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AN INTELLIGENT VISUAL DICTIONARY FOR ITALIAN SIGN LANGUAGE

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Sign languages are visual-gestural languages developed mainly in deaf communities; their tempo-spatial nature makes it difficult to write them, yet several transcription systems are available for them. Most sign language dictionaries interact with users via a transcription-based interface; thus users need to be expert of that specific transcription system. The e-LIS dictionary is the first web bidirectional dictionary for Italian sign language-Italian; using the current e-LIS interface, users can define a sign interacting with intuitive iconic images, ignoring the underlying transcription system. Nevertheless this interface assumes that its users are expert signers, knowledgeable about the formational rules of signs.

The e-LIS ontology, which specifies how to form a sign, allows even non-expert signers to use the dictionary from Italian sign language to Italian. This is realised through a novel visual interface for transparently browsing and querying the e-LIS ontology and the underlying database. The interface prototype was designed following the user centred design methodology. As such, our work constitutes the first attempt at making the e-LIS dictionary an intelligent visual dictionary, usable by learners of Italian sign language who are not expert signers yet.

This paper reports on the design of the first prototype of the ontology-based visual interface, and outlines its evaluation plan.

Keywords: Visualisation, treemap, ontology, web dictionary, sign language

1 Introduction

1.1 Our proposal and its rationale

Sign languages are visual languages used in deaf communities, mainly. They are essentially tempo-spatial languages, simultaneously combining shapes, orientations and movements of the hands, as well as non-manual components, e.g., facial expressions. Roughly speaking, a sign language is a gestural-visual language with signs as lexical units, whereas a verbal language is an oral-auditive language with words as lexical units. A sign language and the verbal language of the country of origin are generally different languages.

Currently, the quality and accessibility of courses and support material for sign languages, such as dictionaries, grammar books and textbooks, are insufficient [1]. In particular, the vast majority of dictionaries are paper dictionaries, e.g. [2] for Italian sign language (*Lingua dei Segni Italiana*, LIS). The paper format cannot precisely render the spatio-temporal nature of signs. In this respect, multimedia dictionaries and in particular web dictionaries are more expressive.

The creation of an web dictionary for LIS is part of the e-LIS project [3], which commenced at the end of 2004. The e-LIS dictionary from LIS to verbal Italian was conceived for expert signers searching for the translation of a LIS sign. At the start of 2006, when the development of e-LIS was already in progress, it was realised that the potential users of a web dictionary would also include non-experts of LIS, more specifically, of the formational rules of signs adopted in the dictionary. Then the idea of an ontology and the associated technology for the dictionary took shape: they aim to allow also non-expert signers who are learning LIS to use the dictionary; in other words, they aim to *allow more web users to consult the dictionary.*

This paper outlines the e-LIS ontology, which formalises the decomposition rules of signs of the e-LIS dictionary. The e-LIS ontology can become the input of a DIG-enabled query tool like [4]; the tool allows the dictionary users to compose a conjunctive query for retrieving a sign by assembling components of the sign in an expert manner, e.g., the tool forbids the composition of sign components which are inconsistent according to the ontology.

However, the interface of that query tools and others is mainly textual, flat, not colourful, hence unlikely to suit deaf users. According to several research findings, deaf signers show difficulties with abstract concepts, expressed in a verbal language; the use of colours can help them recognise different abstract concepts. They privilege spatial demanding hypertexts, in which texts is evenly and sparsely distributed along layers of nodes. They seem to prefer pied dynamic interfaces. Thus we designed a novel visual interface for the dictionary that allows users to query by browsing the e-LIS ontology or parts of it, and that takes into account deaf studies; for instance, our interface renders the ontology with colourful, 2.5D, dynamic, interactive treemaps. Its development, reported in details in this paper, followed the user centred design methodology.

1.2 Related work

The Multimedia Dictionary of American Sign Language (MM-DASL) [33] was conceived in 1980 by Sherman Wilcox and William Stokoe. The innovative idea was the enrichment of the textual information with digital videos showing signing people. MM-DASL developed a special user interface, with film-strips or pull-down menus. This allows users to look up for a sign only reasoning in terms of its visual formational components, that is, the Stokoe ones — handshape, location and movement.

In MM-DASL, linguistic information on the formational components constraints the query for signs one can create; users are not required to specify all the sign's formational components, nevertheless their query must be created along a specific order. Since the e-LIS ontology embodies semantic information on the classes and relations of sign components for the e-LIS dictionary, the ontology can be used as the basis for an ontology-driven dictionary which forbids constraint violations.

The MM-DASL project was never merchandised for several reasons, explained in [33]. For instance, platform independence of the system was a problem for MM-DASL; this is an issue the e-LIS team took into account, thus the choice of having the e-LIS dictionary as a *web application*. The profile of the expected user was not analysed before starting the development of the dictionary, whereas e-LIS aims at a dictionary experts and learners of LIS alike can use.

Time is an important feature of sign languages: sign components may vary in time, for instance, the signer's hands can assume different shapes while performing a single sign. While MM-DASL allows its users to specify the changing hand shapes (up to five), the current e-LIS dictionary requires its users to specify only one of such hand shapes, that is, to partially specify the sign components. The rationale behind such a choice is that e-LIS is a web dictionary, and users of a web dictionary are likely to prefer an interface with few choices and a fast interaction. Moreover, changes are often embedded in the hand shape itself, e.g., closing hand, opening hand, crumbling hand.

Woordenboek (`http://gebaren.ugent.be/`) is a web bilingual dictionary for Flemish Sign Languages (VGT). Users search for a sign by selecting its sign components, as in the current e-LIS dictionary. However, in the current version of Woordenboek: (1) users are not guided through the definition of the sign, thus users can specify a gesture which corresponds to no VGT sign or a sign that does not occur in the dictionary database; (2) the sign components are not represented via iconic images as in e-LIS; they are represented with symbols of the adopted transcription system; thereby the dictionary from VGT to Flemish is hardly usable by those who are not expert of VGT or the adopted transcription system. Our ontology-driven interface to the e-LIS dictionary allows us to tackle such issues.

To the best of our knowledge, ours is the first ontology-driven dictionary for a sign language.

