E-Learning and Deaf Children: A Logic-Based Web Tool

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Abstract. LODE is a LOgic-based web tool for Italian DEaf children. LODE stimulate them to globally reason on an e-story written in a verbal language, such as Italian. In this paper, we focus on temporal reasoning; children are invited to reason on a temporally rich e-story through apt exercises and with the support of an automated reasoner. To the best of our knowledge, LODE is the first E-Learning tool for Italian deaf children that aims at stimulating global reasoning on whole e-stories.

Keywords: E-Learning platforms and tools; pedagogical issues.

1 Introduction

Learning to read and write effectively is a difficult task for deaf people: "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" [23]. According to some findings, their reading ability does not often go beyond that of an eight-year old child [19].

In particular, as highlighted in [3], deaf people tend to reason on single episodes and show difficulties in formulating global relations, such as temporal relations, between episodes of a narrative in a verbal language[1]. This attitude can also depend on the kind of "literacy interventions addressed to deaf children" which tend to "focus on single sentences and the grammatical aspects of text production" [3]. An innovative literacy e-tool for them should thus elicit global deductive reasoning on narratives: we aim at developing an E-Learning tool of this type, namely, LODE, a LOgic-based e-tool for DEaf children.

In this paper we restrict our attention to global reasoning with qualitative temporal relations. To assist the child in inferring the "correct" temporal relation, LODE employs an automated reasoner, namely, a constraint programming system. The essential background on automated temporal reasoning is provided in Sect. 2. The core part of this paper is Sect. 3, which presents the educational

[1] Here, the term *verbal language* refers to any oral-auditive language with words as lexical units; by contrast, *sign languages* are gestural-visual languages with signs as lexical units and no written form, and are mainly developed in deaf communities.

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tasks of LODE. Sect. 4 compares LODE to other E-Learning tools for deaf children, and Sect. 5 concludes with a preliminary assessment of our LODE prototype and an evaluation plan for LODE.

2 LODE and Automated Temporal Reasoning

Temporal Reasoning is a branch of Artificial Intelligence (AI) and involves the formal representation of time and a computational reasoning system for this. An instance of a temporal reasoning problem is provided in the following excerpt from a LODE tale, a simplified version of *The Ugly Duckling* by H.C. Andersen.

> Mammy duck is brooding: she has five eggs, four are small, and one is big. All of a sudden, while she is still brooding, the small eggshells crack and four little yellow ducklings peep out. Mammy duck watches the big egg but sees no signs of cracking... So she decides to keep on brooding. After some days, while she is brooding, also the big eggshell cracks and an ugly grey duckling peeps out...
> **Task:** *do the small eggshells crack* before *the big eggshell cracks?*

Here we adopt intervals as the primitive entities for *formally representing time*; each interval is uniquely associated with a time event. Between any two pairs of events, there is an *atomic Allen* relation, namely, a relation rel of the form

$$\mathsf{before}, \mathsf{meets}, \mathsf{overlaps}, \mathsf{starts}, \mathsf{during}, \mathsf{finishes}, \mathsf{equals}$$

or its inverse rel^{-1}; see Fig. 1 for an intuitive graphical representation of the atomic Allen relations between two events, $e1$ and $e2$. The Allen relations are

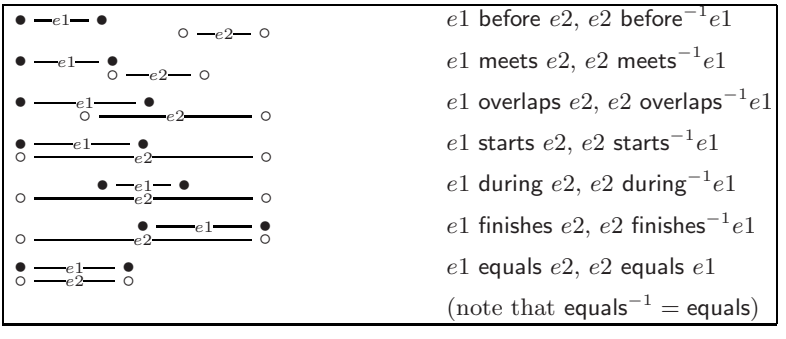

Fig. 1. The atomic Allen relations

employed whenever temporal information boils down to qualitative relations between events, such as "The small eggshells crack *while* Mammy duck broods"; in terms of the Allen relations, the sentence states that the relation "during" holds between the event "the small eggshells cracks" and the event "Mammy duck

broods". As *automated reasoning system*, LODE employs $\mathsf{ECL}^i\mathsf{PS}^e$, a constraint programming system [2]. Once a temporal reasoning problem is formalised in the language of $\mathsf{ECL}^i\mathsf{PS}^e$, it can be *solved* by this. For instance, $\mathsf{ECL}^i\mathsf{PS}^e$ can be invoked to solve the following tasks: to decide on "the big eggshell cracks after the small eggshells crack"; to infer all the Allen relations between the events "the big eggshell cracks" and "the small eggshells crack", implicit in the problem and consistent with it. For a survey on temporal reasoning and constraint programming, we refer the reader to [10].

