A Visual Ontology-Driven Interface for a Web Sign Language Dictionary

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Abstract. 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 languages dictionaries interact with their users via a transcription-based inteface; thus their users need to be expert of their specific transcription system. The e-LIS dictionary is the first web bidirectional dictionary for Italian sign language-Italian; using the current interface, the dictionary users can define a sign interacting with intuitive iconic images, without knowing the underlying transcription system. Nevertheless the users of the current e-LIS dictionary are assumed to be expert of Italian sign language. The e-LIS ontology, which specifies how to form a sign, was created to allow even the non-experts of Italian sign language to use the dictionary. Here we present a prototype of a visual interface based on the e-LIS ontology for the e-LIS dictionary; the prototype is a query-oriented navigation interface; it was designed following the User Centred Design Methodology, which focuses on the user during the design, development and testing of the system.

Keywords: Ontology Visualisation, Querying Task, User Centred Design Methodology, Sign Languages.

1 Introduction

A sign language (SL) is a visual language based on body gestures instead of sound to convey meaning. SLs are commonly developed in deaf communities and vary from nation to nation; for instance, in Italy we have Italian sign language (*Lingua Italiana dei Segni*, LIS). As highlighted in [12], 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 [12] — "Stokoe-based notations can be successfully employed primarily for notating single, decontextualised signs".

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The sign components singled out by a Stokoe transcription system can be classified in the following *Stokoe classes*:

1. the *handshape* class collects the shapes the hand/hands takes/take while signing; this class alone counts more than 50 terms in LIS;
2. the *palm orientation* class gives the palm orientations, e.g., palm up;
3. the *movement* of the hand/hands class lists the movements of the hands in LIS;
4. the *location* of the hand/hands class provides the articulation places, i.e., the positions of the hands (e.g., on your forehead, in the air).

These classes are used to decompose and group signs in the Electronic Dictionary for Italian-LIS (e-LIS). The e-LIS dictionary is part of the homonymous research project lead by the European Academy of Bozen-Bolzano (EURAC). The e-LIS project commenced at the end of 2004 with the involvement of the ALBA cooperative from Turin, active in deaf studies.

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, when the development of e-LIS was already in progress, it was realised that potential users of a *web* dictionary would also be non-experts of LIS. Then the idea of an ontology and the associated technology for the dictionary from LIS to Italian took shape. The e-LIS ontology [9] introduces novel classes and relations among classes of sign components, thereby making explicit relevant pieces of information which were implicit and somehow hidden in the e-LIS 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.

The e-LIS ontology can serve as the input of a DIG-enabled query tool like [1]; this allows the dictionary users to browse parts of the ontology and query the e-LIS database. The visualisation of the browsing and querying should meet the needs of the different users of the dictionary — in particular, deaf users, who are essentially visual learners [14]. However neither the current e-LIS dictionary nor the query tool support this: the former implements a visual interface but is not integrated with the ontology; the latter can be integrated with the ontology but does not implement a visual interface convenient for all kinds of users of e-LIS.

In this paper we present an innovative visual interface for the e-LIS dictionary: it integrates the e-LIS ontology and implements a novel visual metaphor for browsing and querying parts of the ontology. First, we give the necessary background on the e-LIS project and the current dictionary interface. Our novel interface and its development are then presented in details. We conclude with an assessment of our work.

2 The e-LIS Project and Dictionary

The e-LIS project commenced in 2004, focussing on the creation of a web bidirectional dictionary for Italian-LIS; information is shown in both verbal Italian and LIS, thus giving LIS the rank of any other language which can talk about itself. The e-LIS dictionary is available at [6]. In this paper, we concentrate on the dictionary from LIS to Italian, for which our interface is developed.

2.1 The e-LIS Database

Currently, the e-LIS dictionary stores data in XML files; this format forces a specific structure and organisation of information without providing knowledge concerning the semantics of sign decomposition. Thus the dictionary users can easily make mistakes during their search for a sign, e.g., they can easily specify a combination of components that corresponds to no LIS sign. A rather simple 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.

2.2 Interface and Interaction

The e-LIS dictionary [6] 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 LIS>ITA module allows the user to search for the translation of a specific sign. The user has to specify at least one of the Stokoe-based classes of sign components: handshape, palm orientation, location and movement, which in the dictionary are respectively labelled *configurazione*, *orientamento*, *luogo*, *movimento* as shown in Fig. 1.

When the dictionary user selects 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 system and the user is a wizard-like process: the four Stokoe-based classes of sign components are shown, each with their own elements. A visual feedback is shown, representing the element chosen by the user. Figure 1 shows the core part of the LIS>ITA module 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 renders the sign translation with videos. The choice of using icons instead of sign transcriptions (e.g., with a Stokoe transcription system) improves the user's search process; in fact, the average *web* dictionary user is likely not to know any sign transcription system; thus the current interface allows even non experts of sign transcription systems to use the dictionary.