1.3 Outline of the paper

We lay the groundwork in Section 2, which provides the preliminaries on deafness, sign languages as well as issues often encountered in designing tools for deaf people, and in Section 3, which describes the e-LIS project as it was initially conceived. With the preliminaries out of the way, we are ready to move to the matter of this paper. We outline the e-LIS ontology in Section 4, and explain what it can improve on the current e-LIS dictionary. Section 5, the core part of this paper, explains the design of our ontology-based interface for the e-LIS dictionary, and it details its development according to the user centred design methodology.

An analysis and an evaluation plan of our work are proposed in Section 6. Section 7 concludes this paper with an assessment of our work.

2 Preliminaries

2.1 Deafness

There are different types and different degrees of deafness. Deafness can be conductive or sensorineural. Conductive deafness is a form of deafness that results from a blockage of the ear canal or dysfunction of the ossicles or eardrum (sound collecting apparatus) [5]. In conductive hearing loss the auditory nerve is normal, but there exists a physical problem with the sound collecting apparatus. Sensorineural deafness is an irreversible type of hearing loss that occurs when cochlear sensorineural elements or the cochlear nerve is damaged in some way [6]. It can progress to total deafness. Sensorineural deafness can be treated with hearing aids or cochlear implants in most cases [7].

There are basically four degrees of deafness: mild, moderate, severe and profound. Even a mild hearing loss can be serious for children still learning to talk. With a severe degree of deafness, hearing speech is very difficult. With profound deafness, hearing aids may or may not help; cochlear implants are often an option.

Communication abilities of deaf people depend also on the age they become deaf. The situation of children who were born deaf or who lost their hearing prior to the age at which speech is acquired (prelingual deafness) is completely different than that of children who became deaf when they were older (postlingual deafness). Prelingual deaf people learn a spoken language mainly through artificial means, i.e., reading; the result is, often, diminished reading and writing skills [8]. Prelingual deaf children are often socially isolated and unable to pick up auditory social cues, especially if they have hearing parents that are not able to communicate with them. This can result in a deaf person becoming generally irritable or distrustful of hearing people.

2.2 Sign languages

A sign language (SL) is a visual language based on signs instead of sound to convey meaning; a sign can be defined as a complex entity, realised through hands, facial expressions, mouthing and other body gestures. SLs are commonly developed in deaf communities and contrary to popular belief there is not a universal SL: SLs vary from nation to nation, for instance, in Italy we have LIS. Another common misconception about SLs is that they are primitive languages made of gestures and pantomimes, and not fully-fledged languages; people usually believe that an SL is the translation of the verbal language of the country of origin, whereas this is not the case, for instance, American SL is close to French SL, whereas verbal American English and American SL are not similarly related [9].

Such misconceptions caused a general disinterest of researchers towards SLs until recent times; [9] says that linguists' attention for SLs was caught "when in 1960 the American linguist William Stokoe published his book *Sign Language Structure* and showed that signs cannot be considered indivisible wholes but should be analysed as consisting of various smaller component parts, exactly as is the case for the words of spoken languages. This first modern linguistic analysis of a sign language received a great deal of attention and particularly during the seventies other researchers began to express interest in the linguistic structure of signs and sign languages (first mainly in the USA, and from the end of the seventies beginning of the eighties, also in other countries)".

The Stokoe-based decomposition that is adopted in the e-LIS project and originally in the paper dictionary [2] deconstructs a LIS sign in four main components, here referred to as *Stokoe classes* for brevity. They are described as follows:

- the *handshape* class collects the shapes the hand or the hands take while signing; this class alone counts more than fifty terms in LIS;
- the *orientation* class gives the palm orientations, e.g., palm up;
- the class for the *movement of the hand or hands* lists the movements of the hands in the space;

- the class for the *location of the hand or hands* provides the articulation places, i.e., where the hands are positioned in the space (e.g., on the signer's forehead, in the air, on the signer's wrist).

Such a decomposition allows for the transcription hence the ordering of signs in paper dictionaries of SLs. Let us see an example entry of [2]: the sign for "parlare dietro le spalle" (*to gossip behind one's back*) in Fig. 1 is a one-hand sign; the *handshape* is flat with five stretched fingers; as for the *orientation*, the palm orientation is forward and towards the left so that the hand fingers get in touch once with the *location* which is the neck; as for the *movement*, the hand moves to the left only once.

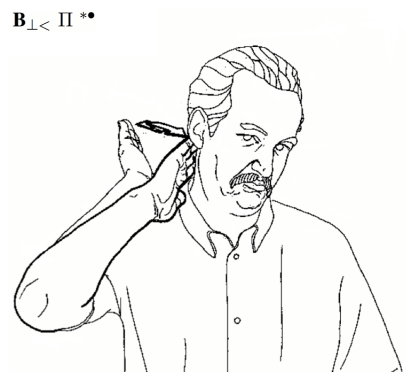

Fig. 1. Sign for Italian expression *Parlare dietro le spalle*, as in [2].

The transcription in the upper-left corner of Fig. 1 (namely, $\mathbf{B}_{\perp<}\ \Pi\ ^{*\bullet}$) encodes all that information, and is used to order the transcribed sign in the paper dictionary. However, figuring out that information from the transcription requires some *expert knowledge* of the adopted transcription system and, above all, of the underlying formational rules of signs. We cannot expect the average user of a web dictionary to have such an expert knowledge.

Before proceeding further, a word on the written representations of SLs is in order. The representation of SLs in written form is a difficult issue and a topic of current research, e.g., see [10, 11]; as reported in [11], SLs can be assimilated to verbal languages "with an oral-only tradition"; their tempo-spatial nature, essentially 4-dimensional, has made it difficult to develop a written form for them; however, as stated in [11], "Stokoe-based notations can be successfully employed primarily for notating single, decontextualised signs" and as such they are used in several SL paper dictionaries. This said, we do not discuss further the topic for it goes beyond the scopes of our work, which is of applied nature mainly.

2.3 Designing tools for deaf people

The unique characteristics of deaf users and the high variability inside this group of users requires sensitivity and special attention in designing user interfaces for them. Specific usability rules should be followed. Clearly, in the design of the user interface of e-tools to be used by deaf people, the visual input should always augment or replace the auditory input [12]. Moreover, captions must be provided with all multimedia presentations and all visual cues must be noticeable even if the user is not looking straight at the screen [13].

