participants)
Core operators: Directionals (only those expressing the orientation or motion of one participant with reference to another participant or to the speaker) Event quantification Modality (root modals, e.g. ability, permission, obligation) Internal (narrow scope) negation
Clausal operators: Status (epistemic modals, external negation) Tense Evidentials Illocutionary Force

The semantic representation is based on a system of lexical representation and semantic roles. The system of lexical representation is based on [27] Aktionsart classification of verbs into states, activities, achievements and accomplishments. There are two additional classes; active accomplishments, which describe telic uses of activity verbs (e.g. devour) and also semelfactives (punctual events). Examples of each class and their formal representation, including their causative counterparts are given in (1) below.

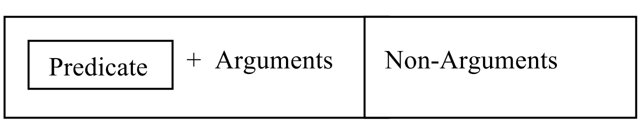

Figure 4: Universal oppositions underlying clause structure [26]

(1) a. States: *be sick, be tall, be dead, love, know, believe, have*
b. Activities: *march, swim, walk* (– goal PP); *think, eat* (+ mass noun/bare plural RP)
c. Semelfactives: *flash, tap, burst* (the intransitive versions), *glimpse*
d. Achievements: *pop, explode, shatter* (all intransitive)
e. Accomplishments: *melt, freeze, dry* (the intransitive versions), *learn*
f. Active accomplishments: *walk* (+ goal PP), *eat* (+ quantified RP), *devour*

A single verb can have more than one *Aktionsart* interpretation. For example the verb *'march'* would be listed in the lexicon as an activity verb, and lexical rules would derive the other uses from the basic activity use. The lexical representation of a verb or other predicate is termed its LOGICAL STRUCTURE [LS]. State predicates are represented simply as **predicate´**, while all activity predicates contain **do´**. Accomplishments, which are durative, are distinguished from achievements, which are punctual. Accomplishment LSs contain BECOME, while achievement LSs contain INGR, which is short for 'ingressive'. Semelfactives contain SEML. In addition, causation is treated as an independent parameter that crosscuts the six *Aktionsart* classes. It is represented by CAUSE in LSs. The lexical representations for each type of verb shown above are given in Table 2.

Table 2: Lexical Representation for Aktionsart classes [26]

Verb Class	**Logical Structure**
State	predicate' (x) or (x,y)
Activity	do' (x, [predicate' (x) or (x, y)]}
Achievement	INGR predicate' (x) or (x,y), or INGR do' (x, [predicate' (x) or (x, y)]}
Accomplishment	BECOME predicate' (x) or (x,y), or BECOME do' (x, [predicate' (x) or (x, y)]}
Active accomplishment	do' (x, [predicate$_1$,' (x, (y))]) & BECOME predicate$_2$; (z, x) or (y)
Causative	α CAUSE β where α, β are representations of any type

8. IRISH SIGN LANGUAGE

Ó Baoill and Matthews [22], describe the signing space as the space within which all signs must be articulated. The signing space usually extends from the waist upwards and includes the shoulders and the face. It extends outwards as far as the arms can extend. To ensure grammatical clarity, the signing space can be sub-divided for meaning. Morphemes are articulated at particular points or *loci* in relation to the signer for pronominal and anaphoric reference. Neutral space is the space immediately in front of the signer and close to the signer's body. It encompasses the area from the head to the waist and extends the width of the signer's body. Neutral space is the space that is used when producing the citation form of an item and generally does not act as a referent for particular or special meaning. The signs of ISL can be divided into eight different categories according to the manner and mode of production, as seen in 2 below. Their description is based on the following parameters, which relates mostly to whether a signer uses one or two hands in the articulation of a particular sign.

(2) a) One handed signs, including body or near body contact during articulation.
b) One handed signs, where the sign is articulated in free space without any body contact.
c) Two handed signs having identical shape, where the hands touch during the articulation of the sign in space.
d) Two handed signs having identical shape, where the hands move in symmetry but without any contact taking place during the articulation of the sign in space.

e) Two handed signs having identical shape, where the hands perform a similar action and come in contact with the body.
f) Two handed signs having identical shape, where the hands are in contact during articulation, however, using one dominant articulator and one passive articulator.
g) Two handed signs showing a different shape, each hand having an active articulator and having equal importance.
h) Two handed signs showing a different shape, where the dominant hand (depending on whether the signer is left-handed or right-handed) is the active articulator and the other hand is the subordinate or passive articulator.

