Educational Resources and Implementation of a Greek Sign Language Synthesis Architecture

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ABSTRACT
In this paper we present the creation and presentation of dynamic linguistic resources of Greek Sign Language (GSL). The resources feed the development of an educational multitask platform within the SYNENNOESE project for the teaching of GSL. The platform utilizes standard virtual character (VC) animation technologies for the synthesis of sign sequences/streams, exploiting digital linguistic resources of both lexicon and grammar of GSL. In SYNENNOESE, the input is written Greek text from early elementary school textbooks, which is transformed into GSL and animated on screen. A syntactic parser decodes the structural patterns of written Greek and matches them into equivalent patterns in GSL, which are then signed by a VC. The adopted notation system for the lexical database is HamNoSys (Hamburg Notation System). For the implementation of the virtual signer tool, the definition of the VC follows the h-anim standard and is implemented in a web browser using a standard VRML plug-in.

Categories and Subject Descriptors
J.5 [**Arts and Humanities**]: Language translation, H.5 [**information interfaces and presentation**]: Multimedia Information Systems – *Artificial, augmented, and virtual realities*, H.5 [**information interfaces and presentation**]: Multimedia Information Systems – *Training, help, and documentation*

General Terms
Design, Human Factors, Standardization, Languages.

Keywords
Sign language synthesis, linguistic content, h-anim, educational resources.

1. INTRODUCTION
Greek Sign Language (GSL) is a natural visual language used by the members of the Greek Deaf Community with several thousands of native or non-native signers. Research on the grammar of GSL per se is limited; some work has been done on individual aspects of its syntax, as well as on applied and educational linguistics. It is assumed that GSL as we now know it, is a combination of the older type of Greek sign language dialects with French sign language influence. Comparison of core vocabulary lists exhibit many similarities with sign languages of neighboring countries, while in morphosyntax GSL shares the same cross-linguistic tendencies as many other well analyzed sign languages [1][16].

GSL has developed in a social and linguistic context similar to most other sign languages. It is used widely in the Greek deaf community and the estimation for GSL users is about 40,600 (1986 survey of Gallaudet Univ.). There is also a large number of hearing non-native signers of GSL, mainly students of GSL and families of deaf people. Although the exact number of hearing students of GSL in Greece is unknown, records of the Greek Federation of the Deaf (GFD) show that, in the year 2003 about 300 people were registered for classes of GSL as a second language. The recent increase of mainstreamed deaf students in education, as well as the population of deaf students scattered in other institutions, minor town units for the deaf and private tuition may well double the total number of secondary and potential sign language users. Official settings where GSL is being used include 11 Deaf clubs in Greek urban centers and a total of 14 Deaf primary, secondary and tertiary educational settings.

In consultancy with the Greek Pedagogical Institute, the SYNENNOESE project helps young pupils acquire the proper linguistic background so that they can take full advantage of the new accessible educational material. The platform offers students the possibility of systematic and structured learning of GSL for either self-tutoring or participation to virtual classroom sessions of asynchronous teaching, and its design is compatible with the principles that generally define systems of open and distant learning. Besides teaching GSL as a first language, in its present form the platform can be used for the learning of written Greek through GSL, and it will also be open to future applications in areas of other subjects in the school curriculum.

Figure 1 describes the abstract architecture and dataflow between the components of the integrated system. In this paper we describe the procedures followed during the compilation of the educational material and the implementation of the sign language synthesis component of the educational platform. In this process we utilized existing software components for the web-based animation of an h-anim virtual character; the adoption of widely accepted character definition and animation standards caters for the extensibility and reusability of the system resources and its content.