However, verbal information must be carefully used. Due to a limited exposition to the language in its spoken form in their first years of life, deaf people lack the primary, natural means of acquiring literacy skills: "deaf children have unique communication needs: unable to hear the continuous, repeated flow of language interchange around them, they are not automatically exposed to the enormous amounts of language stimulation experienced by hearing children" [14].

Research findings point out that deaf people hardly achieve verbal language literacy; they tend to reason on single episodes and show difficulties in formulating coherent global relations, such as temporal relations, between episodes of narratives in a verbal language [15], to the effect that their ability of reading is often limited [16].

According to other research studies [17], deaf and hearing people encode information differently, with different strategies in the organisation and access to knowledge stored in the work and long term memory. In particular, according to [18], user interaction with hypertext involves at least two tasks related to memory process, namely: an information retrieval task, during which users may have to get familiar with the hypertext structure; a learning task for acquiring a profound understanding of the subject matter. As for information retrieval, deaf people seem to obtain poorer results than hearing people with texts rich of verbal information, concentrated in a few nodes; in contrast to that, they seem to obtain better performances in spatial demanding hypertexts, in which textual information is sparse and evenly distributed. As for the learning task, this is mainly related to the reading comprehension; however, "deaf people could overcome their verbal deficit in other kinds of hypertext structures such as deep structures, where the verbal information could be distributed and it would become more dependent on visuo-spatial abilities. [...] They could even take advantage of the spatial clues to improve their comprehension of the contents" [18]. Therefore the authors conclude that "the most developed visuo-spatial abilities of deaf users could be exploited by website designers distributing verbal contents in spatial demanding web structure (with more layers of nodes), which in addition could serve as semantic spatial clues for comprehension".

The use of graphics and hypertext in the e-LIS dictionary must consider such findings.

3 The e-LIS Project

The e-LIS dictionary [19] is part of the homonymous research project lead by the European Academy of Bozen-Bolzano (EURAC) [3]; e-LIS is the acronym of *bilingual electronic dictionary of LIS-Italian* (e-LIS).

The project commenced at the end of 2004. The ALBA cooperative from Turin, active in deaf studies, was involved in the project for the necessary support and feedback on LIS. As clearly stated in [1], most sign language dictionaries form a hybrid between a reference dictionary and a learner's dictionary. On the contrary, the e-LIS dictionary is conceived a semi-bidirectional dictionary, explaining LIS signs using LIS as meta-language and vice-versa.

The e-LIS dictionary contains two modules: one for translating words into signs and the other for translating signs into words; in the dictionary, the modules are respectively labelled ITA>LIS and LIS>ITA. The ITA>LIS module presents no research challenges: users transparently query the database by writing the word of which they want the LIS translation, like in a bimodal dictionary, say, from verbal Italian to verbal French; see Fig. 2 for a snapshot. On the contrary, the lack of a well established written representation for LIS and SLs in general

Fig. 2. A snapshot of the ITA>LIS module of the e-LIS dictionary.

is the first obstacle encountered in the creation of the LIS>ITA module. In this paper, we concentrate on this challenging module, and for simplicity we refer to it as the e-LIS dictionary in the remainder.

Currently, the e-LIS dictionary stores data in XML files; this format forces a specific structure and organisation of information without providing users with any information concerning the semantics of sign decomposition. This means that the dictionary users can easily make mistakes during their search for a sign. In fact, they are not expertly guided in the choice of the sign's components, that is, the *Stokoe classes* presented in Section 2.2; hence they can specify a combination of components that corresponds to no LIS sign or that corresponds to a sign not present in the e-LIS database — the signs stored in the e-LIS database constitute a subset of all the LIS signs.

A search engine allows the user to retrieve signs from the e-LIS database. The engine performs a translation of the user's selection in ASCII strings, and then queries the database looking up for that specific string. If no match occurs, the engine searches for similar strings, namely, for signs with one of the parameters equal to those defined by the user. In this manner, the engine always shows one or more results, avoiding an empty result set.

The e-LIS interface of the dictionary allows users to search for the translation of a specific sign. Users have to specify at least one of the Stokoe-based classes — handshape, palm orientation, location and movement, which in the dictionary are respectively labelled *configurazione*, *orientamento*, *luogo*, *movimento* as shown in Fig. 3.

When the dictionary users select a class (e.g., the handshape), the system shows all the elements of the chosen class (e.g., a specific handshape); once the user chooses an element of the class, this element represents a search parameter. After that, the user can choose to either trigger the search engine or to set another sign component.

The interaction between the interface and the users is a wizard-like process: the four Stokoe-based classes are shown, each with their own elements. A visual feedback is shown, representing the element chosen by the user. Fig. 3 shows the core part of the dictionary after the user has chosen a specific handshape (*configurazione*), with the palm orientation class (*orientamento*) as the current choice.

The current interface of the e-LIS dictionary has some positive characteristics: it provides an iconic representation of sign components and it shows information directly in LIS by using digital videos. The choice of using icons instead of sign transcriptions (e.g., a Stokoe-based transcription) should simplify the user's search process; web dictionary users in general do not know any sign transcription system, thus the current interface should allow non experts of sign transcription systems to use the dictionary. Moreover, the use of LIS videos is likely to increase user satisfaction; firstly, LIS videos allow to clearly render LIS signs; secondly, they are also employed to provide information concerning the usage of a sign, such as examples and local variants, thus stressing that LIS is an autoreferential language as much as verbal Italian is.

Fig. 3. The core part of the LIS>ITA module of the e-LIS dictionary, after the user has chosen a specific handshape (*configurazione*), with the palm orientation (*orientamento)* as the current choice; all available orientations are shown.

However, the current design makes the dictionary difficult for non-expert signers, and in general for those that are not aware of the formational rules of signs adopted in the dictionary. How to overcome such a limitation? We propose to use a dictionary ontology, and design a novel interface for browsing and querying it. The remainder of this paper describes them.

4 The e-LIS Ontology for an Intelligent Dictionary

Initially, the e-LIS dictionary from LIS to verbal Italian was intended for expert signers searching for the translation of an Italian sign. At the start of 2006, it was realised that potential users of a *web* dictionary would be also learners of LIS, not expert of the adopted transcription system or its formational rules of signs.