3 LODE and Its Educational Tasks

Temporal global reasoning on texts written in a verbal language can be problematic for deaf children, as outlined in Sect. 1. LODE aims at tackling this issue with the help of famous stories for children. More precisely, LODE presents a list of e-stories the child can choose among. They are simplified versions of traditional children tales, such as *The Ugly Duckling*, so that the language is more suitable to an eight-year old deaf child; they are also enriched with explicit temporal relations so as to focus the attention of the child on temporal reasoning. The child has to choose a story from the list in order to begin his/her exercise session. We explain the educational exercises of LODE in Subs. 3.1 and outline the visual interface of LODE in Subs. 3.2.

3.1 Educational Exercises

Once the child chooses an e-story, he/she can start reading it. Words which are unusual for deaf children are explained in an e-dictionary of LODE; there, each word is illustrated by means of an image and a short textual explanation; example sentences are also available; future versions of LODE will also feature a translation of these words into Italian Sign Language (LIS). The dictionary simplifies the comprehension of the story and the association grapheme-meaning in beginning readers, a step which may be necessary with young deaf users.

Then the chosen story is presented, split across different pages. There are two or three sentences with an explanatory image on each page. Every few pages, the child starts a new exercise session for *reasoning* on the tale. LODE features two reasoning exercise types: comprehension; production.

Comprehension. In *comprehension exercises*, the child is presented with temporal relations connecting events of the story; the relations may be implicit in it. More precisely, the child is proposed four temporal relations; each relation corresponds to an atomic Allen relation. The child is asked to judge which relations are inconsistent with the text he/she has already read, playing the role of the 'teacher' who eliminates the incoherent ones. The four cases are constructed with the assistance of the $\mathsf{ECL}^i\mathsf{PS}^e$ automated reasoner to determine which temporal relations are (in)consistent with the narrative.

Production. In the *production exercises*, the children are shown scattered sentence units extracted from the given story; then he/she is asked to compose a

grammatically correct sentence with them, forming a temporal relation consistent with the story and which may be implicit in the story. For instance, suppose that the available sentence units are: BEFORE, WHILE, AFTER, MAMMY DUCK BROODS, THE DUCKS, SWIM. Two are the possible correct sentences the child can compose, consistent with the tale. The first one is: MAMMY DUCK BROODS BEFORE THE DUCKS SWIM. The second sentence is: THE DUCKS SWIM AFTER MAMMY DUCK BROODS. If the child composes a wrong sentence, because it is ungrammatical or inconsistent with the story, LODE will provide suggestions to correct the sentence with the help of the automated reasoner $\mathsf{ECL}^i\mathsf{PS}^e$ and a natural language processor for Italian.

The difficulty of the reasoning exercises increases with the portion of the story the child has to reason on. The first and simpler exercises relate two temporal events which occur in the portion of the tale, temporally rich, that the child has just read. If the score reached so far by the child is reasonably good, then LODE proposes the more challenging tasks, namely, those that require a deep global understanding of the story and the creation of global temporal relations: these exercises relate two temporal events, one of the current session and the other of a previous session—the farther is this session the more difficult is the exercise.

Moreover, note that the comprehension exercises focus on stimulating global inferences between events of the story; the production exercises demand this and something else, that is, to compose parts of the story. Therefore, the production exercises also aim at teaching children Italian grammar.

3.2 Visualisation

Deaf children are *essentially visual learners* [21], with (visual) learning strategies of their own; thus LODE employs cartoons and images for assisting children in the story narration and exercises. In a LODE story, each significant temporal event is illustrated with an image; this should help children in focusing on the temporal event and comprehending it; note that the visual aid is important because deaf children do not usually know tales[2]. As LODE is a tool for improving the reading capabilities of deaf children, the text is visually predominant so as to capture the child's attention.

