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A different description of orientation in sign languages

Una descripción distinta de la orientación en las lenguas de signos

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Abstract: Sign languages are a very interesting object of linguistic study, posing challenges not present in oral languages. One of these challenges is describing and transcribing the internal structure of the language in a way that is adequate to its characteristics but also compatible with existing linguistic practice. The phonology of sign languages is of special interest. We focus on one phonological feature: that of hand orientation. We propose an interpretation and description system that better captures underlying meaning and structure, and that is more appropriate for its formal and computational treatment.
Keywords: Sign language, transcription, orientation, phonology

Resumen: Las lenguas de signos son un objeto de estudio lingüístico de gran interés. Presentan retos y dificultades distintos a los de las lenguas orales, como describir y transcribir la estructura interna de la lengua de una manera adecuada a sus características únicas pero también compatible con la práctica lingüística actual. El caso de la fonología es especialmente interesante. Nos centramos en un rasgo fonológico concreto: la orientación de la mano. Proponemos una interpretación y un sistema de descripción que capturan mejor la semántica y la estructura subyacente, y que además permiten un tratamiento formal y computacional más adecuado.
Palabras clave: Lengua de signos, transcripción, orientación, fonología

1 Introduction

Recently, sign languages are of increasing interest for the linguistic community, as well as society in general. As languages for the Deaf and hearing-impaired, social goals of accessibility and equal opportunity make the general public more aware of their existence and overall characteristics. From a scientific point of view, sign languages completely ignore sound –for obvious reasons– and their essentially multimodal nature presents challenges and opportunities in their understanding and formal description. The fact that they are natural languages, evolved within their communities by natural processes, also make these linguistic inquiries important from a general linguistic or psycho-linguistic point of view. Discoveries and advances made in sign language studies may bring along advances for language in general and the language capacity in humans. See Senghas and Coppola (2001) for an interesting example.

Nowadays, linguistics rely heavily on computers, and the digital treatment of linguistic data. Formal accounts of language are expected to be computationally treatable, even if only in theory. And the engineering side of the issue is of ever increasing importance, the ability of computers to understand and process natural language gaining both efficiency and public awareness every year. However, sign languages present a sizeable challenge in this department. Most of NLP technologies and algorithms are based on the assumption that there exists an accurate, or at least rea-

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sonable, representation of language using sequences of characters, which is not (yet) true for sign language.

Much existing work to computational processing of sign languages takes a word-based approach. It works as in languages where the written form of a word has moderate to low relation to the oral form, like those with ideographic writing (Chinese, Japanese), or, maybe not so extremely, English. The idea is to observe the physical realization of a word (or sign) and transcribe it to a character-based representation, see Starner, Weaver, and Pentland (1998) or Karayilan and Kiliç (2017). In the case of sign languages, this approach is very limited. The visual signal is more complex than the audible one, and this also allows for information to sometimes appear in disjoint, parallel manifestations (think of two hands working together to perform a single sign). Therefore, these approaches are often limited to the recognition of a fixed vocabulary of signs, and eschew any structure or inflection they might present.

Signs have a very rich inner complexity. This structure, which can sometimes parallel that of oral languages, has not only descriptive importance, but is often lexically or grammatically significant. Even at the phonological level, sign languages are organized in a manner not immediately equivalent to that of oral ones. In the literature, signs are classified phonologically using a number of features, including location, shape, contact, movement, and orientation (Liddell and Johnson, 1989). These describe the configuration and movement of the hand in space, and while there are additional non-manual features of sign language, the hands are the most salient and important elements.