Only then took shape the idea of an ontology and the associated technology for the e-LIS dictionary. The first ontology that was developed is a domain ontology [20]; the domain of the e-LIS ontology is the Stokoe-based classification outlined in Subsection 2.2 above. The ontology was constructed in a top-down manner starting from [2], with the expert assistance of a linguist. It was designed using the ICOM ontology editor [21]. From now onwards, we refer to that domain ontology as the e-LIS ontology.

The e-LIS ontology [22] introduces novel classes and relations among classes of sign components, thereby making explicit, formal hence unambiguous pieces of information which were implicit and somehow hidden in the reference paper dictionary. For instance: it makes explicit that each one-hand sign is composed of at least one handshape by introducing an appropriate relation among the corresponding classes, `one-hand sign` and `handshape`; it groups together all the twelve different types of cyclic movements of hands in the `movement in circle` class, not present in the paper dictionary. By revealing implicit information or wrong assumptions, the domain ontology helped improve the flow of information within the e-LIS team. As such, it played an important role in the requirement analysis and conceptual modelling phase of the e-LIS database schema. The ontology was developed in ICOM hence we could use a DIG-enabled DL reasoner to check that the decomposition rules of the ontology are consistent [21]. We refer the interested reader to [23] for a more detailed description of the ontology.

The ontology can then become the input of a DIG-enabled query tool such as [4]; the two main modules of this tool are the `compose` module for assisting the user in effectively composing a query, and the `query` module for directly specifying the data which should be retrieved from the data sources. In particular, with input the e-LIS ontology, `compose` will propose sign components (ontology classes) which are related to the user's current selection, as specified in the ontology; e.g., if the user selects "one-hand sign" then the query tool will not show "hands relational position" as next possible choice to the user, because the ontology does not relate these concepts. We refer the reader to [4] for more information on the query tool and its integration with a database.

However, the query tool is not specific for the e-LIS ontology, hence for its end users; nor can they directly browse the e-LIS ontology, which is written in a formal language. The browsing and querying of the ontology need to be mediated by a visual interface, developed specifically for the e-LIS ontology and the dictionary users. The interface is the final step in the development of an intelligent visual dictionary for e-LIS. We discuss it in the remainder.

5 The Ontology-Based Interface for an Intelligent Visual Dictionary

The current e-LIS interface cannot be integrated with the e-LIS ontology [23], thus it does not provide users with the benefits of the ontology and the related technology. For instance, without the ontology, the dictionary users cannot acquire any new knowledge on sign components and their relations; thus the browsing of the current e-LIS dictionary does not train users to become expert users of the dictionary. Without the ontology, the dictionary users can arbitrarily combine sign components and specify gestures that do not exist in LIS, hence the current dictionary is difficult for inexpert signers.

Secondly, the current e-LIS interface lacks powerful undo tools; this implies that, if users commit to an erroneous choice, they do not have efficient tools to backtrack to the previous state, that is, to undo their last choice. Therefore the current interface does not effectively support the decision-making process.

Finally, the definition of a sign with the current interface is a long and tedious procedure, e.g., users may need to perform several mouse clicks. This is indeed a drawback for a web dictionary, since web users privilege fast interactions.

In the remainder, we focus on the design of a brand new interface which can exploit the e-LIS ontology for overcoming the aforementioned drawbacks of the current e-LIS interface.

The interface proposed in this paper was designed following a standard methodology in the area of human-computer interaction, namely, the *User Centred Design Methodology* (UCDM). The UCDM consists of:

(i) understanding and specifying the context of use,
(ii) specifying user and organisational requirements,
(iii) producing design solutions,
(iv) and evaluating design against requirements.

Such activities are always performed referring to the system users so as to achieve effective, efficient and satisfying results. By achieving effectiveness, efficiency and user satisfaction we improve the *usability* of the dictionary. Several definitions of usability exist [24]; in particular, [25] defines usability as "the extent to which a product can be used with efficiency, effectiveness and satisfaction by *specific users* to achieve *specific goals* in a *specific environment*". From this perspective, usability is the quality of interaction between the system and its users.

In the remainder, we present our interface prototype, explaining how its design followed the UCDM activities.

5.1 Specifying the context of use

First of all, we analysed the background of the e-LIS project, more specifically, the current online dictionary and the e-LIS ontology, explained in Section 3 and 4 of this paper, respectively. Secondly, we analysed issues related to the design of tools for deaf users, reported in Section 2.3. Therefore we decided not to entirely adhere to the e-LIS ontology [22], but to base our interface on a smaller taxonomy resulting from the e-LIS ontology, thus moving towards a hierarchical structure sometimes referred to as *light-weight ontology* [26] — still, our interface can easily be extended to the overall e-LIS ontology.

Why such a choice? Because our taxonomy renders our interface more intuitive for users as well as closer to the structure of the current e-LIS dictionary. More precisely, we extracted the taxonomy of the following concepts associated to the aforementioned Stokoe classes:

(i) `handshape`, used to define the configuration of the hands (e.g., open hand with five extended fingers);
(ii) `palm orientation component`, which formalises the orientation of the palms (e.g., palm towards the signer);
(iii) `location`, used to define the initial position of the hands in space (e.g., neutral space in front of the signer or contact of fingers with the cheek);
(iv) `one-hand movement component` and `relational movement component`, used to define the movement of the hands for one-hand signs and two-hand signs, respectively (e.g., straight movement towards the left or hands crossing).

These concepts are grouped into intermediate ones; the resulting taxonomy has a multilevel hierarchical structure, in which every element has one parent and possibly one or more children, like in classical trees. Concepts corresponding to Stokoe classes (e.g., handshape) are always 0-level elements; their direct children are 1-level elements; and so on.