8.1 The Non-Manual Features of ISL

Non-manual features (NMF) or markers in signed languages refer to those meaningful units of the visual-gestural language, which are used to convey additional information to the meaning being expressed by manual handshapes. The existence of NMF within signed languages has been well documented by researchers [28] [29] [30] [31]. NMF consist of various facial expressions such as eyebrow movement, movement of the eyes, mouth patterns, blowing of the cheeks and also include head tilting and shoulder movement. While NMF are normally accompanied by a signed lexical item, they can be used to communicate meaning independent to manual accompaniment. Within the linguistic system of ISL, NMF are used to express various emotions. They are also used to modulate or intensify the content of the information. In this sense NMF function as intensifiers. The use of NMF to express various syntactic properties is an identifying feature of sign languages and ISL is no exception to this. [22] NMF function as both morphological and syntactic markers in ISL. While the majority of functions expressed through the use of NMF occur at the single lexical item level, there are certain syntactic functions that are expressed by means of NMF, but are not attached to any lexical item. The following list identified by Ó Baoill and Matthews [22], include all the relevant functions provided by NMF.

(3) a) To show the degrees of emotion
b) To denote intensification or modulation
c) To distinguish declarative or interrogative sentences
d) To denote negation
e) To define topic or comment structures
f) To indicate conditional clauses
g) To show sarcasm

8.2 Hand Configuration in ISL

Stokoe [32] identified the various parameters which are relevant for the analysis of sign language. He suggested that the articulation of a sign encompassed three different parameters. A designator, which was used to refer to the specific combination of hand configuration, abbreviated to *dez*. A tabulation, used to refer to the location of the hands and abbreviated to *tab*, and a *signation* used to refer to the movement of the hands and abbreviated to *sig*. Dez, tab and sig were examples of what he called *cheremes*, the signed equivalent of phonemes. Later research refers to these parameters of sign language as *handshape*, *location* and *movement*. [33] [34] [35] Later research claimed that a fourth parameter is necessary in order to be able to fully transcribe signs. This fourth parameter was called orientation, and denotes the orientation of the hands and fingers during the articulation of the sign. The abbreviation of orientation is *ori.*

9. THE PARSE AND GENERATE PROCESS FOR ISL AVATAR

9.1 Overview of the Process

Figure 5 shows a diagram of the RRG Interlingua bridge [8]. Using the RRG Interlingua bridge we create an intermediate semantic representation of the source text, based on RRG logical structures. These logical structures can then be used to generate our target language (ISL). The architecture of the parse and generate process for the ISL avatar is shown in figure 6. This architecture describes the flow of processing. It documents the processes from the user inputs text until an ISL articulation is produced via the Blender interface. The model accepts input in the form of an English sentence or English text. Once the inputted text has been parsed into its various parts of speech it is stored in the parts of speech (POS) lexicon. The next phase involves the syntactic parser. This parser retrieves the tokens or lexical items with their various information from the POS lexicon. It then uses the RRG linking system to convert from a syntactic description to a semantic description of the sentence or text. The output of this phase of parsing is a rich logical structure.

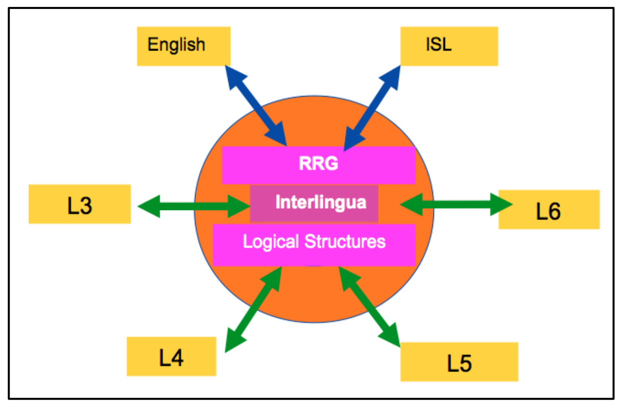

Figure 5: The RRG-based Interlingua Bridge [8]

