Menusigne: A Serious Game for Learning Sign Language Grammar

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Abstract

We present Menusigne, a serious game designed to help beginner students learn basic sign language grammar. At the first level, the game uses a generation grammar and a signing avatar to let the student create signed utterances from menu-based patterns; at higher levels, the game presents avatar-generated or human-produced signed utterances, and the student uses the menus to indicate the meaning. The intention is to introduce the students to the principles of sign language grammar, and the game in particular emphasises the crucial role played by non-manual (non-hand) movements. We describe an initial course for teaching basic Langue des Signes Française (French sign language) to French students.

Index Terms: CALL, sign language, serious games, grammar

1. Motivation and background

To a greater and greater degree, sign languages are becoming accepted as having the same status as conventional (aural/oral) languages, a trend that is paralleled by changes in their legal status. There are now many hearing people, not just relatives of Deaf people[1], who are interested in learning a sign language for reasons similar to those which might have led them to learn an aural/oral language: because they wish to understand Deaf culture (there is a rich body of recorded Deaf literature), because they want to broaden their mental horizons, or simply because they are curious. This is particularly the case in the US and Australia, where ASL and Auslan courses have been popular for some time; other countries are catching up.

The idea of providing CALL tools to support students is as natural for sign languages as it is for aural/oral languages and can be justified in similar terms. There are never enough language teachers. People do not want to pay for expensive tuition, or they cannot find time to attend classes. Conversation exchange (tandem learning) is unattractive for beginners, who feel that asking anyone to talk with them is an unwarranted imposition until they have acquired some basic fluency. In addition, some issues specific to sign language make CALL even more relevant than it is normally. A student can read an elementary Spanish textbook on the bus, and may well pick up useful grammar and vocabulary; reading a book on sign language is not nearly as useful, since sign languages have no accepted written form. Books for beginners tend to make heavy use of diagrams showing hand movements, but the problems with this approach are obvious. While signs are dynamic, paper is unfortunately static.

It is easy to see why CALL technology might be useful for students of sign language, but systems developed to date are rather simple, and basically amount to environments for showing and recording video clips [2], connecting teachers to students through the web [3], or in the best case performing word-for-word translation of an aural/oral language into a sign language [4]. In this paper, we describe an initial attempt to build a more ambitious type of application, where we have combined grammar-based language generation and signing avatar technology to construct a simple web-deployed game, "Menusigne", that helps beginner students practice understanding sign language[2]. Menusigne was built by reconfiguring resources from speech2sign [5], a platform wrapping software resources including the JASigning avatar [6, 7], which we have developed to support rapid creation of web-based speech to sign language translation applications. The game is freely available online. Instructions and a link to the live demo can be found at `http://www.issco.unige.ch/en/research/projects/MenusigneDoc/build/html/index.html`.

The rest of the paper is organised as follows. §2 presents an overview of the game from the user perspective. §3 briefly outlines speech2sign, and §4 describes how it was used to build the sign language game. §5 describes current content, and §6 initial reactions from users. The final section concludes and suggests further directions.

2. Overview of Menusigne

Menusigne is designed to help beginner students of Langue des Signes Française (LSF; French sign language) learn basic properties of the language. One obvious aspect is to teach a hundred or so signs, giving the student some initial vocabulary. More interestingly, it also aims to give the student a grounding in the elements of LSF grammar.

A common misconception concerning sign languages is that they are signed forms of spoken languages, with spoken words replaced by hand signs; so, in the present case, LSF would be in one-to-one correspondence with French. This view is entirely wrong. Sign languages have in virtually all cases a completely different syntax from the oral/aural language of the surrounding hearing community, and LSF syntax, in particular, is completely different from French syntax. It is also not true that sign languages are only rendered by hand signs. Movements of other parts of the body ("non-manual components") have integral importance for nearly all sign languages. Important examples include shaking and nodding the head, eye widening and narrowing, direction of eye gaze, raising and furrowing of the eyebrows, and shrugging of the shoulders. Thus, for example, the sentence "I am Swiss" would normally be rendered in French as *Je suis suisse*; in LSF, it is rendered as as a sequence of the two signs usually glossed as MOI (pointing to oneself) and SUISSE (making a cross over the left chest). This is already rather different from French; the differences become

[1] We follow the widely recognized convention of using the upper-cased word *Deaf* to describe members of the linguistic community of sign language users and, in contrast, the lower-cased word *deaf* to describe the audiological state of a hearing loss [1].