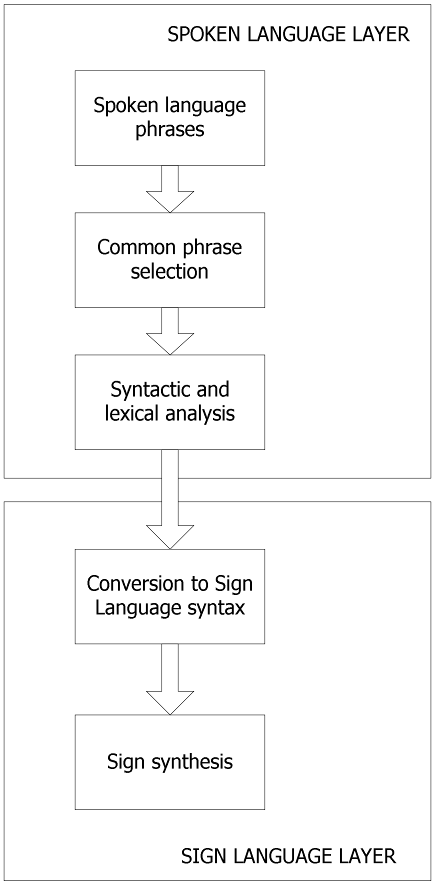

Figure 1: Overview of the proposed architecture

2. LINGUISTIC RESEARCH BACKGROUND IN THE AREA OF SIGN LANGUAGES

In Greece there have been some serious attempts of lexicography in the recent past (PROKLESE, a Dictionary of Computing Signs, NOEMA: a Multimedia Dictionary of GSL Basic Vocabulary and A Children's Dictionary of GSL) mainly for educational purposes, but complete decoding of the language structure is not yet publicly available.

The linguistic part of the project is based on overall assumptions for the adequacy of signed languages as by Stokoe [20] and Woll and Kyle [15], among many. Greek sign language is analyzed to its linear and non-linear (simultaneous) components [18][8]. The linear part of the language involves any sequences of lexical and functional tokens and their syntactic relations, while non-linear structures in GSL, as in all known sign languages, are present in all levels of the grammar. Each sign in GSL is described as to its handshape, location, movement, orientation, number of hands and use of any obligatory non-manually articulated elements (e.g. mouth patterns, head and shoulder movements, facial expression and other non-manual features), based on the Stokoe model.

In the project it was considered essential that the output is as close to native GSL as used in the Greek deaf community. In this respect, forms of 'signed Greek' or other manual codes for the teaching of Greek were excluded and the two languages (GSL and Greek) were treated as the first and second language respectively for the users of the platform, quite as other bilingual platforms may function outside the domain of special education.

3. LANGUAGE RESOURCES OF THE PROJECT

Implementation of both the tutoring and the summarization tools of the platform require collection of extensive electronic language resources for GSL as regards the lexicon and the structural rules of the language [6]. The actual data of the study are based on basic research on GSL analysis undertaken since 1999 as well as on experience gained by projects NOEMA and PROKLESE [7]. The data consist of digitized language productions of deaf native GSL signers and of the existing databases of bilingual GSL dictionaries, triangulated with the participation of deaf GSL signers in focus group discussions. The project follows methodological principles on data collection and analysis suitable to the minority status of GSL. Wherever the status of individual GSL signs is in consideration, the Greek Federation of the Deaf is advised upon, too.

Many of the grammar rules of GSL are derived from the analysis of a digital corpus that has been created by videotaping native signers in a discussion situation or when performing a narration. This procedure is required, because there exists little previous analysis of GSL and rule extractionhas to be based on actual data productions of native signers. The basic design of the system, except for the educational content this currently supports, focuses on the ability to generate sign phrases, which respect the GSL grammar rules in a degree of accuracy that allows them to be recognized by native signers as correct utterances of the language.

In this respect the SYNENNOESE project offers a great challenge for in-depth work on both directions, lexicography and linguistic analysis of GSL. For the first time, research goes beyond a mere collection of glosses and moves further from many previous bilingual dictionaries of sign languages [4], into the domain of productive lexicon [21], i.e. the possibility of building new GSL glosses following known structural rules, and also challenge automatic translation in predictable environments, using an effective module/interface for the matching of structural patterns between the written input and the signed output of the platform. It is a design prerequisite that the system of GSL description should have an open design, so that it may be easily extendible allowing additions of lemmas and more complicate rules, with the long term objective to create an environment for storage and maintenance of a complete computational grammar of GSL. From a linguistic point of view the resulting database of glosses, rules and tendencies of GSL will be a significant by-product of the project, of great value to future applications.

3.1 Grammar content definition

In the early implementation phase, the subsystem for the teaching of GSL grammar covered a restricted vocabulary and a core grammar capable of analyzing a restricted number of main GSL grammatical phenomena, which might be argued that belong to signing universals. Synthesis of GSL requires the analysis of the GSL signs into their phonological parts and their semantics. It was agreed that only monomorphemic signs that use only one handshape were to be initially analyzed, so that feedback from the technical team would determine further steps. In the second stage, more complicated sequential structures of signs are considered (e.g. compound word-signs) and once individual signs are transcribed and stored in a database, additional tiers such as basic non-manual features can be added without technical difficulties.

