Combining the user friendliness of SignWriting with the precision of linguistic parameters

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Abstract

This paper presents TraduSE, a Progressive Web Application designed to bridge the gap between the user-friendliness of SignWriting and the precision required for sign language processing tasks. Capturing sign language complexity is crucial, but parameter-based approaches often have a steep learning curve and require specialized tools. SignWriting offers a more accessible alternative for representing signs, and TraduSE addresses the challenge of making linguistically well-informed systems accessible to signers, learners, and researchers by using SignWriting as an input for a native sign language dictionary: the Spanish Sign Language Signary.

It does so by allowing users to upload or draw SignWriting images, which are recognized by an existing artificial vision pipeline. The SignWriting elements found are then converted into a parametric description, recovering along the way the 3D signing space information from the 2D SignWriting. Finally, the resulting parameters are used to search the Spanish Sign Language Signary. Fuzzy matching allows for error resilience and finding similar tokens, enabling users to locate signs even with incomplete or imprecise information. Search results are presented as videos and Spanish glosses, while also displaying and explaining the linguistic parameters, serving as a didactic tool.

Our approach not only provides a crucial bridge between visual sign representation and precise linguistic analysis, widening the reach of sign language research, but also demonstrates flexibility in handling the inherent fuzziness and potential errors in everyday language use and user input.

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CCS Concepts

• **Computing methodologies** → *Natural language processing*; *Computer vision*; Machine learning; • **Information systems** → Information retrieval; • **Human-centered computing** → *Accessibility*.

Keywords

Sign Language, SignWriting, Sign Language Dictionary

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1 Introduction

Sign languages are very complex at the phonetic level. This complexity arises, in no small part, from having many articulators (five fingers in both hands, but also the upper body and head) simultaneously operating. Gloss-based approaches use spoken language words to stand for signs as a whole, thus making them unable to capture the full detail of that complexity [22].

However, capturing that complexity is needed for any substantial processing of sign languages [7, 9, 12]. None of the sign languages that we know of are completely analytic, in the sense that utterances are composed by straight sequences of dictionary forms. Instead, they modify some of the components of the sign to indicate prosodic or pragmatic features, but also grammatical information such as agreement or tense: in other words, signs can be inflected. The linguistic tradition calls these components, however they are specified or classified, parameters [2].

Parameter-based approaches are necessary for most interesting tasks related to sign language processing. Avatar generation needs to inflect signs according to context, lest the sign become robotic to the point of unintelligibility [10]. Translation, in order to capture the actual meaning of signing, needs to pay attention to inflected features that alter this meaning significantly [1, 15]. Even lexicographical approaches cannot forgo parameters in their methodology. For a corpus to be maximally useful to a researcher, signs need to be indexable by parameter, in order to be able to find similar signs, variations in actual production, or other phenomena [3, 5].

Even user-oriented dictionaries need this information. When users find unknown signs in the wild, they cannot rely on the spoken language equivalent to find the translation, but rather need to be able to search by the actual observed realization. This is also fundamental in order for users to be able to find dictionary forms of inflected words they might see, or to account for the inevitable imprecisions and errors that might occur. For example, if someone sees the sign "TO ASK" performed in a particular conversational context, it might not share the same space and orientation as the form recorded in the dictionary. If users can search via fine-grained parameters, they will be able to find the sign present in the dictionary, which might have a different presentation but still the same lexical identity and translation.

In spite of this, parametric representations of sign languages suffer from a steep learning curve, requiring some effort to understand and use. In some cases, they also require non-trivial computer tooling to be usable, be it either in the form of specialized typographies, input systems or complex coding infrastructure [22]. This is not only true for motivated actors like students or researchers, but especially so for native signers, who might not even see the need to engage with the whole paradigm. Nevertheless, an alternative exists in SignWriting [19], an image-based transcription system that captures signing in a visual and iconic way.

SignWriting presents an opportunity for making linguistically well-informed systems more accessible to signers, learners and researchers. It still codifies the material representation of signs, meaning parameters are actually there and not glossed over, but it is arguably easier and more approachable for non-trained users to produce and consume. In this paper, we present TraduSE: a project which aims to combine the ease of use of SignWriting as input system with the power of a parametric sign dictionary.