[2] "Menusigne" is pronounced in the French style, to rhyme with "limousine".

even clearer when we transform the simple declarative statement into a question or a negation. "Are you Swiss?" will in French be *Es-tu suisse?* or *Est-ce que tu es suisse?* In LSF, the sentence consists of a sequence of two signs glossed as TOI (pointing to the other partner) and SUISSE; the question marking is rendered using nonmanual elements, so the sign SUISSE is accompanied by lowering the head and slightly moving forward the right shoulder. Similarly, "I am not Swiss" is in French *Je ne suis pas suisse*, but in LSF is the three sign sequence glossed as MOI SUISSE PAS. Here, the sign PAS is a left-to-right movement of the raised forefinger, but the sentence is almost incomprehensible if the hand signs are not accompanied by a head-shake on the PAS.

The idea of the game is to introduce students to LSF vocabulary and grammar in a series of levels. Content is divided up into lessons, each of which contains a number of patterns presented in the L1, here French. Continuing the example from the previous paragraph, a simple pattern might be

```
je suis <NATIONALITY>
```

This is presented to the student as two words of fixed text followed by a menu. In the first level of the game, the student uses the menu to produce signed utterances. For example (Figure 1), they can select SUISSE as the value of `<NATIONALITY>` and press "Submit" to see signed LSF for MOI SUISSE produced by the JASigning avatar. Other lines in the figure show a related pattern for `je suis <OCCUPATION>` and patterns for single signs.

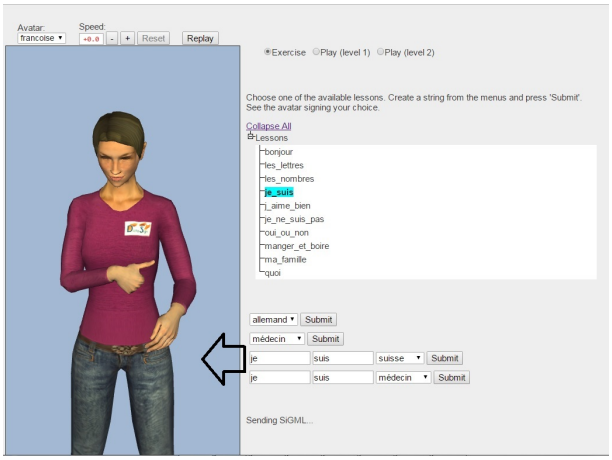

Figure 1: *First level of game: the student selects items from the menus, and presses "Submit" to create avatar-animated signing.*

When the student has experimented enough with the first level that they feel confident they know the vocabulary and grammar introduced, they can proceed to the second level, which turns the game around. This time, the app randomly creates avatar-based signing from the patterns, and the student responds by choosing from the menus to show that they have understood. For example, if the app signs MOI ETUDIANT ("I am a student"; ETUDIANT is signed by a gesture miming the student raising their hand in class), the student needs to use the fourth pattern, selecting ETUDIANT as the value of `<OCCUPATION>` (Figure 2).

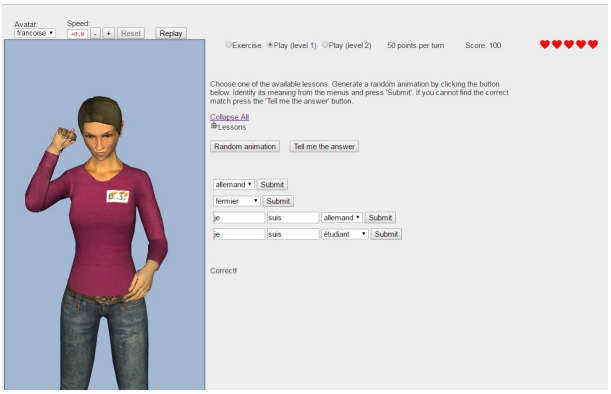

Figure 2: *Second level of game: the student presses "Random animation" to get avatar-animated signing, and then selects appropriate items from the menus to show they have understood.*

Finally, the student may progress to the third level. This is structurally like level 2, but with the important difference that the student does not watch the rather artificial avatar animations, but recorded videos of signing produced by human signers (Figure 3). Thus, in three moderately easy steps, the student has progressed to understanding simple but nonetheless real signed language.