At the stage of grammatical analysis, findings from other sign language grammars, as well as the views of our deaf native user consultants are taken into account in order to verify findings. It is admitted that there is even more work to be done on the pragmatics of GSL and its relation with real-world situations (e.g. for the use of indexes or classifiers), and these are noted as future aims of the platform.

Furthermore, an interesting parameter of a virtual signer is the ability to sign letters of the written alphabet (fingerspelling). This technique is useful in cases of proper nouns, acronyms, terminology or general terms for which no specific sign exists. Fingerspelling is used extensively in some other sign languages such as the American Sign Language (ASL) or the British Sign Language (BSL); our evidence in GSL suggests that it is only used occasionally, rarely incorporating fingerspelled loans into the core of the language. From a technical point of view, however, it is quite simple for a VC to fingerspell as this process includes no syntax, movement in signing space or non-manual grammatical elements. Many previous attempts of sign animation would go up to the level of fingerspelling or signing only sequential structures of a representation of the written or spoken language. Since then technology has developed and so has linguistic description of sign language structures. On the other hand few deaf people in Greece use fingerspelling or a code such as 'Signed Exact Greek' extensively. For these reasons the present work aims to represent a form of GSL as close to natural fluent signing as possible, and only uses fingerspelling occasionally, for example in language games, where teaching of written Greek is the focus.

3.2 Notation and glossing

In order to decide on the notation to be followed for sign recording in the lexical resources database, the existing international systems of sign language recording were evaluated. Notation represents a vital part of the whole engine as it serves for the communication between the linguistic subsystem that determines the meaningful movements in the context of GSL and the technological subsystem that performs these movements with a synthetic 3D model signer.

Tools utilized for the transcription and notation include HamNoSys, a pictographic notation system developed by the University of Hamburg for the description of the phonology of signs [19]. This notation forms the corpus of GSL lemmas while for the representation of sequential structures, i.e. in the phrase level, the ELAN language annotator developed by the Max-Planck Institute of Psycholinguistics in Nijmegen, the Netherlands, will be used. We considered these two systems as most suitable to the text-to-sign animation according to reviews of recent relevant projects. The classic Stokoe model is used for the morpho-phonological description, with one additional tier with written Greek words of harsh semantic equivalents of utterances. An aim of the project is to add more tiers as the project continues, such as those mentioned above on the use of non-manual features and on pragmatics, using the existing symbols in HamNoSys and ELAN. Signwriting was another transcribing tool under consideration, but was not chosen, given the expected compatibility of HamNoSys within the Elan tiers in the near future.

4. TUTORING SYSTEM DESCRIPTION – CORPUS OF EDUCATIONAL MATERIAL

The test bed learning procedure concerns teaching of GSL grammar to early primary school pupils, whereas the platform also incorporates a subsystem that allows approach by the deaf learner to material available only in written Greek form by means of a signed summary. The learning process in practice will involve an initiator of the session, the students in groups or alone and a teacher-facilitator of the process, physically present with the students. The process can take place in real-time or can be relayed. There is provision of a virtual whiteboard, icon banks and chat board visible in the screen along with the virtual signer for common use in the classroom. The participants will also be able to see each other in real time through a web camera, in order to verify results of GSL learning.

Specifications for the formation of GSL resources of the application are crucially based on exhaustive research in the official, recently reformed, guidelines for the teaching of Greek language and of GSL in primary schools for the deaf. The educational content of the platform follows the same guidelines as the hearing children's curriculum, so that the same grammatical and semantic units can be taught in the two languages, GSL and spoken / written Greek. Concepts such as subject-object relations, types of verbs, discourse functions of the language form the units of the curriculum in the SYNENNOESE project so that the same principles are taught under the same platform, but without projecting a mirror image of the Greek grammar onto GSL. For the selection and arrangement of the educational material the project is in close cooperation with the Pedagogical Institute in Athens, which is the main official agency in charge of the development of educational material.