Using SignWriting also presents advantages compared to video processing approaches [4, 23]. These approaches require the user to have an adequate video capture setup (full body, clear lighting) and to provide their personal image. Video is also more expensive to process than images, and furthermore presents a complete realization of the form, not allowing searches by parts or components, or the finding of uninflected forms.

TraduSE is a progressive web application, usable in computers, smartphones and most such devices. It allows users to upload images of SignWriting, or to draw them themselves on their device. It then analyzes the SignWriting, extracting the parameters, using them to search for signs in the Spanish Sign Language Signary. Results are presented to users as videos and Spanish glosses, but also the parameters are present and explained, serving as a gentle introduction and teaser for the more linguistically oriented user.

The rest of the paper is structured as follows. In section 2 we present some background on the state of the question, while section 3 explicates our approach and developed application. Section 4 draws some conclusions about the usefulness of our work, and discusses some limitations and possible future work.

2 Background

2.1 SignWriting

SignWriting is a logographic transcription system, in which signs are recorded as two-dimensional graphical abstractions of the realization in signing space. Hands are represented via highly iconic but standardized depictions of their shapes, as well as body parts and facial expressions. Movement, orientation and location in 3D space are captured in the page by placing the articulator icons in the equivalent relative positions, using arrows following the intended trajectory, and rotating symbols in an intuitive way. The highly visual nature of SignWriting, as well as its closeness to the signed form, make it a candidate for a more intuitive and easy to learn representation of sign languages [6, 11].

In our experience, it is also the preferred transcription system in our signing community, though it must be noted that this varies wildly in different regions and even in ours it is still a small fraction of signers which know of it and can use it.

In terms of processing, the complexity of SignWriting lies in the fact that some graphemes must be interpreted in relation to other graphemes present in the context. By virtue of this, one grapheme may simultaneously encode several parameters, so a computational system dealing with this kind of representations should extract different pieces of information from a single graphical unit.

Additionally, some signs may have more than one possible SignWriting representation. This is especially the case when it comes to hand orientation: the same orientation may be illustrated with the hand on the vertical plane (eg. the palm facing the person who is signing) or on the horizontal plane (the edge of the hand as though viewed from above). This lack of strict correspondence must be addressed to ensure computational efficiency.

2.2 Spanish Sign Language Signary

The Spanish Sign Language Signary (*Signario de Lengua de Signos Española*, https://griffos.filol.ucm.es/signario) is a dictionary that encodes signs using a transcription system called Signotation. This consists of a linear sequence of keyboard-accessible characters—letters, digits, and common symbols—that captures the different aspects of the phonological representation of signs (including hand configuration, orientation, location, contact, different types of movements, bimanuality, and repetitions). In addition, it has the advantage that each character or combination of characters corresponds to a single possible interpretation, and vice versa [14].

In this way, parameterization is an inherent part of the Signary, allowing signs to be searched for by filtering on various aspects of their material realization. For example, it is useful for searching for a sign when its equivalent meaning in spoken language is unknown. Furthermore, the Signary is based on the perspective of the sign language, which also means that the selection of entries included has been made according to the lexical units of sign language and not their spoken equivalents [13].

Due to the progressive filtering and fuzzy search approach, it is possible to find signs even when not all the details of their realization are known, either due to errors in production, perception, or just memory on the part of the searcher. This approach allows users to find the dictionary form of a word, even when searching for a form in which some parameters have changed due to inflection.

Unlike other sign language dictionaries, the Spanish Sign Language Signary offers the possibility of searching in the sign-to-spoken direction, which can be of great help to native Spanish Sign Language speakers, since this language is the starting point. It is also useful for interpreters, students, and scholars of Spanish Sign Language in general.

3 Methodology

In order to use SignWriting to search for signs in the Signary, a three-step process is required. First, the input logogram must be processed, and the constituent elements extracted. These are already a parametric representation of signs, although one centered on their pictorial representation, not on the linguistic features we need for their further processing. Therefore, we must convert the parameters to a more phonological codification, in our case the transcription system that the dictionary uses. Finally, signs must be searched in the dictionary according to these parameters in an intelligent and useful way.