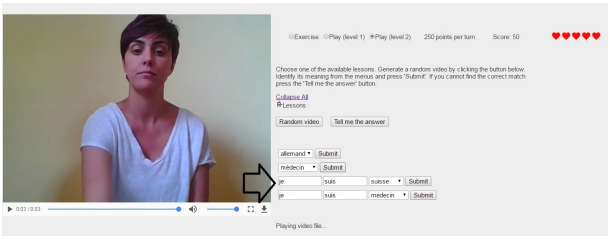

Figure 3: *Third level of game: the student presses "Random video" to get a video of real human signing, and then selects appropriate items from the menus to show they have understood.*

In the next two sections, we explain how the functionality described above has been implemented using resources taken from the speech2sign platform.

3. The speech2sign platform

The basic purpose of the speech2sign platform is to wrap resources for avatar-based production of sign language and grammar-based speech recognition in a way that makes it possible for people whose expertise is in linguistics rather than software engineering to create grammar-based speech-to-sign translation apps. Sign language animation is handled by the JASigning avatar [6, 7] and speech recognition by the commercial Nuance Recognizer platform. To avoid the necessity of installing various kinds of complex software, the platform is fully web-enabled. The details of how to write, upload, compile and run apps are presented in the online documentation [8].

For the app described here, speech recognition is irrelevant and we will only discuss the part of the system which has to do with sign language. There are three levels of representation, which correspond to the traditional notions of phonology, syn-

tax and semantics. Partly due to the special requirements of sign language, each of these is interpreted in a somewhat non-standard way. Starting at the bottom, the phonological level represents the simulated bodily movements used to create the signed language produced by the JASigning avatar. This level is encoded in SiGML [9], an XML-based representation based on the well-established Hamburg Notation System for Sign Languages (HamNoSys) [10]. A SiGLM form is a sequence of elements, each of which consists of two parts, which respectively represent the manual (hand) and non-manual components. There is thus an implicit assumption that non-manual activity is always synchronised with some manual activity, which is generally believed to be true for non-manual activities that serve linguistic functions. A problem is that non-manual activities cannot be extended across *several* manual activities in a straightforward way; however, workarounds are possible [11].

As one would expect from an essentially phonological formalism, SiGML is not convenient as a representation level for describing syntax. The level used for syntax, the "sign table", is an abstracted version of the SiGML. A sign table is a matrix with one column for each sign and one row for each channel of non-manual activity, modelling the basic structure of the SiGML representation but removing the phonological detail. Figure 4 shows the sign table for the two sign utterance realising the question "Are you Swiss?". The top row shows glosses for the signs, and the others the non-manual activity. The question marking is in the `head` and `shoulders` rows for `SUISSE`. Note also the `mouthing` line; (silent) mouthing is an important part of sign language. Sign tables are similar to the diagrams commonly used in books on sign language linguistics [12, 13].

```
gloss     TOI     SUISSE
head      Neutral Down
gaze      Neutral Neutral
shoulders Neutral HunchRightForward
mouthing  twe     suis
```

Figure 4: *Sign table for "Are you Swiss?" The non-manual part of the second sign expresses the question marking.*

The third level is for the semantic representation. In most formalisms, this will be some kind of structured expression like a lambda-calculus form. We have however found it convenient to make semantic representations simply another string; so for example the semantic representation we assign to "Are you Swiss?" might be

```
yn-question you swiss
```

The framework perhaps looks somewhat nonstandard, but the design choices are not random: the payoff for doing things this way is that the transformation rules can be made very simple. The transformation between the syntax and SiGML levels is specified by two tables; one maps glosses to HamNoSys strings, the other non-manual constants to SiGML non-manual forms. More interestingly, the mapping between the semantic and syntactic levels can be written as a set of rules in a version of Synchronised Context Free Grammar (SCFG; [14, 15]). The online documentation and the earlier papers referred to give more details; Figure 5 shows a simple example of how SCFG rules can be used to link together the semantic and syntactic levels for the running example.

```
Utterance
Source yn-question you $$nationality
gloss     TOI        $$nationality
head      Neutral    Down
gaze      Neutral    Neutral
shoulders Neutral    HunchRightForward
mouthing  twe        $$nationality
EndUtterance

TrPhrase
TrPhraseId $$nationality
Source    swiss
gloss     SUISSE
mouthing  suis
EndTrPhrase

(... more nationalities ...)
```

