

Design and Implementation of a Greek Sign Language Synthesis System

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Abstract: - In this paper we present the design and implementation of a dynamic synthesis platform for Greek Sign Language (GSL). The platform utilizes standard virtual character animation and web3d technologies for the synthesis of sign sequences/streams, exploiting digital linguistic resources of both lexicon and grammar of GSL. The input to the platform is written Greek text from early elementary school textbooks, which is transformed into GSL and animated in a standard browser environment. 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.

Keywords: - Sign language synthesis, h-anim, virtual characters, avatars, animation, universal access, web 3d.

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. In this paper, we present the design and implementation of a platform that transforms selected lexical and syntactical phenomena of written Greek to GSL; this platform is put to use in an environment that offers students the possibility of systematic and structured learning of GSL, compatible with the principles that generally define systems of open and distant learning.

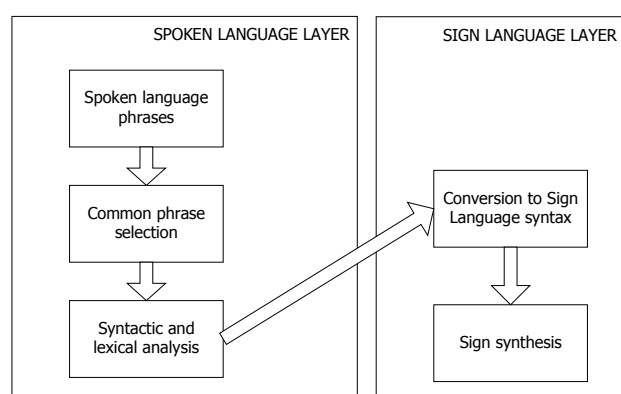


Figure 1: Overview of the proposed architecture

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.

2. LANGUAGE RESOURCES OF THE PLATFORM

In Greece there have been some serious attempts of lexicography in the recent past 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 [15] and Woll and Kyle [11], among many.

Greek sign language is analyzed to its linear and non-linear (simultaneous) components [13][5]. 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, num-

ber 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.

Research goes beyond a mere collection of glosses and moves further from many previous bilingual dictionaries of sign languages [2], into the domain of productive lexicon [16], 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.

2.1 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. 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. 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.

2.2 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 [14]. 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.

3. 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 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'. 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. 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.

4. 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, Theotos, SignSynth and eSIGN among them) that the platform uses as background.

H-anim [7] 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.

4.1 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) [7] 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 util-

ized 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 [6].

In the project, a syntactic parser decodes the structural patterns of written Greek and matches them into their equivalents in GSL [1]. 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 2 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 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.



Figure 2: An instance of ‘yt’ signing ‘donkey’

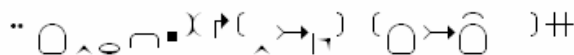


Figure 3: The HamNoSys sequence for the GSL version for ‘donkey’

The issue of eye gazing towards the signers palm, which could be considered as an end effector of a chain of links in robotics, during the animation of the sign was tackled as a combination of rotating vectors about an arbitrary axis and standard forward kinematics [17]. Thus given the rotating axis and the angle of each joint of the articulated body we can calculate the parameters required for the turn of the head.

5. IMPLICATIONS AND EXTENSIBILITY OF THE EDUCATIONAL PLATFORM

As an educational tool above all, the 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 the platform 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 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.

6. PROBLEMS AND LIMITATIONS

The main limitations of the study are described below. 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. 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.

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 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

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 [9]. 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 [12] based platform. A nice example of maturing MPEG-4 synthetic technology is the VC named 'Greta' [3] 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.

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 lan-

guage with no written tradition such as GSL. Realistically the teams involved in the 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.

7. CONCLUSION

In this paper we have described the design principles and implementation of a web-based virtual signer system, that 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.

8. ACKNOWLEDGMENTS

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