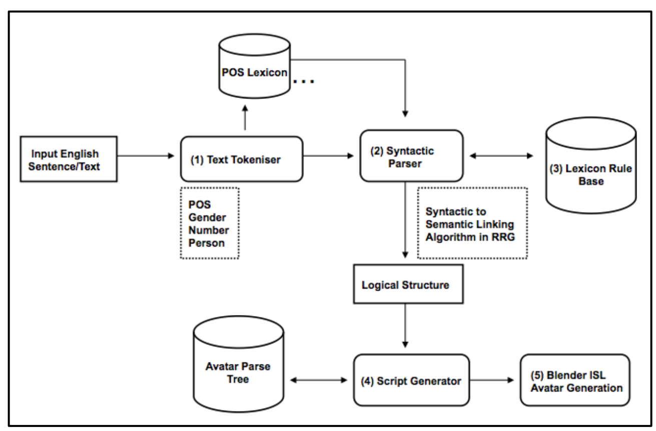

Figure 6: Architecture of the Parse and Generate Process for the ISL Avatar

Phase 4 is concerned with expanding the logical structure to produce what can be described as a meta representation of the parsed sentence. This will include agreement features, operators and constituents as well as information pertaining to the modality of the target language, i.e. the manual and non-manual features of

ISL. The final phase or phase 5 of the processing is the generation of an articulation in our target language which is ISL. ISL is a visual gestural language and therefore the ISL is outputted to the user by the implementation of a conversational avatar via the Blender UI. Blender provides Python programming interfaces and Python scripting access for the development of custom and procedural animation effects. The Python script developed at phase 4 will be used as input for the Blender interface and the result will be the generation of an articulation of the input sentence or text in ISL by the conversational avatar.

9.2 Phase 1 processing – finding the lexical items

In the initial processing phase, an English sentence will be inputted and stored in the form of a String. With regard to RRG, the sentence will be classified as one of the following: State, Activity, Achievement or Accomplishment. The sentence will then be tokenised and saved in a suitable data structure, where each token is a word. For each token the lexicon must be searched to see if the word is present and decipher its parts of speech (POS) (gender, number, person). The information must then be stored with the lexical item in the specified data structure. Once this step has been carried out for all tokens, there will be a better sense of the word order of the String.

9.3 Phase 2 processing – creating the rich logical structure of the utterance

The initial step for phase 2 is to identify where the NP is in the String. Then it must be interpreted as transitive, ditransitive or intransitive. This will clarify the type of sentence that is being processed. The next step for this phase involves the extraction of the logical structure for the verb from the lexicon. The tokens from phase 1 can then be retrieved and mapped based on the RRG theory of grammar.

(4) < …. < …. < …. [do [x… pred x, y, z] >>>

(5) The 1st NP into x, the 2nd. into y and the 3rd (typically in preposition) into z.

From the information recorded above (in the verb and the form of the verb for example run, ran, will run) information regarding the tense can be extracted and consequently the verbal and nominal structure can be determined. At the conclusion of this phase a rich logical structure will have been generated.

9.4 Phase 3 – The ISL Lexicon as an XML structure

It is envisaged that the lexicon will be developed using Extensible Markup Language (XML). XML is a platform neutral markup language, which is easily understood, while also lending itself well to computational parsing. XML will be used as a data structure for the storage and organisation of the various lexical entries i.e. verbs, nouns etc. to include the lexical items of ISL. It will be necessary at this phase of development to extend the lexicon to provide for the storage of the morphophonological handshapes of ISL as a visual gestural language. Signs are composed of both manual and non-manual features. Non-manual features are used to convey additional information to the meaning being expressed by manual handshapes. The lexicon architecture must be extended so that it is sufficiently universal to encompass both the syntactic and the semantic content of an articulation in ISL. This constitutes present work. We describe the characteristics of ISL in section 8 of this paper.

9.5 Phase 4 processing – expanding the logical structure to sign the utterance

This part of the processing will involve the development of the underlying linguistic model with bi-directional RRG. This will enable the conversion of the English text into a meta-representation in RRG logical structures and generate ISL on output to the embodied conversational agent in real time using Python scripting. ISL language specific information, for example manual and non-manual features will have to be considered at this phase of processing. The structure will then have to be expanded so that it is sufficiently universal to encompass all of the necessary parameters consistent with ISL.