In this paper we focus on orientation. Orientation is a simple but essential feature of sign language at the phonological level. It indicates the rotation of the hand as a whole, without regard for its shape and the individual positions of the fingers. Some examples can be seen in Figure 1, along with its "traditional" notation in SignWriting. Orientation is essential in the sense that it is necessary, it cannot be omitted and it often contributes to meaning in a significant way. There exist minimal pairs that are distinguished only by orientation: an example from Spanish Sign Language[1] is that of the number "1", the letter "g" in fingerspelling, and the sign "today"

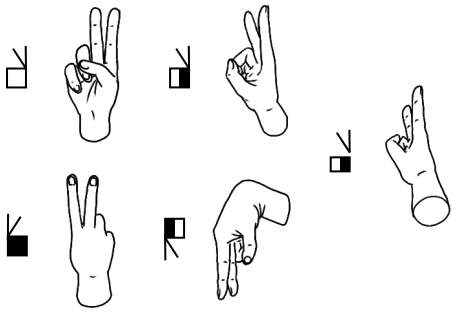

Figure 1: Some orientations of the hand, with the shape of the number two. The SignWriting representation is given to the left of each drawing

(Herrero Blanco, 2009). As a feature, orientation can be assimilated, for example in the formation of compound words, and is subject to substitution in speech errors (Sandler and Lillo-Martin, 2006, Chap. 10).

However, the "traditional" description of orientation in sign language is, to us, not sufficient. It presents a number of problems, both from a linguistic and a computational point of view. In this paper, we present a different description of the feature of orientation, which provides some improvements in its understanding and how it contributes to meaning. Our proposal is also very computer-friendly, meaning its formalization and computational treatment are also strong points for its adoption. We accompany our theoretical analysis with a proposed notation system, which allows its better input and storage in digital media.

In Section 2 we present the SignWriting approach. In Section 3, our theoretical interpretation is explicated, while Section 4 presents the provisional notation for its representation. Finally, in Section 5 we draw some conclusions and discuss some possible extensions of this work.

2 SignWriting approach

Existing approaches for the description of orientation tend to look at the hand by itself, and observe how it is rotated. In SignWrit-

[1]Throughout this article, we use drawings of hands in space to illustrate some points. Most of the time, these hand configurations are not signs, and we believe that the feature under discussion is "low-level" enough that our proposal is language-independent. However, most examples come from Spanish Sign Language, and there may be language-dependendent phonotactic constraints we are unaware of.

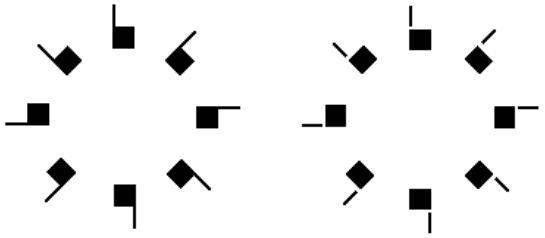

Figure 2: Eight possible rotations on the vertical plane and on the horizontal plane, respectively

Figure 3: The palm facing the signer, with the fingers pointing left. These are equivalent SignWriting transcriptions for the same handshape and orientation. If the signer looks forward, it is a white located on the vertical plane. If the gaze is directed from top down, it can also be interpreted as a black-white situated on the horizontal plane

ing (Sutton, 2009), a widely spread notation system, a color code is used. White identifies the palm of the hand, black the reverse. This allows us to distinguish signs by noting which side of the hand the signer can see, and if both, the exact profile is determined by placing them in an iconic way that transcribes how the hand is seen. Additionally, SignWriting makes a difference between hand configurations located on the vertical plane and those on the horizontal plane (by convention, the latter case is represented with the fingers detached from the hand root). Furthermore, rotation is allowed on each of those planes (Figure 2). In sum, the hand can rotate almost freely in the X, Y and Z axes and, in order to fully specify orientation, SignWriting approaches usually draw the hand in an iconic sign space, which has its own tricks to transform the three dimensions into two.

This approach is useful in that it is enough to fully capture the possible realizations, and its iconicity makes it easily understandable and transparent. However, it has some limitations. First, it is tied to the graphical representation. A more abstract approach that can be transcribed with Latin characters would be useful, especially for enabling computational treatment.

Second, sometimes it is possible to represent the exact same handshape and orientation in two different ways, just depending on whether the perspective is from the vertical or the horizontal plane (both configurations in Figure 3 are identical). This lack of biunivocity in the transcription unnecessarily increases computational complexity, inasmuch as it requires to store more configurations, or to add a layer of interpretation to undo the duplication. From the viewpoint of generation, it yields underspecification of expected results.