Figure 5: *Toy SCFG rules that map semantic expressions representing "Are you <Nationality>?" into sign table form.*

The framework contains one more construction, a mechanism for abstracting over rules. The top-level rule in Figure 5 translates the pattern exemplified by "Are you Swiss?". We could duplicate the rule and modify it slightly to create a similar rule for expressions like "Are you happy?", where the first element, as before, is a personal pronoun and the second an adjective expressing an emotional state. A more compact solution is to define a *rule template*, which can be instantiated to create both rules. Figure 6 illustrates in schematic form how this works.

```
Template ynq_pron_property PROPERTY
Source yn-question you PROPERTY
gloss     TOI        PROPERTY
head      Neutral    Down
gaze      Neutral    Neutral
shoulders Neutral    HunchRightForward
mouthing  twe        PROPERTY
EndTemplate

Apply ynq_pron_property "$$nationality"
Apply ynq_pron_property "$$emotional_state"

(... rules for $$nationality...)
(... rules for $$emotional_state...)
```

Figure 6: *Toy rule template that generalises over semantic expressions representing both "Are you <Nationality>?" and "Are you <EmotionalState>?"*

4. Implementing the game

Having introduced the speech2sign framework, we now describe how we used it to implement the sign language game. There are two separate sets of issues: defining the rules that map menu-based pattern content to sign language, and packaging the functionality as a usable web game.

4.1. Menu-based generation of sign language

In principle, the framework makes it straightforward to define the mapping from menu-based pattern to sign language. We let each menu choice create a piece of text at the semantic representation level, concatenate these pieces of text together to form a string, and provide flat rules like the ones shown in the preceding section, one per pattern, to map the strings produced by each pattern into the correct sign tables. For example, the top-level rule in Figure 5 can in a natural way be associated with a pattern which contains a menu for nationalities, mapping the sentences produced by the menu into a sign table in the way shown.

In practice, there are two problems which make the exercise less than trivial. First, we wish to have a large number of patterns, and if we implement a flat mapping rule for each one it will be difficult to keep the rules coherent with each other. This is in particular the case with the non-manual elements, which as we have seen are important to the syntax of sign language. Considerations of this kind dispose us towards the idea of writing a more "linguistic" grammar, where rules share common structure. This leads us to the second problem: in our group (and, we suspect, in many others working with sign language), the relevant expertise is divided between several people. People with a mainstream language technology background are comfortable writing the structured grammar, if they receive some input from a sign language expert. The sign language expert must however design the course, which will require frequent changes to the patterns and menus. The question is how to set things up so that responsibility can be cleanly divided.

The solution we have adopted is to define two separate levels of semantic representation, which call "interlingua" and "pattern". The complex set of structured rules, which is maintained by the language technology expert, maps the interlingua level to the sign table; at the level above, a large collection of flat rules, maintained by the sign language expert, maps the menu patterns to the interlingua. The first set of rules encode the linguistic structure, namely the relationship between abstract semantic representation and sign table. The second defines the pedagogical structure, namely the relationship between the patterns shown to the student and the abstract semantic structures they are associated with.

In §5, we describe the initial content we have created at these two levels.

4.2. User interface and gamification

The game is implemented using a standard client/server architecture. Most of the processing, in particular grammar-based generation and avatar-based synthesis, is carried out on remote servers. A thin HTML5/jQuery client wraps the main functionality. The user interface is illustrated in the screenshots from §2. The avatar pane includes controls which make it possible to change the number of frames per second (in effect playing the animation faster or slower), and rotating the character. This makes it possible to replay a piece of avatar signing, viewing it from several angles.