Moreover, the use of LIS videos is likely to increase the user's satisfaction: firstly, LIS videos allow to clearly render LIS signs; secondly, they are also employed to provide information concerning the translation of a sign, such as examples, thus stressing that LIS is an autoreferential language as much as verbal Italian is.

However, the design of the current interface of the e-LIS dictionary needs to be improved. Firstly, the current e-LIS interface cannot be integrated with the e-LIS ontology [9], thus it does not provide its users with the benefits of the ontology and the related technology. For instance the e-LIS ontology, which specifies how sign components are related, would allow for the creation of a dynamic interface for the e-LIS dictionary, that is, the interface would change according to the user's choices; by traversing parts of the ontology, the dictionary users could watch how their choices are related to other sign components. Without the ontology, the dictionary users cannot acquire any new knowledge on sign components and their relations; thus the navigation of the current e-LIS dictionary does not train users to become expert users of the dictionary. Moreover, without the ontology, the dictionary users can arbitrarily combine sign components and specify gestures that do not exist in LIS or the e-LIS database.

Secondly, the current e-LIS interface lacks powerful undo tools; this implies that, if a user commits to an erroneous choice, the user does not have efficient tools to backtrack to the previous state, that is, to undo the 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 long and tedious, e.g., the user may need to perform several mouse clicks. In this manner, web users are likely to soon get tired and abandon their search rather soon.

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

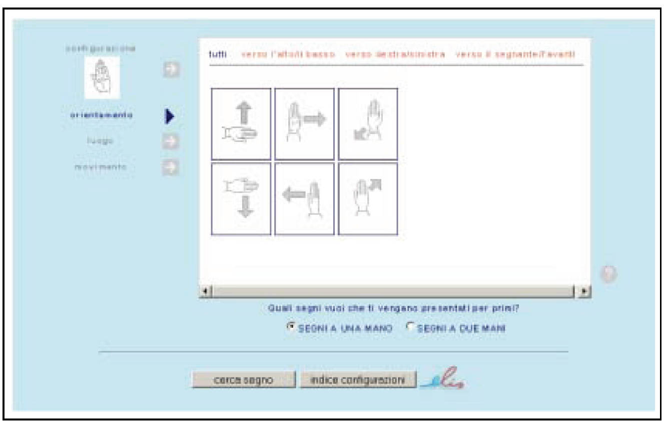

Fig. 1. The core part of the LIS>ITA module, after the user has chosen a specific handshape (*configurazione*), with the palm orientation (*orientamento)* as the current choice; all the available orientations are shown

3 The Interface Proposal

The interface proposed in this paper was designed following a standard methodology in *Human-Computer Interaction*, which focuses on the system users as the focal point of the whole development process. This is the *User Centred Design Methodology* (UCDM) [5], which consists of the following activities:

1. understanding and specifying the context of use,
2. specifying user and organisational requirements,
3. producing design solutions,
4. 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 [5]; in particular, [4] 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 of this section, we present our interface prototype, explaining how its design followed the UCDM activities.

3.1 The Context of Use

The context of use is the environment in which the project is developed, necessary to define the set and the type of intended users, tasks and environments in sufficient details so as to support the system design [5]. Therefore we analysed the background of the e-LIS project and the current online dictionary, studying the existing application domain, in particular, the e-LIS ontology. We decided not to entirely adhere to the e-LIS ontology [9], but to base our prototype on a smaller and more intuitive taxonomy resulting from the e-LIS ontology. Our simplification makes the new interface of the e-LIS dictionary more usable and closer to that of the current e-LIS dictionary. More precisely, we extracted and rendered the taxonomy of the following concepts of the e-LIS ontology:

1. handshape, used to define the configuration of the hand(s);
2. palm orientation component, which formalises the initial position of the hand(s);
3. location, used to define the part of the body with which fingers or hands contact;
4. one-hand movement component and relational movement component, used to define the movement of the hand(s) for one hand signs and two hand signs, respectively.

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

Our interface visually renders only the taxonomy of these concepts, without any concern about relations different from *is-a* ones.

As for the handshape concept, the e-LIS ontology follows and extends the classification of [13]; this is hardly intelligible by the average user of the dictionary. We thus decided to group the handshapes following the more intuitive criterion of the current e-LIS dictionary: the number of extended fingers. In our simplified ontology, we have 0-finger handshapes, 1-finger handshapes, and so on.

Such a simplified version of the e-LIS ontology is the basis of our interface.