It should also be noted that the graphical approach does not capture the underlying meaning structure properly. It is too tied to the realization, which makes it cumbersome in some cases.

For example, in Spanish Sign Language, there is a sign with the general meaning of "to ask". It is a simple sign, with the hand in the shape of a "Q"[2], and two repetitions of a slight movement whose direction depends on the identity of the grammatical subject and the (indirect) object. For the signer, this is not a complication, but rather makes a lot of sense. The sign "comes from" the asker, and "goes to" the one being asked. But it is not only the movement that follows this pattern; the orientation does too. The "Q" hand is pointed horizontally, and the finger tips point toward the askee, as in Figure 4.

This means that for "I ask you", the sign is black, and for "you ask me", it is white. One could say that it is normal for inflected forms to have to be listed separately, but what with "I ask him", or "She asks you"? Orientation is more subtle here, requiring the full expressive power of the graphical description to be transcribed, and then, only capturing individual utterances.

It is clear that in the "ask" sign itself the syntactic spaces of subject and object are embedded in the orientation of the hand. The following proposal for transcription of orientation can capture this, and has some additional advantages.

While other approaches for sign language notation are not as heavily reliant on the

[2]The shape of the letter "Q" in the Spanish Sign Language fingerspelling alphabet. It is a configuration of all the fingers flexed at the first falanx, and the thumb lying against their tip. A drawing can be seen in Figure 4.

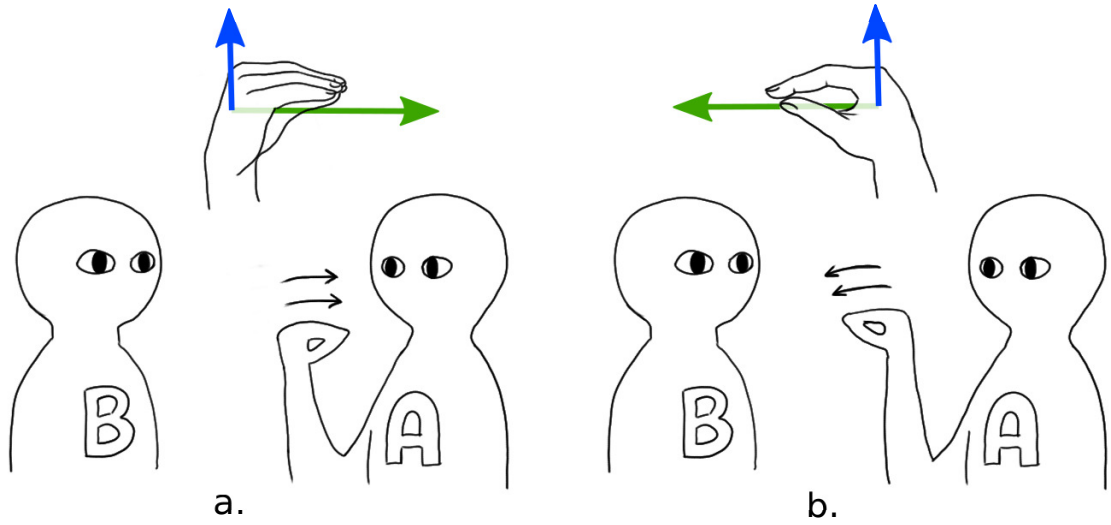

Figure 4: Two situations, where A is talking to B. In a., A says "You-Ask-I", in b., A says "I-Ask-You". This sign, for the verb "to ask" can then be understood as inflecting, and having different forms with different orientation. In our proposal, this can be succintly expressed by saying that the palmar vector is oriented from the subject to the (indirect) object of the verb

picture or drawing of the hand orientation, similar criticism as with SignWriting can be made. In the HamNoSys notation system (Hanke, 2004), features are transcribed separately, but still with pictograms and symbols. Hand orientation is also treated holistically and by itself, with no reference to space, so the issues with the "ask" sign remain. In Stokoe notation (Stokoe, Casterline, and Croneberg, 1976), a linguistically motivated transcription system, orientation is described with a fixed set of symbols, again limiting the expression of the inner structure.