9.6 Phase 5 processing – generate the utterance via Blender

This phase will allow for the interaction between the Blender interface and the output from phase 4 processing. It is anticipated that the gap between Blender and the generated logical structures from phase 4 will be bridged by the utilization of Python scripts. The Blender API provides Python scripting access for custom and procedural animation effects. The output of this phase will be the generation of the ISL articulation via the Blender UI.

10. CHALLENGES AND ISSUES

ISL, our target language, is a visual gestural language and by its very nature will prove challenging at the generation phase of this research. The development of a computational framework that will be capable of bridging the gap between the lexicon and the generation of ISL is a very complex and challenging issue. The development of a meta representation of the data, which must be sufficiently rich to encompass all of the necessary information consistent with ISL is also very challenging. Factors such as synchronisation of various articulators including articulators for manual and non-manual features of the language are currently being researched. Figure 5 is a first draft at resolving the question of how any given sign may be generated using our 3D animation tool, Blender.

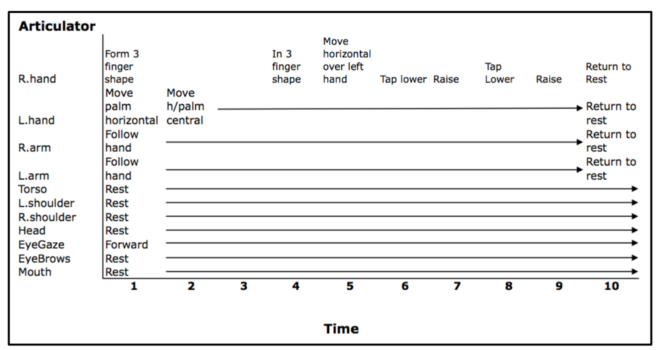

Figure 7: Realisation diagram for the sign "Mother" in ISL

It is envisaged that the articulators as shown in this figure will be choreographed and orchestrated simultaneously, equivalent to instruments in an orchestra at the generation phase. This provides a signature for the orchestration of a method to generate the sign for Mother in ISL. It is followed by the pseudocode for this signature in Figure 8.

The pseudocode provides a high level insight into the implementation details on the programming side for the avatar. It is envisaged that the avatar will be driven using the Blender-Python interface. Blender utilises the Python programming language as a scripting language. Python scripts can be used to extend Blender's functionality allowing creation of custom made or procedural animation effects. Parameters that encompass an ISL articulation such as orientation and movement together with the various articulators for manual and non-manual features will have to be considered at the implementation phase of research. Implementation details regarding synchronisation of movement of the various articulators are provided here at a high level.

```
Sign: mother = method
{           do{
                Rhand(sign 51, orientation)
                Tap(RH, LH, 2, x, y)
                Lhand(sign 51, orientation)
                Rarm(rest)
                Larm(rest)
                Head(rest)
                Lshoulder(rest)
                Rshoulder(rest)
                Torso(rest)
                Eyebrow(rest)
                Eyegaze(forward)
                Mouth(rest)
}           }
```

Figure 8: Pseudocode for the sign for "Mother" in ISL

11. DISCUSSION

The research presented here is a work in progress. To date the avatar for our research has been developed using Blender version 2.49b and MakeHuman. The avatars polygonal mesh was imported from MakeHuman and then the armature, which was developed in Blender, was attached or skinned to the mesh. The imported mesh was sculpted and edited using various tools and modifiers in Blender. The Blender particle system was used to add hair and eyebrows to the model. Various modifiers and tools were also used to develop clothing and shoes for the model. The various handshapes of ISL have been researched and identified. Ó Baoill and Matthews [2] indicate the 66 different handshapes are utilised within ISL in the formation of signed vocabulary. Within these handshapes Ó Baoill and Matthews [2] also identify the marked and unmarked handshapes of ISL, revealing a high correlation between ease of articulation in handshapes and frequency of occurrence. These handshapes provide us with an understanding of the building blocks of the formation of signs. The RRG linguistic framework and the RRG lexicon for this research have been mapped to XML. The next phase of research will involve the development of the underlying linguistic model with bi-directional RRG. This will enable the conversion of English text into a meta representation in RRG logical structures and generate ISL on output to the ECA in real time using Python scripting.

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