Gamification [16] has in recent years become extremely common in CALL, and forms an important part of many widely-used apps. (A prominent example is Duolingo). Menusigne is gamified using a simple score-and-leaderboard model. The student "practices" at the first level and "plays" at the second and third levels. At the "play" levels, each correct response scores points which are added to the running total for the current game. The number of points awarded per response depends on the difficulty of the lesson, which is determined by the total number of prompts available and the modality. Video prompts and lessons with more prompts give higher scores, the intention being to tempt the student out of their comfort zone. Every incorrect response loses a life. When the student has lost all their lives, the game is over. If the final score is high enough, it is posted on the leaderboard, an HTML page which is displayed inside the game. It is also externally accessible in case players should wish to link to it.

In later versions, we may make the gamification more elaborate. An obvious idea is to add a timer, with the time available to respond to a prompt decreasing as the student's score increases.

4.3. Videos

The example videos used at the third level of the game (cf. Figure 3) are created using an efficient workflow integrated into the grammar compilation process. At compile-time, two files are created. The first of these contains a list of declarations, one for each string that can be generated from the defined menus; a declaration line says that a video example should be created for the string in question. The intention is that the course designer will edit this file, retaining the examples they wish to use, and incorporate it into the grammar. The second file lists the declared video examples which have not yet been recorded. This is uploaded to a web tool which prompts the signer to create the actual videos [17].

5. Initial content

We have used our framework to build an initial course for teaching LSF to French-speaking hearing students. The content is designed to give the student a vocabulary of about 125 signs and a knowledge of basic LSF syntax. We describe the linguistic and pedagogical content.

5.1. Linguistic content

The linguistic content is encoded as a speech2sign SCFG grammar and lexicon which map interlingua-level text strings into LSF sign tables. The lexicon contains about 300 signs. Each sign is associated with a HamNoSys entry taken from a lexicon developed at LIMSI under the ViSiCAST project [18]; less than half of the signs are used in the initial course. The grammar provides basic coverage of letters (used for finger-spelling), numbers, pronouns, nouns, adjectives, verbs (transitive, intransitive, subcategorising for VP and null copula), YN-questions, WH-questions, negation and adverbs.

The grammar has a structure loosely based on GPSG [19]. There are three main groups of rules, for S, VP and NP; the interesting ones are in the S and VP groups. To summarise very briefly, the basic LSF word order is SOV. WH-questions, as is common for sign-languages, are formed by *right*-movement of the WH+ phrase. Thus for example "You drink beer" is the three sign sequence

```
TOI BIERE BOIRE
```

i.e. "You beer drink", while "What do you drink?" is the three sign sequence

```
TOI BOIRE QUOI-q
```

i.e. "You drink what-q", where the "-q" indicates simultaneous non-manual question movements of the head and shoulders.

Name	Grammar	Signs	Patterns	Videos	Example patterns
Greetings	Politeness	4	1	4	[GREETING]
Letters	Finger-spelling	28	3	8	[LETTER] My name is [FINGER-SPELLED-WORD]
Numbers	Numbers	27	6	18	[DIGIT] I am [TENS-NUMBER] [UNITS-NUMBER] years old
I am	Adjectives	15	4	16	I am [NATIONALITY] I am a [PROFESSION]
About me	Declarative sentences	27	10	21	I like [LOVABLE-THING] I like living in [FINGER-SPELLED-CITY]
Negation	Negated sentences	1	7	27	I don't like [LOVABLE-THING] I don't like living in [FINGER-SPELLED-CITY]
Questions	Yes-no questions	0	7	20	Do you like [LOVABLE-THING] Do you like living in [FINGER-SPELLED-CITY]
Food and drink	Requesting	16	11	18	I want [FOOD] please I like drinking [DRINK]
My family	Third-person subjects Possessives	7	7	39	My [FAMILY-MEMBER] is a [PROFESSION] My [FAMILY-MEMBER]'s name is [NAME]
What?	WH-questions	1	2	4	What do you [TRANSITIVE-VERB] What do you like to [TRANSITIVE-VERB]

Table 1: *Lessons in current sign language course. For each lesson, we list the grammatical constructions covered, the number of new signs introduced, the number of patterns and example videos provided, and one or two examples of patterns. French pattern content has been translated into English. Uppercase items in square brackets are menus.*

Following standard practice, the central rule-schema in the grammar is of the form

```
VP --> COMPS V
```

(Since the clausal word-order is verb-final, the COMPS naturally precede the V). S-level rules define declarative sentences, YN-questions and WH-questions; because of the unusual word-order, the rule for WH-questions with a wh+ question element is schematically of the form

```
S --> NP VP/NP NP:[wh+]
```

Here, the "slash category" `VP/NP` represents a VP with an NP gap. VPs and Vs are marked for negation and possession of a question-element.