The first group of exercises deals with signs that use the same handshape but start from different positions with respect to the signer's body or the neutral signing space and consist of different movements. An example of such a group in GSL includes the words 'table', 'house', donkey', 'slipper' and 'tent'. In this framework, young pupils are initially presented with the VC signing each word in a particular group and a sketch depicting the same concept; the use of sketches instead of written words is adopted since very young pupils have not developed skills related with spoken or written languages and thus, their mother tongue is the relevant sign language. In the following, pupils go through a number of drills, similar to the ones found in usual language teaching classes. These drills consist of choosing the correct sketch relating to a random sign performed by the VC and matching different instances of the VC with the correct sketch, by picking from an on-screen sketch pool.

The second group of exercises includes signs with similar or semantically related meaning, signed with the same or different handshapes. An example is the group 'human', 'tall', 'fat', 'child', 'female'. The drills here are the same with the ones in the first exercise group, as is also the case with the third group of exercises. In this category, sign pairs are formed, consisting of signs composed of same phonological features (handshape, movement, location, palm orientation) but differing in their grammatical classification, e.g. 'sit-chair', 'eat-food' and '$love_{verb}$-$love_{noun}$' by means of movement repetition.

5. TECHNICAL CONSIDERATIONS

The implementation team has reviewed currently available VC and animation technologies for the representation of sign language in order to adopt one of the most prominent technological solutions. The movements of a synthetic 3D signing model have to be recorded in a higher and reusable level of description, before they are transformed in parameters of body movement (such as Body Animation Parameters – BAPs according to the MPEG-4 model). In the area of text-to-sign animation there have been some similar projects (VISICAST, Thetos, SignSynth and eSIGN among them) that SYNENNOESE uses as background.

H-anim [11] is a set of specifications for description of human animation, based on body segments and connections. According to the standard, the human body consists of a number of segments (such as the forearm, hand and foot), which are connected to each other by joints (such as the elbow, wrist and ankle). As is mentioned in the standard description, the main goals of the h-anim standard are compatibility, flexibility and simplicity. In this framework, a human body is defined as a hierarchy of segments and articulated at joints; relative dimensions are proposed by the standard, but are not enforced, permitting the definition and animation of cartoon-like characters. In addition to this, different levels of skeleton articulation (Levels of Articulation – LOA) are available, catering for applications with different requirements: for example, a cartoon-like character and a martial arts computer game have inherently different needs for the flexibility of the relevant VC's body. Another welcome feature of the h-anim standard is that prominent feature points on the human body are defined in a consistent manner, via their names and actual locations in the skeleton definition. As a result, a script or application that animates an h-anim compatible VC is able to locate these points easily and concentrate on the high level appearance of the animation process, without having to worry about the actual 3D points or axes for the individual transformations. In the developed architecture, this is of utmost importance, because sign description is performed with respect to these prominent positions on and around the virtual signer's body.

For the recording and definition of handshape and gestures, motion tracking and haptic devices (such as CyberGrasp or Acceleration Sensing Glove with a virtual keyboard) were initially considered; however, it was agreed that, if the HamNoSys notation commands would provide acceptable quality, based on the initial implementation, motion capture sequences will not need to be applied. In any case, semantic notation is a far more flexible and reusable solution than video files or motion capture, since an h-anim VC can take advantage of the dynamic nature of phonological and syntactic rules.

5.1 Adopted 3D technologies

For the content designer to interact with a VC, a scripting language is required. In our implementation, we chose the STEP language (Scripting Technology for Embodied Persona) [10] as the intermediate level between the end user and the virtual actor. A major advantage of scripting languages such as STEP is that one can separate the description of the individual gestures and signs from the definition of the geometry and hierarchy of the VC; as a result, one may alter the definition of any action, without the need to re-model the virtual actor. The VC utilized here is compliant with the h-anim standard, so one can use any of the readily available or model a new one.