3 Proposed interpretation

Barring physical constraints that limit the range somewhat, the hand has free rotation in space, being able to rotate around the three directions. But the palm is basically flat and, in order to describe the position and orientation of a flat object in a 3D space, mathematically it is enough with two vectors. We can ignore the fingers for now, since their position is taken into account by the hand shape, a different feature.

3.1 Hand vectors

The hand has a number of natural vectors that we can identify. In this approach, the three most natural and useful are selected. The first two, both of equal and great importance, are the "distal" and "palmar" vectors.

The distal vector is the one that goes from the wrist to the fingers, parallel to the palm. It points to where the index finger points when fully extended.

The palmar vector is perpendicular to the distal one, and in general perpendicular to the plane of the palm itself. It points to the inside of the closed hand, or what we as humans generally consider the palm to "point" to.

The lateral vector is perpendicular to the previous two. It points where the thumb points when the hand is open or, for example, in the thumbs-up gesture. In Figure 5 and in Figure 6, the three vectors are represented in a few different situations.

Since the left hand is a mirror image of the right hand, if the orientation of any two vectors is shared between both hands, the respective third vectors will point opposite to each other. For example, if we assume unit vectors and we take the cross product of distal and palmar, it will be equal to the lateral vector for the right hand, and opposite to it for the left hand:

$$\overrightarrow{distal} \times \overrightarrow{palmar} = \begin{cases} \overrightarrow{lateral} & \text{right hand} \\ -\overrightarrow{lateral} & \text{left hand} \end{cases}$$

But if two vectors are enough to describe the orientation, why define three? The mathematical answer is that this way we may fully describe our variation space (three dimen-

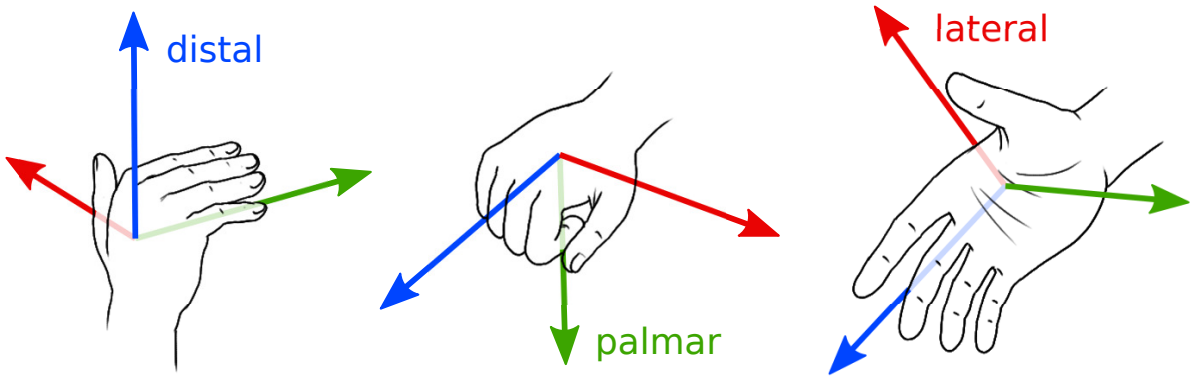

Figure 5: The "hand vectors" we propose to use for describing orientation. The distal vector points in the direction of the extended fingers, the palmar one in the direction of the palm, and the lateral one towards the extended thumb. Notice that flexion of the fingers does not affect the direction of the vectors

sions, three vectors). The linguistic answer is that it allows us to describe some signs in a more succint and semantic way.