3.1 SignWriting recognition

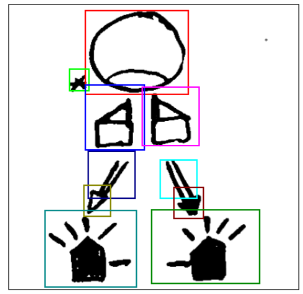
SignWriting recognition is the process of turning images depicting SignWriting logograms into structured information. But why not use an existing SignWriting codification, such as that in SWML or Unicode [18, 20, 21]? The reasons are twofold.

On one hand, using a codified SignWriting representation as input to the whole system would defeat the point of using SignWriting at all. The advantages that this transcription system provides are its ease of use and its freedom and flexibility. Using a codified SignWriting system requires specialized tools and software, while using images just requires that the user knows the system well enough to produce, using pen and paper or finger on screen, reasonable approximations of the sign.

On the other hand, codified SignWriting systems are not expressive and detailed enough to be useful for our purposes. As detailed in [17], in order to do useful processing the full detailed parameters need to be extracted. SignWriting codifies linguistic information in rotation and fill, for example, which SWML does not provide but as a full package. Interestingly, the Unicode chars for SignWriting do provide this information in a somewhat analytic way, but unfortunately they do not seem to be in use at all, and the structuring is not enough.

Using the tools from [16], we can extract a rather more convenient representation. The deep learning pipeline in that paper is able to separate the different graphemes in a logogram, and return their multi-featured linguistic representation. This includes, for example, splitting arrow heads from the movement segments in order to distinguish dominant vs non-dominant hands or repetitions. Hand graphemes are analyzed into shape, rotation, fill and reflection values, giving the information needed to be able to reconstruct the underlying linguistic parameters. The full processing is encapsulated in a web API named VisSE (visualizing SignWriting).

In figure 1, an example of this processing can be seen. The parameters of SignWriting, which encode signing in a graphical, 2D way, have been extracted and structured into computational codes that can be further processed.



	CLASS	SHAPE	VAR	ROT	REF
	HEAD	chin	VAR	ROT	REF
	DIAC	touch	VAR	ROT	REF
	HAND	picamr+	w	E	n
	HAND	picamr+	w	W	y
	STEM	d	VAR	SE	REF
	ARRO	b	VAR	SE	REF
	HAND	PICAM	hb	N	y
	STEM	d	VAR	NE	REF
	ARRO	w	VAR	SW	REF
	HAND	PICAM	hb	N	n

Figure 1: Artificial vision analysis of SignWriting graphemes. In this visual depiction, the structured information captured by the automatic recognition process is shown. Atomic meaning-carrying graphemes are located and demarcated, and this meaning provided in the form of multiple tags (in the table to the right).

3.2 Translation to parameters

While the information extracted from the image in the previous step codifies the linguistic information present in the logogram, it is only halfway through what we need. It is still bound to the two-dimensional abstraction of signing space that SignWriting provides, and organized into bundles corresponding to graphemes rather than articulators. For our purpose of searching the Spanish Sign Language Signary, parameters need to be converted back to 3D space and organized in the way it expects.

To achieve this, we have implemented a rule-based system. This system codifies the expert knowledge implicit in both the VisSE SignWriting representation and the Signary parametric description, and translates between them.

A small part of this process is straightforward. Hand shapes are already codified in compatible and very similar notations both for VisSE and the Signary, so no modification is required. Some unchanging graphemes, like Head pictograms or dynamics-representing marks, can be translated by a lookup of what each grapheme means. This is not straightforward, since there is not a one-to-one correspondence, and some information is codified in different ways. For example, types of contact in SignWriting present an ample variety of graphemes to codify them, while in Signotation the same symbol is used (*) but attention is paid as to when in the Signotation string the contact occurs. The resulting system of rules can be consulted in the source code, since it is all freely available online[1].

Somewhat more complex is the translation of the SignWriting 2D space to "real" 3D signing space.