Scripted animation is an interchangeable and extensible alternative of animation based on motion capture techniques. One can think of the relation between these two approaches similarly to the one between synthetic animation and video-based instructions: motion capture can be extremely detailed with respect to the amount and depth of information, but is difficult to adjust or adapt when produced and typically requires huge amounts of storage space and transmission capacity to deliver. On the other hand, scripted animation usually requires manual intervention to compile and thus is minimal and abstract in the way it represents the various actions of the avatar. As a result, such scripts require a few hundred characters to describe and can be reused to produce different instances of similar shape [9]. This is illustrated in the code snippet in Figure 2, which illustrates the required transformations for the right hand to assume the 'd'-handshape. As is easily demonstrated, the same code of the left hand can be compiled by mirroring the described motion, while other, more complicated handshapes can start with this representation and merely introduce the extra components into it.

```
par([
   turn(humanoid,r_thumb1,rotation(1.9,1,1.4,0.6),
   very_fast),
   turn(humanoid,r_thumb2,rotation(1,0.4,2.2,0.8),
   very_fast),
   turn(humanoid,r_thumb3,rotation(1.4,0,0.2,0.4),
   very_fast),
   turn(humanoid,r_index1, rotation(0,0,0,0),
   very_fast),
   turn(humanoid,r_index2,rotation(0,0,0,0),
   very_fast),
   turn(humanoid,r_index3,rotation(0,0,0,0),
   very_fast),
   turn(humanoid,r_middle1,rotation(0,0,1,1.5999),
   very_fast),
   turn(humanoid,r_middle2,rotation(0,0,1,1.5999),
   very_fast),
   turn(humanoid,r_middle3,rotation(0,0,1,1.5999),
   very_fast),
   turn(humanoid,r_ring1,rotation(0,0,1,1.7999),
   very_fast),
   turn(humanoid,r_ring2,rotation(0,0,1,1.5999),
   very_fast),
   turn(humanoid,r_ring3,rotation(0,0,1,0.6000),
   very_fast),
   turn(humanoid,r_pinky1,rotation(0,0,1,1.9998),
   very_fast),
   turn(humanoid,r_pinky2,rotation(0,0,1,1.5999),
   very_fast),
   turn(humanoid,r_pinky3,rotation(0,0,1,0.7998),
   very_fast)
])
```

Figure 2: STEP code for a handshape

In the SYNENNOESE project, a syntactic parser decodes the structural patterns of written Greek and matches them into their equivalents in GSL [3]. These are fed into an automated system that decodes HamNoSys notation sequences for each lemma; this system essentially transforms single or combined HamNoSys symbols to sequences of scripted commands. A typical HamNoSys notation sequence consists of symbols describing the starting point configuration of a sign and the action that the signing consists of. Symbols describing the initial configuration refer to the handshape that is used during the sign and the starting position and orientation of the hand that performs the sign; if the other hand takes part in the sign, as is the case in the GSL version of 'doctor', it is the relative position of the two hands that matters, for example 'the main hand touches the elbow of the secondary arm'. Other information includes symmetry, if both hands follow the same movement pattern and any non-manual components. Figure 3 shows a frame of the signing sequence for 'donkey'; the VC shown here is 'yt', by Matthew T. Beitler, available at http://www.cis.upenn.edu/~beitler. A demonstration with limited vocabulary and some phrase examples can be found online at http://www.image.ece.ntua.gr/~gcari/gslv.

Figure 3: An instance of 'yt' signing 'donkey'

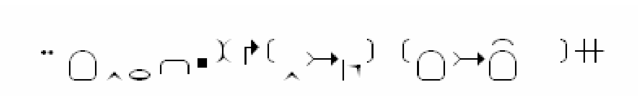

Figure 4: The HamNoSys sequence for the GSL version for 'donkey'

Figure 5: The GSL version of 'child'

Figure 4 shows the HamNoSys sequence for the particular sign, shown on the top of the page of the user interface. The first symbol here indicates that both hands perform the same movement, starting from symmetrical initial locations with respect to the signer's torso. The second symbol indicates the handshape, which here is an open palm, referred to as the 'd'-handshape in GSL, while the next shows palm orientation. The following symbols handle the starting position of the palm, which here almost touches the temple of the signer's head. Symbols contained in parentheses describe composite movements, while the last character forces the signer to repeat the described movement.

```
par([
   turn(humanoid,r_elbow,
   rotation(-0.722,0.2565,0.1206,1.5760),fast),
   turn(humanoid,r_shoulder,
   rotation(-0.722,0.2565,0.1206,0.0477),fast),
   turn(humanoid,r_wrist,
   rotation(0,1.5,-1,1.570),fast)
]),
sleep(500),
par([
   turn(humanoid,r_shoulder,
   rotation(-0.598,0.2199,0.1743,0.0812),fast),
   turn(humanoid,r_elbow,
   rotation(-0.598,0.2199,0.1743,1.2092),fast)
])
```

Figure 6: The STEP code for the sign 'child'

Figure 7: The GSL version of 'children'