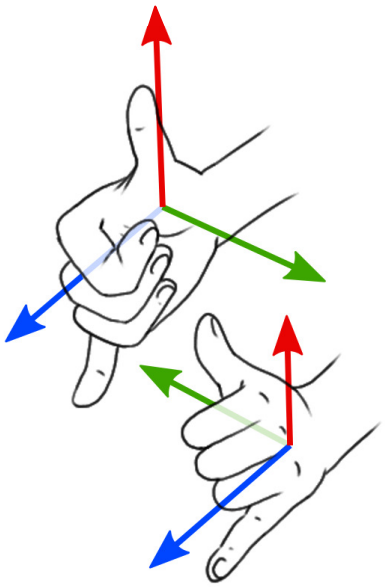

Figure 6: Hand vectors in the two hands. Notice that the vector systems are not equivalent, one can not be rotated to match the other

3.2 Underspecification

For most signs, specifying the distal and palmar vectors will be enough. Together, they both solve the spatial rotation of the hand and the black/white distinction, in a natural way. Numbers, for example, are distal "up" and palmar "front" (see Figure 1 again). In Spanish Sign Language, some numbers are palmar "back", however. This distinction is as easy to make with this approach as with the white/black one. Furthermore, the distal vector may be left out in some informal accounts, since it is the most natural when producing cardinal numbers (provided they are not integrated with some other morpheme). The only salient information would in that case be the distinction between palmar "front" or "back", and only that vector needs to be noted.

And here lies one of the strong points of this approach. Underspecification is an extremely important characteristic of the phonology of languages (Steriade, 1995). With the graphical approaches, however, we are forced to commit to a particular realization of the sign, including redundant information and even slight, uninformative phonetic details.

With the proposed approach, only the necessary information has to be specified. To take an example from a gesture in popular culture, rather than a sign, in the "thumbs-up" gesture, the important orientational information is that the lateral vector (thumb) points up. Distal and palmar vectors are irrelevant, and so they can just be omitted. Upon realization, the producer can select the orientation that best fits the context, or the more comfortable one for the situation.

This "lateral" extra axis is also useful for signs presenting some movement of the hand that affects orientation. In the "there is not" sign of Spanish Sign Language, for exam-

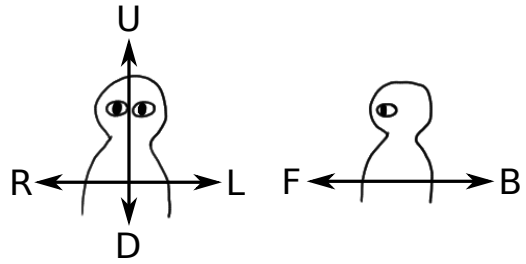

Figure 7: Points in the topographical sign-space, corresponding to the general directions Up, Down, Left, Right, Front and Back. Note that space is always transcribed from the point of view of the signer

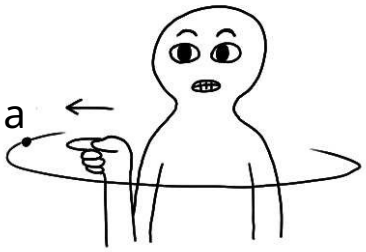

Figure 8: A 3rd person "placed" in syntactic sign space. The facial features are the mark of a 3rd person pronoun, with the finger pointing to the antecedent's location in sign-space (or postcedent if it will be specified later)

ple, both distal and palmar vectors change. The lateral vector remains static, however, pointing backwards. We can thus understand the orientation and movement combined as a "minus quarter" rotation around the lateral, which points back, or alternatively distal from up to left, lateral back: (U,L)::B[3].

This is the underspecified notation for (U,L):(L,D):B, and it could also have been written (U,L):(L,D), but the common practice should be to underspecify in the most economic way possible. Note that this apparent diversity of transcriptions is different from the previously mentioned issue of SignWriting regarding lack of biunivocity. The full vectorial transcription of orientation always entails three vectors and is unique for each specific configuration. However, given that the vector system only has two degrees of freedom (the position of one vector is always determined by that of the other two), then the most convenient vector can be omitted, following the principles of underspecification.

4 Proposed notation

Accompanying the different approach to orientation that has been described, we also propose a succinct and expressive notation that can be used to transcribe it. We rely on a theoretical existing notation for space, which is out of the scope of this paper. For now, we will use a simple one, specifying general directions[4] with uppercase letters (Up, Down, Left, Right, Front, Back), as in Figure 7, and pronominal spaces ("placed" constituents) with lowercase letters not belonging to any general direction (a, b, c, x, y...). In other words, lowercase letters represent variables that are subject to deictic or anaphoric interpretation. Figure 8 shows an example of a 3rd person in sign-space.