As detailed in section 2, SignWriting uses a number of techniques to precisely capture the three-dimensional location and orientation of articulators and their movements. Graphemes can be geometrically transformed, in a projection of signing space to the page, either via rotation or reflection. But they can also be altered, using the fill color or pattern, or using slightly different typographical variations. For example, hands with "detached" fingers are oriented in the horizontal plane, or movements with double arrow stems are parallel to the wall. SignWriting relies on human intuition and

[1] https://github.com/NILGroup/tfg-2425-signos

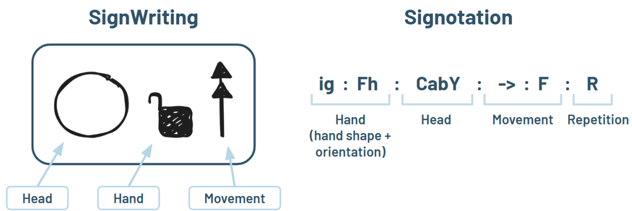


Figure 2: SignWriting and Signotation representations of the same sign (TEACHER, "profesor" in Spanish). The hand has the index bent in a hook, and is facing forward (black fill in SignWriting, "F" in signotation orientation). It is near the head, and the movement to the front is repeated twice.

understanding to pick the correct choice, so in order to reverse the projection, something beyond a dictionary lookup is needed. A system of expert rules in TraduSE takes the different graphical properties, as well as the relevant graphemes involved in a spatial compound (for example, the possible multiple arrow heads for a movement) and converts it back to 3D information, encoded in Signotation.

As a last comment, suprasegmental information in SignWriting must be also captured and translated. The most important of these is repetition, codified in SignWriting by repeating some of the graphemes (sometimes arrow heads, sometimes contact symbols, sometimes the full arrow) but parametrically represented in signotation with just an R.

While this is not the whole system, it is quite a comprehensive account. An example of the translation process can be seen in figure 2. Beyond its use for our concrete pipeline as described here, we believe it may be useful as inspiration or starting point for similar approaches which want to use SignWriting as a gentler input layer to their system.

3.3 Fuzzy search

After the translation step explained in the above, the result we obtain is a string of Signotation parameters, though not necessarily a correct Signotation representation of the input SignWriting. There are some edge cases in the translation that have not been taken into account. Additionally, the signotation strings obtained are extracted from each grapheme, but there is no process for interpreting the compositional meaning of the logogram, which would require more sophisticated processing than what time allowed.

Nonetheless, for simple cases we obtain a full parametric representation of the sign, and for the rest a significant proportion of relevant information is captured. This information can be enough to identify a sign in a dictionary, or at least narrow down the search so that users can find what they are looking for in the small set of results. To achieve this, a document search system capable of dealing with partial information is needed.

We use ElasticSearch [8], an industrial-strength software package for storing and retrieving documents. Usually, the documents stored in this software are long form and written in the words of a spoken language, the most common of which have built-in support; for less common languages or needs, ElasticSearch allows writing custom tokenizers. Since our parametric representation, Signotation, is based on ASCII characters, it is straightforward enough to make it work with ElasticSearch: the segments in Signotation are separated with colons, so splitting the strings on each of them provides the search engine with linguistically relevant chunks to use. We also enable trigram search and some fuzzy matching, allowing the engine to find similar tokens, contributing to the error resiliency of the system.

3.4 Progressive web app

The pipeline explained above was put together into a Progressive Web App (PWA), available at https://holstein.fdi.ucm.es/tfg/2425/traduse. A capture of its operation can be seen in figure 3. A PWA is an application built with web technologies that offers a user experience similar to that of a native application. Developing native applications can be costly and time-consuming because they require specific versions for different operating systems like Android and iOS. PWAs overcome this by running in a browser, making them compatible across various operating systems. Using React and TailwindCSS, the app was made responsive, meaning the interface can adapt to the dimensions of the user's device.

Apart from the responsiveness and ease of use of being available in most user devices, the interface brings together a number of features. It has two separate modes of operation. The first one is for uploading images: for example, photographs of some SignWriting example found in a paper dictionary, or a scan of a quickly recorded SignWriting transcription of a sign observed live. This can help students when self-studying or reviewing existing literature which uses SignWriting. The second mode allows hand drawing the logogram, either with the finger, stylus or whatever means the user's device provides. This can help find signs by quickly sketching the SignWriting representation of any features that can be recognized. Since SignWriting is very iconic, this process is intended to be quick, and the nature of the pipeline makes it error-resistant. For example, as mentioned above, users might see someone signing "TO ASK". They might not be able to observe the full detail of the sign, but quickly sketch the hand configuration and movement perceived. They will then receive a list of possible signs, including video and Spanish gloss, allowing them to find the one that was actually performed.