3.2 User and Organisational Requirements

Starting from the analysis of the context of use, we determined functional, user and organisational requirements with two main goals in mind:

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

Users of the e-LIS dictionary are mainly deaf or hard-of-hearing people; according to some research findings, their ability of reading does not often go beyond that of a eight-year old child [11]; in particular, abstract concepts [3, 7] seem to be problematic for some deaf users. These are critical observations for the design of our e-LIS interface; e.g., our e-LIS interface must be highly visual. Moreover, not all deaf people have the same knowledge of LIS; in general, the average web user of the dictionary is likely not to know LIS at all; thus we did not assume that the dictionary web users have any prior knowledge of LIS.

Given such profiles, we turned to the design of our prototype interface and the tasks it supports: its users should be able to

1. specify the components of the sign they are searching for in an intuitive and clear manner,
2. transparently query the e-LIS database in order to retrieve the signs that match the sign components they selected,
3. interact with the results, that is, they can browse the results.

All the aforementioned tasks are carried on by exploiting the ontology; to this end, they are mapped into ontology interactions. At the current stage of the project, we decided to focus on the first task: the aim of our current interface is to simplify the composition of signs and to reach an interface usable by all the e-LIS users, whether hearing or deaf. The composition of sign can be performed by navigating the ontology; with our interface, the dictionary users see only the concepts related to their current choice.

Starting from the dictionary user profiles and the tasks of our interface, we set up 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 fast (e.g., mouse clicks are minimised) and 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 by using the e-LIS ontology and implementing a treemap visual technique.

3.3 Design Solutions

During the design solution activity, several mock-ups and prototypes are realised; designers and users analyse each version in order to highlight its pros and cons with respect to the usability goals of the interface.

Usually, designers start producing several mock-ups in order to evaluate the system from the functional perspective. When the final mock-up is usable, designers deploy the first prototype, representing the first version of the overall system. Designers, along with users, evaluate this prototype against several criteria. The idea of the design solution activity is to incrementally deploy the final system, since editing a prototype is better than editing the whole system.

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-up. Two screen-shoots of the current interface prototype are shown in Figs. 2 and 3.

The prototype presented in this paper is a visual interface designed to support the composition of a sign by navigating the e-LIS ontology. It is an *information visualisation* system, thus it is characterised by three main components [2]:

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

Visual metaphor. We adopt the tree metaphor as the visual metaphor, and in particular the *treemap*. The treemap visual technique [15] is shown in Fig. 2. Such a technique allows us to show a tree in a space-constrained layout, that is, the tree is turned into a planar space-filling map. Treemap uses the Shneiderman algorithm to recursively fill the available space with several areas. In our interface, the treemap technique visually renders the ontology classes and their subsumption relations.

Number of dimensions. We decided to use 3D as the number of dimensions in order to show the four Stokoe-based classes simultaneously: each treemap represents one Stokoe-based class or a subclass of its. Each treemap is embedded in a 3D plane, that is, a 3D treemap; the third dimension saves space and suggests the idea of a link between the classes.

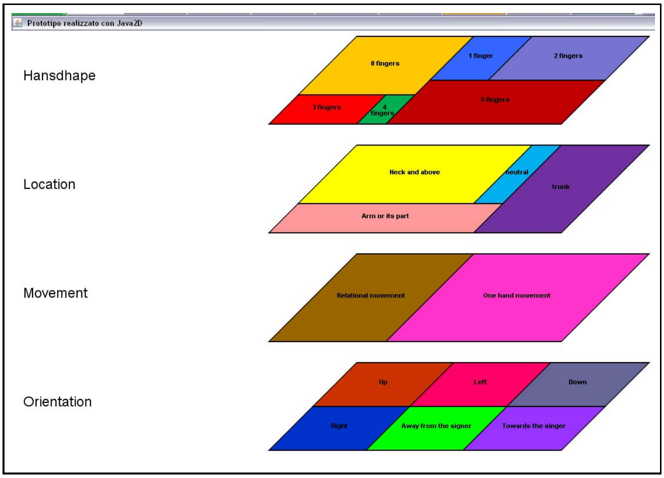

Fig. 2. The interface of the current prototype

Space-saving strategy. The space-saving strategy we adopt is the *focus* + *context* strategy [2]. In particular, in order to maintain the context, we introduce the miniatures of planes: by referring to Fig. 3, 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.

1. In the first step, in the left part, the interface visualises the four labels of the Stokoe-based 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. 2, 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.
2. From the second to the fourth and last step, the layout of the interface is 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 Fig. 3. In the left part, the interface visualises the four labels of the Stokoe-based 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.