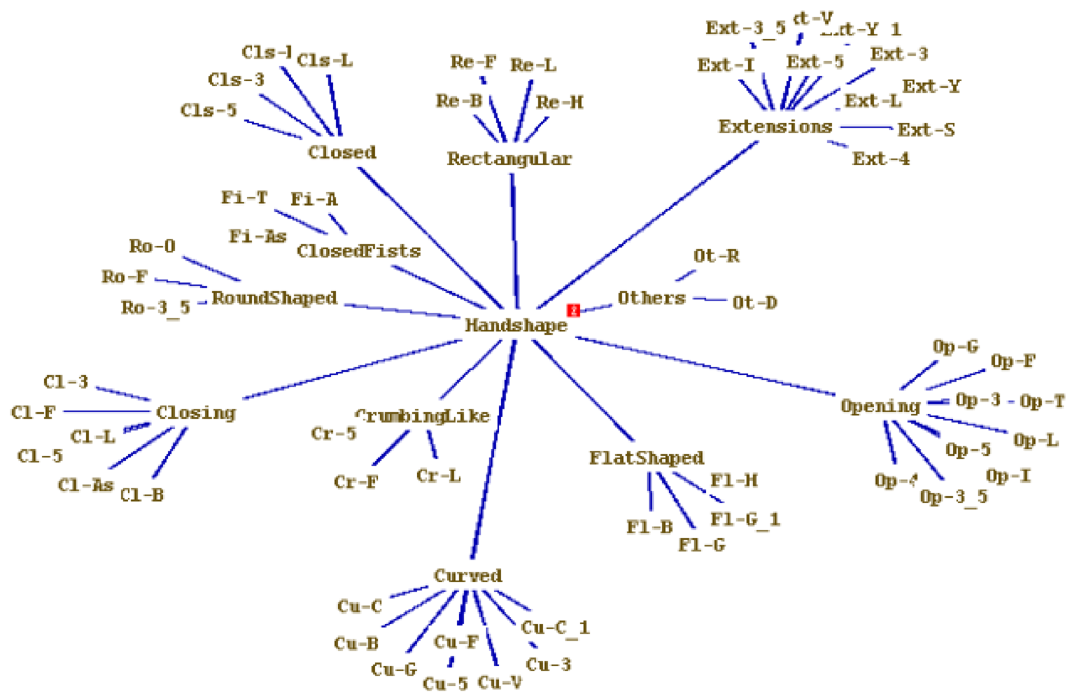

Fig. 4. Visualisation of the taxonomy of the `handshape` concept in the e-LIS ontology.

As for the `handshape` concept, the e-LIS ontology is based on the classification of [2], visualised in Fig. 4; this is hardly intelligible by the average user of the dictionary. Instead, our taxonomy groups the handshapes following the more intuitive criterion of the e-LIS dictionary: the number of extended fingers. In our simplified taxonomy, we have 0-finger handshapes, 1-finger handshapes, and so on. An example is the sign for “he/it”, a one-hand sign with one extended finger (see Fig. 5). In our taxonomy, its handshape is classified as 1-finger.

Such a simplified version of the ontology is the basis of our interface. In fact, in the UCDM prototypes are successively developed and refined in order to present the main idea, as in our case.

5.2 Specifying user and organisational requirements

Starting from the analysis of the context of use, we did

- the *profiling of the dictionary users*, in order to highlight their social, cultural, physical and psychological characteristics,
- the analysis of the *tasks* that the users of the dictionary perform.

Such steps are necessary for determining the functional, user and organisational requirements.

Fig. 5. The LIS sign for "he/it".

5.2.1 User profile

Since the e-LIS dictionary is a web-oriented system, its users are heterogeneous. However we can group them as follows: deaf and hearing people, subdivided in expert and non-expert signers who are learning LIS. At this stage of the project, we mainly deal with deaf people, that can be expert as well as non-expert signers.

According to the research studies reported in Subsection 2.3, deaf people tend to privilege complex spatial structures with textual information evenly sparse. Moreover, they seem to prefer pied visual interfaces to homogeneous and static ones; they are attracted by different shapes, different colours, etc. These are critical observations for the design of our interface.

As for the knowledge of LIS, deaf people are not all proficient in LIS; in general, the average user of the dictionary is likely to be a non-expert signer; thus our interface design presumes no expert knowledge of LIS or its Stokoe-based decomposition.

5.2.2 User tasks

Equipped with such information and feedback from experts in deaf studies, we started the design of our interface and the tasks it should support. As for the latter, the dictionary users should be able to:

- specify the components of the sign they are searching for in an intuitive and clear manner;
- transparently query the e-LIS repository in order to retrieve the signs that match the sign components they selected;
- interact with the results.

At the current stage of the project, we concentrated on the first task and exploited the ontology for this. The dictionary users can specify the components of a sign by transparently browsing and querying the ontology via our interface. More precisely, in our interface, the dictionary users see only the concepts related to their current choice, as specified in the ontology. For instance, suppose that the user watches the sign for "he/it" but ignores its translations in verbal Italian. Still, the user can observe that its handshape has one extended finger only. Correspondingly, in our visual interface, the user first selects the handshape class;

then the 1-finger handshape is shown and the user can select this in order to retrieve the video of the sign and its translations in verbal Italian.

5.2.3 Usability goals

Starting from the dictionary user profiles and the tasks of our interface, we determined the *usability goals* of our interface:

***effectiveness*:** the dictionary users should be expertly guided during their search for a sign, thus minimising errors and obtaining satisfactory results out of their search;

***efficiency*:** the interaction with the interface should be as fast as possible (e.g., mouse clicks are minimised), since e-LIS is a web dictionary; the decision-making process should be effectively supported by the interface reducing the need of undo tools;

***users' satisfaction*:** the interface should be well organised and plain, thus minimising the cognitive effort of users — a satisfactory interface keeps the users' attention alive.

Next, in explaining the design solution activity, we show *how* our interface aims at meeting such usability goals.

5.3 Designing solutions

During the design solution activity, several mock-ups and prototypes are realised; in this paper we focus on the current prototype of our ontology-based interface, which is the result of successive refinements of the initial mock-ups. Three screenshots of the current interface prototype are shown in Figs. 6 and 7.

The prototype presented in this paper is a visual interface designed for the composition of a sign by browsing and querying the e-LIS ontology. It is an *information visualisation* system, thus it is characterised by three main components:

- the visual metaphor, i.e., the graphic elements used to render information;
- the number of dimensions, either 2D or 3D;
- the *space-saving* strategy, that is, a trade-off between the amount of information to be represented and the available space.

Visual metaphor. Since the e-LIS ontology is a tree (see for instance Fig. 4), we adopted the tree metaphor as the visual metaphor. Furthermore, since our visual interface is also for non-expert signers, we opted for a tree metaphor that supports our users in building their query/sign in a step by step fashion; since we are rendering a hierarchical structure (i.e., the taxonomy of concepts), we adopted a *treemap*. The treemap visual technique is shown in Fig. 6. Such technique allows us to show a tree in a space-constrained layout, that is, the tree is turned into a planar space-filling map. In our interface, the treemap technique visually renders the ontology classes and their subsumption relations.