The application is also designed with didactic use in mind. Some SignWriting examples are provided, to familiarize newcomers with the application use. The parametric representation of signs is also always present, to help interested parties improve their understanding of it. If users click on the signotation segments, Spanish language descriptions of the meaning of the parameters are presented. It is however not presented in an obstructive way nor required for the correct use of the search function.

4 Discussion

Our main goal in developing this application was providing a SignWriting interface to the Spanish Sign Language Signary. SignWriting is transcription system in use in our community, even if mostly by more linguistically-oriented signers; it is also used as a teaching tool in sign language courses. By creating a translation module from SignWriting to our choice of linguistic parameters, we can bridge

Figure 3: Capture of the application. To the left, the hand drawn SignWriting is shown. The top shows the extracted parameters, and the list of videos to the right shows the possible matching signs in the Spanish Sign Language Signary. These are as TEACHER ("profesor" in spanish), the first one and actual translation, but also SPECIAL-EDUCATION or STUDENT, relevant partial matches of the search.

the gap between our research and many possible beneficiaries of it. SignWriting is also purportedly more user friendly and approachable, and maybe closer to the very visual way of thinking about their language in the signing community. It may be unfortunate, but linguistic parameters and "codes" tend to be off-putting and scary for the common user.

But besides this bridge, that widens the reach of our research and developments, our pipeline has an additional very interesting property: it is flexible and can deal with the fuzziness of language in its everyday use.

This is thanks to the "problem" that all the steps in the pipeline are susceptible to errors: the artificial vision component might not find some of the graphemes, or make mistakes in their classification. The translation step cannot deal with the more complex uses of SignWriting, and might probably never be able to translate some of the edge cases. Finally, there may be errors in the dictionary, be them omissions or maybe differences in interpretation. By using an analytic framework, separating components into individual meaning-carrying units, our system is resistant to small errors and can recover useful information even given input errors.

This error resistance is not only useful to overcome the technical limitations in the software components. It is also useful in order to handle erroneous or incomplete user input. Users might not have a precise, complete or even fully correct knowledge of the signs they are searching for, but any approximation they produce can be consumed by the system in order to retrieve possible matches. This is especially useful for a dictionary, but we believe it might also be useful for other sign language linguistic systems which are intended to be used by non-specialists.

A final useful contribution from this work is one that maybe seems not so obvious, or scientifically interesting. For the pipeline we have presented to work smoothly, the pre-existing components (SignWriting recognition system, parametric dictionary) needed to be made usable and accessible from third parties. On the input side, this meant containerizing VisSE and augmenting its API. Thanks to this, now it's easier to deploy without having to wrangle dependencies and AI libraries, and the artifact is freely available online[2]. At the other end, the Signary needed an API so that its results were not only available from its own web interface, but also from connecting third parties. While all this seems more of a technical and implementation detail, often academic works sit unmaintained and become unusable due to difficult integration, so we believe that the work done here to make these systems more interoperable is also valuable. Source code can be freely accessed online at https://github.com/NILGroup/tfg-2425-signos.

4.1 Limitations and future work

Due to the time-constrained nature of this project as bachelor thesis, some straightforward work remains to be done. Currently, the translation system can get confused when many hands are detected in an input image. SignWriting relies on the human intuition to be able to know which hands are right and which are left, which ones are at the onset of the movement and which ones at the end, etc. We decided to warn the user and not produce any translation in these cases, but some further work will allow many hands to be processed. Key for this is the fact that a completely correct parametric representation is not needed, but providing the hand descriptions to the search engine will help it find the signs even without knowing which is which. There are some more SignWriting details that we have found out of scope for now, and may or may not be able to tackle in the future.

Again, due to the nature of this project, the results needed to be a self-contained application, but we want to integrate more tightly it with the Spanish Sign Language Signary so it is readily available to users. At the same time, the precision and fuzziness of the search component will probably benefit from some adjustment and fine-tuning. Regarding the interface, perhaps adding some point-and-drag elements will help users who are not so familiar with SignWriting, while retaining the expressivity of freehand drawing, for example, for movement transcription.

Finally, an evaluation based on real user interaction with the system will likely provide valuable improvement avenues and feedback. It will probably be interesting to examine usage patterns in the different available search inputs in the Signary, to ascertain not only whether SignWriting actually proves to be more user-friendly, but also to check effects on users' choice of queries to the system based on the input system provided to them.

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