Orientation can then be notated using colons to separate the spaces to which the hand vectors point, starting with the distal vector, following with the palmar and finishing with the lateral. To leave a vector unspecified, the corresponding colon is used, but no letters in the place where they should be. As a shorthand, if distal and palmar vectors are specified, the second colon and lateral space can be omitted.

Some relevant examples can be seen in Table 1. In Table 2, a more complete enumeration of different orientations and their vector transcription is given.

5 Discussion and Conclusions

Description and transcription are two fundamental endeavors in linguistics, and intimately related. A good description enables natural and expressive transcription, and proper transcription shows the strengths and weaknesses of a particular conceptual model. In a feature seemingly simple such as hand orientation in sign language, we have shown that changing the way it is interpreted allows to discover underlying structure and meaning.

[3]Here, we separate the vectors with ':' in the order distal, palmar, lateral, but we leave out the palmar since it is predictable given the other two. The values inside the parentheses represent the consecutive orientations.

[4]Points in the "topographical" sign-space.

Examples	SignWriting[i]	Vectors[ii]
Letter a, numbers		U:F
Past		(U,B)::R
More, "thumbs-up", work		::U
Bicycle, Sit		F:L
Child		F:D
Letter g		L:B
I ask *a*, I understand *a*	–	U:a
a (anaphora)[iii]	–	a:

[i] Only orientation feature, plus the shape from the first listed example (the shape cannot be omitted in this notation).

[ii] The parenthesis and comma are a shorthand for bisyllabic transitions.

[iii] As in Figure 8, indicating a 3rd person by pointing. The shape is "point" or "1" (extended index), and the only relevant orientation is the distal vector.

Table 1: Examples of the orientation feature in different signs, and its transcription in SignWriting and vector notation

Our representation highlights the pieces of information that are phonologically relevant. Redundant or predictable phonetic aspects must be filled in at a later stage in the derivation, and may be subject to particular realizational constraints or variants. This move brings the analysis of sign languages closer to that of oral languages, by capturing general principles of phonology, like underspecification.

In addition, we want to point out the very natural treatment of this representation that can be done with computers. The abstract or symbolic notation is much more amenable to digital processing than graphical representations, and the use of vectors and space locations may make mathematical treatment of animated agents easier, or even help with computer-vision recognition of signed language.

One issue remains that we can see. In some signs, the vector which matters is that of the index finger. Think for example of the basic pointing sign, where an element of the sign space is referred to. Here, the important direction is the tip of the index finger. If this finger is fully extended, that coincides with our distal axis. However, in a natural realization of the sign, the finger can be flexed, taking it out of alignment with the distal vector.

Some possibilities arise. The easiest, of course, is to think that the ideal sign is the one with the index fully extended, and the distal vector pointing properly, but "laziness" and other realization constraints mean that the actual hand shape is often more relaxed.

Other possibility is to add another axis, corresponding to the extended fingertip. It would then have to be seen if others fingers also would benefit from this treatment, how many of them would be needed, and how to describe this phenomenon with a concise but comfortable notation.

In order to decide this issue, more data and study would be needed. However, the underlying technique of using vectors pointing to space locations to specify orientation seems to be sound, useful and expressive.

Acknowledgements

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SignWriting	Vector	SignWriting	Vector	SignWriting	Vector	SignWriting	Vector
	U:B		U:L		U:F		U:R
	L:B_a		L:D_b		L:F_c		L:U_d
	D:B		D:R		D:F		D:L
	R:B_e		R:U_f		R:F_g		R:D_h
	F:U		F:L		F:D		F:R
	L:U_d		L:B_a		L:D_b		L:F_c
	B:U		B:R		B:D		B:L
	R:U_f		R:F_g		R:D_h		R:B_e

Table 2: Main variations of orientation and their corresponding vector notation, using distal and palmar vectors. Subscripts signal orientations that have a twofold representation in SignWriting (subscript *a* is the same as the example previously presented in Figure 3). The generalization is that all orientations with distal either Left or Right have two possible SignWriting notations, because they refer to points where the vertical and the horizontal planes converge

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