In general, each treemap is composed of several areas, whose extents are computed with the Shneiderman algorithm [15]; the area's dimension is proportional to the number of child concepts the area represents. Each area in each treemap

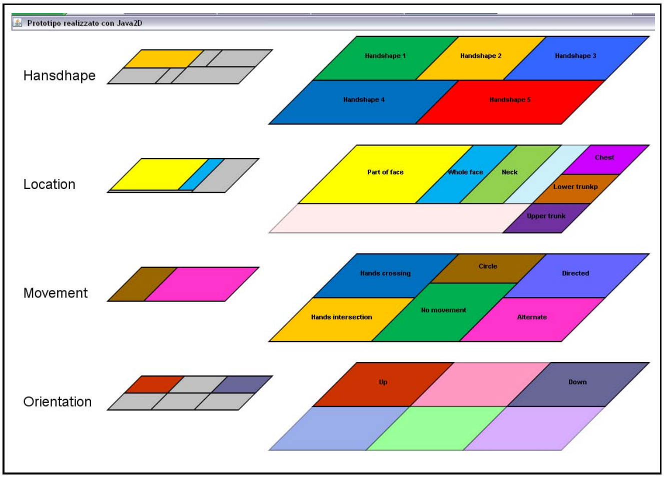

Fig. 3. The interface after the user has chosen the 1-finger handshape class

has a unique colour, because this visual feature is not used to convey a specific meaning — similar colours do not highlight related areas.

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 navigation of the e-LIS ontology is organised in steps. 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 click over a specific area. With the mouse-over effect, we gain the following benefits:

1. from the user's perspective, moving the mouse is less obtrusive than clicking with it, since the latter is the consequence of a conscious will to make a click;
2. 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 assume that in the first step, illustrated in Fig. 2, the user chooses the 1-finger concept. The second step is shown in Fig. 3; 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 users terminate the interaction with the treemaps and hence the navigation of the ontology, they have created a query with sign components.

4 Related Work

Electronic dictionaries for SLs offer numerous advantages over conventional paper dictionaries; they can make use of the multimedia technology, e.g., video can be employed for rendering the hand movements. In the remainder, we review available electronic dictionaries from an SL to the verbal language of the country of origin, which are of interest to our work.

The Multimedia Dictionary of American Sign Language (MM-DASL) [16] 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); search for signs is constrained via linguistic information on the formational components. Users are not required to specify all the sign's formational components, nevertheless there is a specific order in which they should construct the query. 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 [16]. For instance, platform independence of the system was a problem for MM-DASL; this is an issue the e-LIS team is taking into account, thus the choice of having the e-LIS dictionary as a web application. The profile of the expected user was never analysed, whereas e-LIS aims at a dictionary non-experts of LIS can use.

Woordenboek [8] 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 an SL.

5 Conclusions

The current e-LIS dictionary has innovative features. As explained in Sect. 2, e-LIS uses LIS as a self-explaining language, e.g., LIS videos are also employed to propose examples of the use of a sign, or its variants. The dictionary can also be used by non experts of the Stokoe-based transcription system of e-LIS, since the elements of the so-called Stokoe classes introduced in Sect. 1 are represented via expressive icons, hence neither transcribed nor explained in verbal Italian. The mix of these features makes the e-LIS dictionary usable also by people with literacy difficulties, as it may be the case of deaf people [11].

In Sect. 3, we presented an innovative interface for the e-LIS dictionary that retains the advantages of the current e-LIS interface and integrates the e-LIS ontology. By using this as the "hidden shepherd" in the search for a sign, our interface prototype allows for the minimisation of the user's selection errors: the user can only specify a sign which is consistent with the composition rules encoded in the ontology. In this manner, expert knowledge of neither the Stokoe transcription system nor LIS are required: even non experts can masterly look for signs in the dictionary.

Thanks to our visual interface, all the dictionary users can *transparently* navigate the e-LIS ontology. Our interface can also be integrated with a query tool such as [1]. Notice that the visual metaphor we adopted improves considerably on the text-based interface of this query tool; that is, our treemap interface is essentially visual hence closer to the needs of deaf people, who are visual learners [14]. In this manner, the interface can equally support deaf as well as hearing users during the interaction process; in this sense, we designed an expert visual system, following the UCDM criteria.

Our ontology-based interface allows our users to watch the propagation of a selection of sign components, that is, our users can watch how their selections affect the search path. In this manner efficiency gets improved; users "learn by navigating" hence the interaction process gets 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. Such a dynamic navigation interface effectively supports the decision-making process: the dictionary users can watch the propagation of their choices before committing to them.

The visual interface presented in this paper is still a prototype. As such, it has to be fully evaluated and studied with end-users, as stated in the UCDM [10]. In particular, we must perform usability studies with a sample of end-users, thus testing the robustness of the prototype, its drawbacks and its advantages.

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. Future work includes a deeper analysis of this topic, with an evaluation of the choice of such icons with our end-users.

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