Number of dimensions. We decided to use a 2.5D visualisation in order to show the four Stokoe classes simultaneously: each treemap represents one Stokoe class or a subclass of it. Each treemap is embedded in a 3D plane, that is, a 3D treemap, where the third dimension is simulated through perspective; the simulated third dimension saves space and suggests the idea of a connection between the planes.

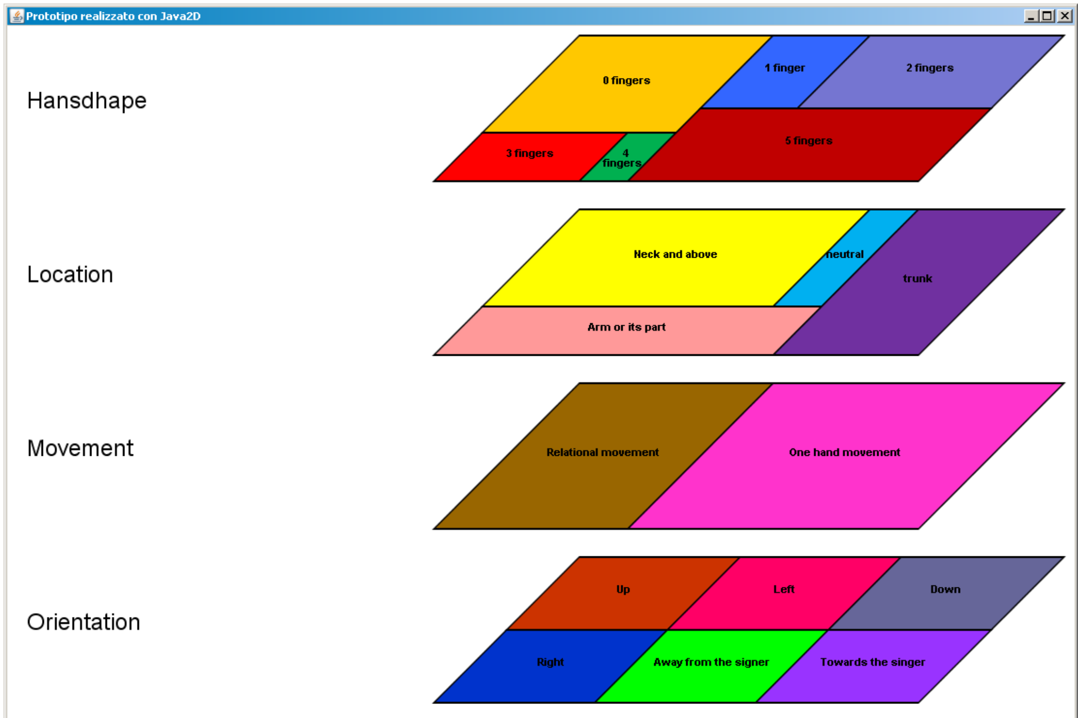

Fig. 6. The interface of the current prototype.

Space-saving strategy. We adopted the *focus* + *context* strategy as space-saving strategy. In particular, in order to maintain the context, we introduced the miniatures of the planes: by referring to the bottom figure in Fig. 7, the four big planes in the right part of the interface represent the focus, whereas the four miniatures in the left part of the interface represent the context.

The visualisation of the ontology is done progressively, as explained in the following.

(i) In the first step, in the left part, the interface visualises the four labels of the Stokoe classes, namely, `handshape`, `location`, `movement`, and `orientation`. In the right part, the interface visualises four planes; each plane is a treemap representing the direct children of the main concepts. In Fig. 6, which represents the first step, the treemap in the high part is associated to the `handshape` concept of the e-LIS ontology; each area of this treemap represents the direct descendant concepts of the handshape concept in the e-LIS ontology: `0-finger`, `1-finger`, `2-finger`, `3-finger`, `4-finger`, `5-finger`.

(ii) From the second to the fourth and last step, the layout of the interface is quite the same as that of the first step except for the presence of four smaller planes on the left. These are the *miniatures*. For instance, see the bottom figure in Fig. 7. In the left part, the interface visualises the four labels of the Stokoe classes; in the right part, the interface visualises the treemaps representing some of the direct descendants as in the e-LIS ontology; in the centre, the interface visualises four smaller planes which are the *miniatures* representing the choice performed in the previous step. Actually, the miniatures represent one level up in the taxonomy of the concept associated to the specific treemap.

In general, each treemap is composed of several areas, whose dimensions are proportional to the number of child concepts each area represents. Each area in each treemap is differently coloured so as to facilitate deaf people in recognising different abstract concepts [16].

The interaction with the interface aims at being simple and intuitive, so as to allow the dictionary users to minimise their cognitive effort. As explained above, the browsing of the e-LIS ontology is organised in steps to support the query composition task. In order to move to the next step, the user has to commit to a choice, that is, to select a specific area in a specific treemap. The choice is divided into two stages: a *preliminary* selection and a *definitive* one. Thanks to this two-stage choice, the system can show how the choice of an area propagates on the other areas of the four treemaps; thus the interface supports the decision-making process. This is the starting point for realising a dynamic visual interface.

The preliminary selection allows the dictionary users to watch how their choice of a sign component affects their search path. To this end, a transparency effect is applied to all the areas which are inconsistent with the current selection. Consistency is evaluated against the ontology.

To improve efficiency and users' satisfaction, the transparency effect is applied when the user moves the mouse over a specific area. The same effect could be applied to the mouse-click, but the mouse-over brings the following benefits: moving the mouse is less obtrusive than clicking with it, since the latter requires the conscious will of clicking; the effects produced by moving the mouse over a specific area can be discovered accidentally. If the dictionary users consider the current selection as the right one, they can make it definitive by clicking on it, thus moving to the next step. Otherwise, they can easily move the mouse over a different area.

Let us make an example. Assume that in the first step, illustrated in Fig. 6, the user moves the mouse over the 1-finger concept, which is now the current temporary selection. All the concepts inconsistent with the 1-finger one are highlighted, that is, a transparency effect is applied to the related areas in the four treemaps, as shown in the top image in Fig. 7. Suppose that the user remembers that the location of the sign is the chest, which is part of the trunk: because this is a temporary choice, the trunk area in the location plane is transparent, thus the user understands that the current selection is not the correct one. The user can then easily change the temporary selection moving the mouse over a different area. Suppose that the user discovers that the 0-finger concept is the correct one. After committing to this choice by clicking on the 0-finger area, the second step is shown in the bottom figure in Fig. 7. Here miniatures are smaller representations of the 3D planes of the previous step.