Figure 5 shows the VC signing the GSL version of 'child', while Figure 7 shows an instance for the sign for 'children'. The design of the automated script production system enables us to use the description of the former sign (Figure 6) to construct the definition of its plural form. In this case, the plural form is shown by repeating the same downward hand movement, while moving the hand slightly to the signer's right; direction is indicated by the symbol preceding the parenthesis, while its content describes this secondary movement. As a result, it is only necessary for the parser to indicate the particular modification of the initial sign required to produce the plural form of the lemma. In GSL, these forms are limited, thus enabling us to come up with efficient production rules, such as the one described above. Another possibility is to change the handshape for a sign, especially when the signer wants to indicate a particular quantity or number. Figure 8 shows the VC signing the GSL version of 'day', while Figure 9 shows the GSL version of 'two days': the difference here is that in the latter case the VC uses a two-finger handshape, instead of the straight-index finger handshape, to perform the same movement, starting from the same initial position. This difference is more evident in Figure 10, which shows the VC in a frontal view; this is actually a nice feature of the Blaxxun Contact 5 [2], the VRML plug-in shown in these figures. Despite the default tilted view being the one of choice from the part of the users, the ability to show frontal and side view of the sign is crucial in learning environments, since it caters for displaying the differences between similar signs and bring out the spatial characteristics of the sign [14][13].

Figure 8: The GSL version of 'day'

Figure 9: The GSL version of 'two days'

Figure 10: The frontal view of the GSL version of 'two days'

6. IMPLICATIONS AND EXTENSIBILITY OF THE EDUCATIONAL PLATFORM

As an educational tool above all, the SYNENNOESE platform offers a user-friendly environment for young deaf pupils aged 6 to 9, so they can have visual translation of words and phrases. The signed feedback acts as a motivating tool for spelling Greek words and structuring sentences correctly, as well for evaluating one's performance. For deaf young students as a group with special needs, the platform draws some of the accessibility barriers, and the possibility of home use even makes it accessible to family, thus encouraging communication in GSL, but also access to the majority (Greek) language. New written texts can be launched, so SYNENNOESE may receive unlimited educational content besides primary school grammar units. On the other hand, unlimited school units, such as the increasing special units with individual deaf students in remote areas can link with one another via the SYNENNOESE platform.

Moreover, text-to-sign translation can be extended and applied to different environments such as Greek language teaching to deaf students of higher grades, GSL teaching for hearing students, Greek for specific purposes such as to adult literacy classes for the Deaf etc. In this context, more domains of GSL grammar can be described and decoded, making the output closer to natural signed utterances as our analysis proceeds. This is a challenge not only for theoretical research, but also for computer science and applied linguistic research.

Furthermore, a database with the bulk of GSL utterances, described as to their features from the phonological up to the pragmatic level will be the major outcome of the whole project. In this way the representation of GSL structures can be matched to the equivalent ones of written Greek, and it will be a challenge to be able to compare directly the grammars of the two languages. In much the same way structures of GSL will easily be compared with counterparts from ASL or BSL [4] for research across signed languages.

7. PROBLEMS AND LIMITATIONS

The main limitations of the study are described below. These are divided into linguistic, educational and technical ones. Most of the limitations are typical to sign animation projects, and they were expected before the beginning of the project.

Regarding the linguistic and educational aspects of the project, one of the major issues that needs to be addressed is the fact that in some areas of the language there are no standardized signs, so there may be some theoretical objections as to the use of particular entries. However, a platform such as the one described allows for multiple translations and does not have any limitations as to the size of files, which was the case, for example in previous DVD-based GSL dictionaries, containing video entries. Moreover, the platform will be open to updates through the script authoring process.

Another issue is the choice of entries to be included in each stage of the platform development depending on the complexity of their phonological characteristics. As mentioned already in the section on grammar content definition, monomorphemic entries were agreed to be included in the first stage. In the next stages there is gradual provision for polymorphemic signs, compound signs, functional morphemes, syntactic use of non-manual elements, sequential and lastly simultaneous constructions of separate lexical signs, each stage to correspond with the level of linguistic research in GSL.

Besides this, the data available in GSL, when compared with data from written Greek, for example, are dauntingly scarce. Error correction mechanisms were sought after in order to assure reliability of results. Such back-up mechanisms are the use of approved dictionaries, the consultancy of Pedagogical Institute and the feedback from the Deaf Community, along with the continuing data from GSL linguistic research.