In the present implementation, features and slash categories are rather unsatisfactorily implemented using the rule template mechanism described at the end of §3; the next version will use a proper feature system. We return to this point in the last section.

5.2. Pedagogical content

We have constructed a basic course in LSF grammar. The current version is divided into ten lessons, containing a total of 58 patterns and 169 example videos, and uses a vocabulary of 125 signs. The student is introduced in turn to politeness phrases, letters and finger-spelling, numbers up to 99, adjectives, simple declarative sentences, negation, yes-no questions, requesting expressions, possessives and WH-questions. Table 1 summarises the current lesson content.

6. Initial user reactions

The game is still in an early phase of testing. During this period, the main focus has been on using it to transfer some practical knowledge of sign language from Irene Strasly, the one member of the team who is a fluent signer, to other members, none of whom previously knew more than a handful of signs.

Using the content shown in Table 1, the first and second levels of the game already seem to work well. It is easy to progress through the course, watching signed animations at the first level and then practising responding to them at the second level; the gamified structure does a good job of encouraging the student to repeat examples enough times to start remembering them. The subjective experience is that these levels of the game are quite engaging and addictive.

For the third level, we are still experimenting with different strategies for creating the videos. Our initial plan was to record them in a "natural" way, i.e. without particular thought for the requirements of the game. This reflects the fact that signing styles vary a great deal, with little standardization, and it conforms to the common pedagogical principle of forcing students to confront this problem head-on from an early stage. Unfortunately, however, the subjective experience was that this strategy made the third level of the game too demanding. Even after watching a video several times, knowing what it meant, it was often hard to understand the signing. After discussing the issues, we created a revised version where the videos were recorded in a more careful manner; the signer used an exaggeratedly slow and explicit style and tried to render most utterances in the same way as the avatar. This does not stretch the student as much, but it seems more appropriate for the beginners who will be the main users of the course; the videos are now readily comprehensible, and the game is fun to play at the third level as well. We anticipate making further adjustments as we get more user feedback.

7. Summary and further directions

We have presented a simple web-deployed game for learning sign language. In contrast to previous work, the game focuses from the beginning on learning real sign language grammar, and in particular stresses the central importance of non-manual

movements. The avatar-based levels of the game clearly work well. The video-based level is still under development and can certainly be improved, but even the version we have now is quite usable.

The current system is only a sketchy prototype, so we are encouraged by the fact that it already seems to be a useful tool for learning sign language. Looking ahead, there are several easy ways to improve it. The first priority is to move to a grammar formalism more expressive than SCFG; although it has so far been possible to write the kinds of grammars we need in this framework, it is not good practice to simulate features using a template mechanism. We do not think it will be necessary to go as far as Marshall and Sáfár [20] and move to a full HPSG grammar, which would pose many technical problems; based on previous experience, a typed feature grammar, compiled down into SCFG form, should be sufficient. We can do this straightforwardly by integrating processing modules from our earlier Regulus project [21] into the compilation sequence of the current platform.

Once we have the extended grammar framework in place, the next step will be to create more content. This will be developed in the context of the newly established Swiss Competence Centre for Barrier-Free Communication[3], where our group plays a leading role. The first practical goal will be to give Deaf sign-language teachers the possibility of assigning more effective home exercises to students. Another potential target group is parents doing "baby-sign" (teaching sign language to very young children; `http://www.babysignlanguage.com/`). This will require development of suitably adapted content—baby-sign typically uses only a simplified form of sign language grammar—but should not be difficult to do.

Finally, an interesting idea is to crowdsource the recording of videos, which is the most labor-intensive part of the content-development process. Since our videos are already created using a web tool closely integrated with the platform (cf. §4.3), this is unchallenging to implement: all that is required is to add a control which allows the user to invoke the recording tool at the practice level, storing the resulting video together with metadata linking it to the sentence selected from the menus. The less obvious question is whether Deaf people will want to get involved. But it is an easy experiment to try, and if it works the payoff is very substantial.

8. Acknowledgements

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