In the current prototype the context is given by the immediately previous step. Since miniatures store the information contained in the previous step, they can be used as an undo tool: a click on them will bring the user back to the previous step. In miniatures, inconsistent concepts are coloured in grey. The grey colour is thus associated to the notion of inconsistency. Such a feature helps users to remember the selection made in the previous step.

When the dictionary users terminate interacting with the treemaps, namely, the ontology browsing, they have created their query with sign components. Notice that users do not need

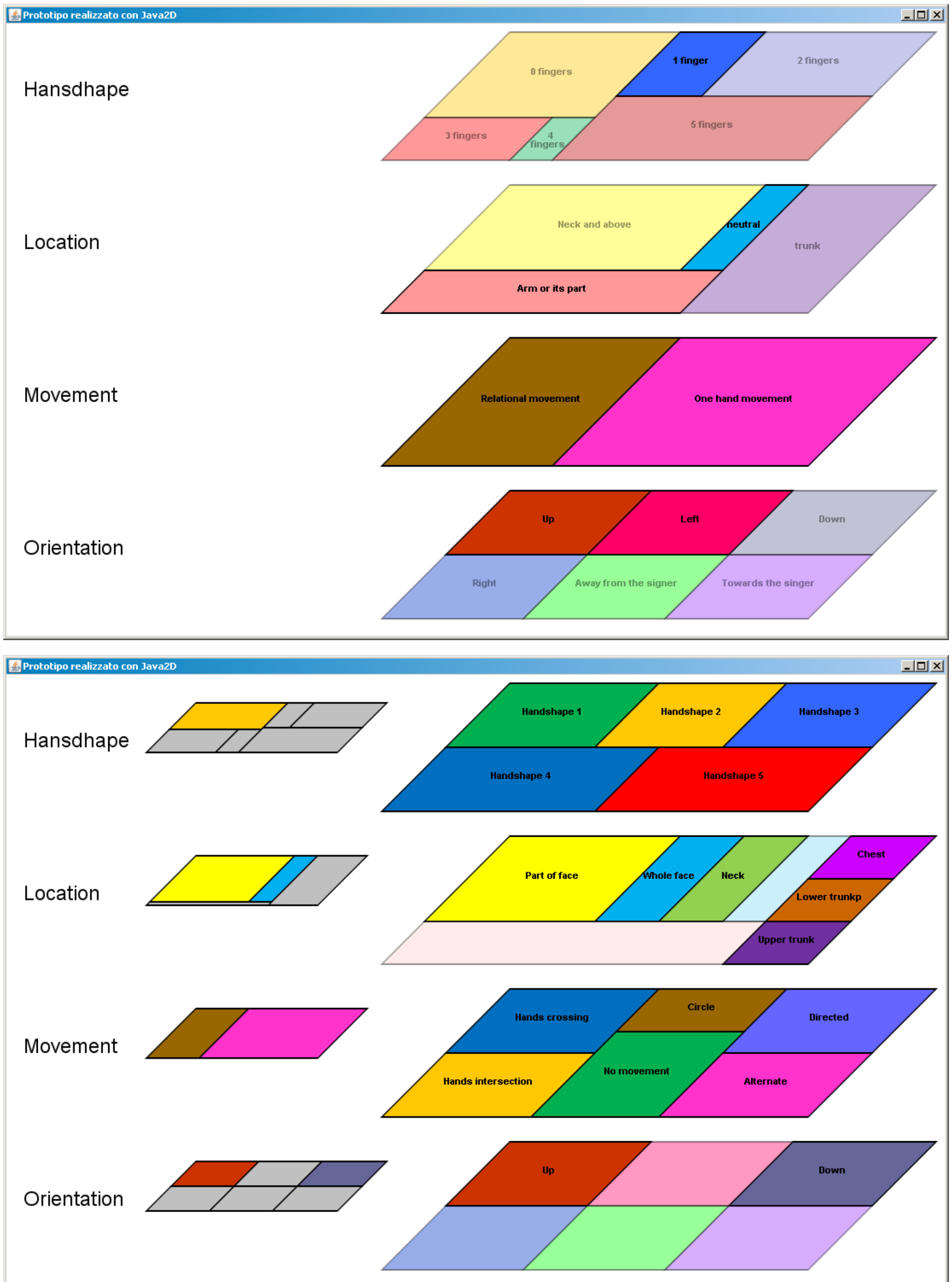

Fig. 7. Top figure: the user moves the mouse over an area, the 1-finger class, and a transparency effect is applied to the areas which are inconsistent with that one. Bottom figure: the interface after the user has chosen the 1-finger class.

to specify all the sign components for retrieving a sign; they could remember only the location, or they could remember only the number of extended fingers. Anytime, they can terminate their composition and retrieve all the results of their sign/query composition, e.g., select all signs with 1-finger as handshape and chest as location. Moreover, they can start interacting with one treemap, and continue with a different one; for instance, users can interact with the handshape treemap in the first step, and with the location treemap in the second step.

6 Our Evaluation Plan and Future Work

In the UCDM, a complex tool evolves through different stages; as described in [24], the UCDM is an iterative design and development methodology which requires several design solution stages and several design evaluation experiments. Table 1 sums up our evaluation plan, that we detail in the following.

6.1 Survey evaluation

Evaluating a tool for deaf users mainly means interacting with deaf people. Several methods for usability testing [27] cannot be directly employed. For instance, due to the literacy problems expounded in Section 2.3, traditional inquiry methods based on questionnaires or oral interviews to deaf users may be rather impracticable.

Another procedure is that of involving in the experiment not only deaf people but also interpreters [28]. In this case, the influence of the presence of the interpreters on the procedure must be observed in details [29]; in fact, their mediation can easily lead to imprecise results. In general, it is important to describe what it is like to participate in a usability test to the session participants before starting the test [27]. In the case of deaf users, it is not always possible for test designers to communicate directly to participants, and interpreters may misunderstand the explanation of the test procedure.