The most important technical problems include a solution for smooth transition between concurrent signs and fusion between handshapes so that neighboring signs in a sentence appear as naturally articulated as possible. In the context of the SYNENNOESE project, this issue has been tackled using a nice feature of the STEP engine, which at any time can return the setup of the kinematic chain for each arm. As a result, when the sign that is next in a sequence begins, the kinematic chain is transformed to the required position without having to take into account its setup in the final position of the previous sign. In general, this would be problematic in general purpose animation, since the h-anim standard itself does not impose any kinematic constraints; thus, random motion might result in physiologically impossible, puppet-like animation. In the case of signing though, almost all action takes place in the signing space in front of the signer and starting from the head down to the abdomen; in this context, there are no abrupt changes in the chain setup.

Another issue regarding the animation representation has to do with circular or wavy movement. Since the description follows the same concepts as keyframed motion, circular movement or generally, paths following a curve must be approximated with discrete key positions. This often results in losing the relative position of the hands, as shown in Figure 11, which depicts the final position for the sign ‘boat’; this sign should normally end up with palms touching, but since this process is designed with the position on the palm in mind, keeping hands together is not a straightforward task.

Figure 11: Problems in the GSL version of ‘boat’

In addition to this, a major factor in sign synthesis is the grammatical use of non-verbal signs, such as meaningful or spontaneous facial expression [12] and eye gaze, particularly when eye gaze has to follow the track of hand movements. Similar problems are anticipated on mouth movements on prosodic features of sign phonology. Mouthing the visible part of spoken Greek words will not be an issue for the project yet, but this, too is anticipated as a problem to deal with in the future, as all of the above non manually signed features are considered as internalized parts of GSL grammar. At the moment, the only possible non-manual sign components possible to animate with the STEP platform are gazing towards the signer’s moving hands and forward torso leaning, in the case of asking a question. In general, the STEP engine does not yet feature facial animation, so the project team is considering moving to a pure MPEG-4 [17] based platform. A nice example of maturing MPEG-4 synthetic technology is the VC named ‘Greta’ [5] which supports all required manual and non-manual components, including visemes, the visual counterpart of phonemes used for lip-reading, high-level facial expression, e.g. ‘surprise’ associated with an exclamation mark or simple facial and head movement, such as raising the eyebrows or tilting the head upwards to indicate negation (see Figure 12).

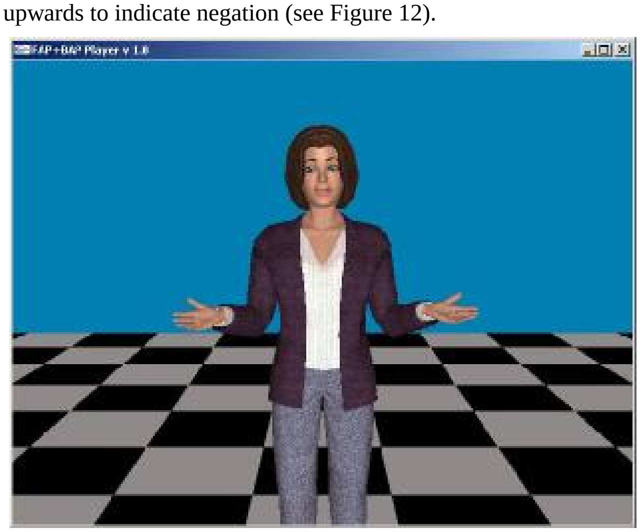

Figure 12: Greta displaying manual and non-manual signs

The ultimate challenge, as in all similar projects, remains the automatic translation of the language. It is still too difficult to produce acceptable sentences in the automatic translation of any language at the moment, even more so a minor, less researched language with no written tradition such as GSL. Realistically the teams involved in the SYNENNOESE project can expect as an optimum result the successful use of automatic translation mechanisms in GSL only in a restricted, sub-language oriented environment with predetermined semantic and syntactic characteristics.

8. CONCLUSION

In this paper we have described the underlying design principles and implementation of a web-based virtual signer software component, utilizing language resources suitable for young pupils. This component uses standard linguistic and virtual character technologies to provide semantic and syntactic information from written text and encode it with reusable and extensible sign notation representations. These representations are readable by the VC platform, making them suitable for teaching GSL and providing signed summaries of documents.

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