Last but not least, recruiting deaf users willing to test e-tools for them is another main problem; deaf people are usually spread on the territory, and, due to a long history of isolation, they generally tend to be distrustful of hearing people [30].

Supported by such observations, we decided to design a preliminary evaluation session. The method used in this preliminary evaluation session is the *survey evaluation method* [32]; this method offers a broad evaluation of usability since the users' viewpoint allows to identify potentially critical aspects in the design of the system. The e-LIS project leader consulted deaf users from the ALBA community of Turin, involved in the project, and their observations further convinced us to simplify the e-LIS ontology for the visual interface as explained in Section 5. After reading the literature summarised in Subsection 2.3, we designed our prototype of the e-LIS visual interface. We then asked hearing experts on deaf studies or usability studies about their opinion on the prototype; interviews mainly revolved around our choice of colours and interaction issues, e.g., if the the mouse-over effect is intuitive. We gathered critical observations we are taking care of in the observational evaluation, e.g., the suggestion of using similar colours for related concepts in the ontology.

Clearly, this preliminary experiment is not sufficient to have a complete feedback on the first interface prototype; we need to perform several other evaluation experiments with a sample of end-users.

6.2 Observational evaluation

Our choice of a treemap for visualising the ontology is also motivated by the literature findings reported in Subsection 2.3 according to which deaf people can easily cope with complex and layered spatial structures, with text sparsely and uniformly distributed. However, we have to evaluate the treemap choice with our end-users; the tree metaphor is a reasonable way for visualising sign decomposition as in the ontology, but it may result not intuitive and require a significant amount of cognitive processing for the expert signer. We also have to evaluate our use of colours, or if it is better to highlight related concepts with the same or similar colours. The interaction strategy should also be tested, in particular, the idea of a two-stage selection and the use of mouse-over effects.

In order to evaluate the interface design, the UCDM [24] suggests to use the *observational evaluation method* [34]. This method involves end-users, in our case deaf people, that are observed while using our interface. Depending on the specific situation, we may either apply the observational evaluation by direct observation, or record the interaction between the users and the system using a usability laboratory. Since we deal with deaf people, we plan to use recording with video cameras in order to well evaluate the critical points during the interaction (e.g., when the user has to consult the hearing expert, when and where she or he is blocked), the time a user spends in performing a task, the mistakes a user makes, and so on.

6.3 Controlled experiment

At the start of this paper, we stressed why we cannot assume literacy in verbal Italian of all the dictionary users, thus the need of effective intuitive icons in our treemap-based interface, replacing the current textual labels. In the current prototype, we decided to use textual labels in order to focus the users' attention on the treemap paradigm. Future work includes the design and usage of specific icons and an evaluation of the choice of such icons with our end-users. In fact, as substantiated in [18], "when a search task involves not only visuospatial factors but also semantic ones, the mere substitution of words and sentences by pictures and icons is not recommended without a previous study of aspects related to user memory, especially of the organization of knowledge [. . .] and the familiarity of users with such visual representations".

We plan to use the *controlled experiment method* [35] in order to make a comparative evaluation study about the effectiveness of using icons instead of textual labels. This method is apt for testing how a change in the design project, that is, icons instead of textual labels, could affect the overall usability of the tool. It mainly aims at checking some specific cause-effect relations, and this is achieved by checking as many variables as possible. The tasks the user are tested in a controlled experiment strongly depends on the used prototype, thus we choose this method for the last prototype of our interface.

7 Conclusions

This paper reports on the first prototype of an intelligent visual interface for the e-LIS dictionary, intended for expert and non-expert signers alike. More precisely, it outlines the e-LIS ontology, and then describes a visual interface for the dictionary, integrating the ontology.

Our interface offers several advantages with respect to the current e-LIS dictionary, as specified in Sections 4 and 5. For instance, the user can select sign components only if they

Table 1. Our evaluation plan.

Experiment	**Design Solution**	**Evaluation Milestone**	**Users**	**Evaluation Method**
I	1*st prototype*	*preliminary feedback*	*expert users*	*survey evaluation* [32]
II	1st prototype	treemap	deaf	observational evaluation [34]
III	2nd prototype	colours	deaf	observational evaluation [34]
IV	2nd prototype	interaction	deaf	observational evaluation [34]
V	3rd prototype	labels/icons	deaf	controlled experiments [35]

are consistent with the composition rules encoded in the ontology; thus, by exploiting the ontology, our interface allows for the minimisation of the user's selection errors. Our interface also allows the dictionary users to watch the propagation of their selection of sign components, that is, users can watch how their selections affect the search path. In this manner efficiency is likely to be improved: users learn by browsing, hence the interaction of the user with the dictionary gets faster and faster. Visually showing the effects of the users' choices can also minimise the need of undo tools: the dictionary users will start a search path only if the prospected next choices are suitable to them. Finally, since the dictionary users can watch the propagation of their choices before committing to them, the dynamic browsing of our interface effectively supports the decision-making process. Such are all relevant features, which are missing in the current interface of the e-LIS dictionary, and that are likely to render the dictionary more usable by non expert signers.

The visualisation of ontologies is a topic of current research, and the novelty of our work is also in applying a well studied visualisation technique, namely, the treemap, to the browsing of a specific ontology, innovative per se — to the best of our knowledge, there is no ontology for LIS signs at the time of writing. With our visual interface, all the dictionary users can transparently browse the e-LIS ontology in their search for a sign, and of its translation in verbal Italian. Our interface can also interact with a query tool such as [4], meant for querying DIG ontologies. The interfaces of such query tools are generic, for any ontology, whereas our treemap interface is for the e-LIS ontology and the dictionary users: our interface is essentially visual, pied, dynamic, thus it meets the requirements of our end users as specified in Section 2.

Section 1 reports on electronic dictionaries for sign languages similar to e-LIS; our comparison indicates that ours is the first visual dictionary for a sign language which exploits ontologies and the associated techniques, further corroborating the rationale of such a dictionary.

The development of the first interface prototype followed the user centred design methodology, which lead us to simplify the e-LIS ontology so as to make it more intuitive and usable by web users. We evaluated our first prototype with expert users, as reported in Section 6.

We are well aware that this evaluation is not sufficient and we need to perform several tests in order to assess our intelligent visual interface. Thereby, Section 6 also outlines a complete evaluation plan, with clearly defined milestones and, for each of them, the usability methods we propose to apply.

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