An animated cartoon agent will also assist children through the different educational tasks; it will stimulate children with positive feedback to maintain their attention alive. As highlighted by Stokoe, quoted in [21], a sign language such as LIS and the verbal language of the same nation tend to be very different languages. As LODE aims at being an E-Learning tool for reasoning 'on' e-stories in a verbal language, its users are solicited to reason 'in' verbal Italian; thus instructions in the reasoning exercises are not provided in LIS. LIS videos will instead be employed in the dictionary as a support tool for LIS signers.

[2] Private communication with ENS, Italian National Institute for the Assistance and Protection of the Deaf.

The visual representation of the Allen relations in the comprehension exercises is still an open issue. In the remainder we present two visualisations, one is *textual*, the other is *spatial*; in both, each event is represented by means of an image. For an example, see Fig. 2. In the *textual visualisation*, the two images representing the events are connected by an arc labelled by one of the atomic Allen relations. This visualisation is easy to implement and compact in size; however, children must precisely understand the semantics of the Italian writing of the Allen relations. In the *spatial visualisation*, an atomic Allen relation between the two events is rendered by the spatial position of the relative images of the events along the timeline. Once the children get familiar with this visualisation, the semantics of the relations is likely to be more intuitive to them. Note that the two visualisations differently represent hence differently stimulate the reasoning of children on temporal relations: the spatial visualisation exploits spatial information and reasoning; the textual visualisation represents relations and stimulates reasoning on them with text only.

Fig. 2. A visual representation of the Allen temporal relation before with the textual method (on the left) and the spatial method (on the right)

4 Related Work

Currently, computer science research for deaf or hearing impaired people seems to mostly focus on applications for sign languages, such as LIS, e.g., [5, 15]. Considerable less attention seems to be devoted to the development of E-Learning tools for improving the literacy of deaf children in verbal languages. In the remainder, we overview some E-Learning tools for deaf children which are related to LODE.

In Italian. In Italy, three learning tools were developed in between 1997–1998 to tackle specific aspects of verbal Italian lexicon or grammar: *Articoli* [4] aims at teaching Italian articles (e.g., gender agreement); *Carotino* [6] is an interactive tool for teaching simple Italian phrases; *Pro-Peanuts* [20] deals with the correct use of pronouns. These tools are not developed only for deaf children.

We also found references to a tool developed in 1994, *Corso di Lettura* [8]; according to its specifications, the tool aims at improving the reading capabilities of hearing-impaired children. In order to facilitate the integration of a deaf

girl into an Italian primary school, teachers and students of the school created *Fabulis* [9], a collection of famous stories for children narrated using text and images, based on gestures and LIS signs. Another application born at school is *Nuvolina* [18], the result of a project realised in a fourth class of an Italian primary school: it is a multimedia tale with contents in Italian, English and French, written and spoken; the version in verbal Italian is also presented in LIS videos. Another bilingual tool is *Gli Animali della Savana* [1], a multimedia software based on text, images and videos, featuring an actor who translates the written text in LIS; assisted by a cartoon (a lion), the user navigates through a series of pages presenting the life of 10 wild animals. A more recent and ambitious project is *Tell me a Dictionary* [14, 22], the purpose of which is to offer both deaf and hearing children an interactive instrument to discover and compare the lexicon of LIS and Italian.

In English. The primary goal of ICICLE [13, 16] is to employ natural language processing and generation to tutor deaf students on their written English. ICICLE's interaction with the user takes the form of a cycle of user input and system response. The cycle begins when a user submits a piece of writing. The system then performs a syntactic analysis on the writing, determines its errors, and returns tutorial feedback to make the student aware of the nature of his/her errors.

CornerStones [17] is an approach to literacy development for primary-school children who are deaf or hard of hearing. Academic experts in literacy and deafness, and teachers of deaf students participated in its development. Cornerstones developers were most concerned with three key areas of literacy: first, identification of words in print, second, in-depth knowledge of words, and third, story comprehension. An essential element of Cornerstones is a story taken from the PBS's literacy series *Between the Lions*, complemented by versions of the story in American Sign Language and other visual-spatial systems for communicating with deaf children. Cornerstones developers evaluated their system with children and teachers and results of their evaluation demonstrated an increase in students' knowledge of selected words from pre-test to post-test.

FtL was not intended exclusively for deaf or hard of hearing children, but they have also been considered as potential users [7]. FtL is a comprehensive computer-based reading program designed to teach beginning and early readers to read accurately and fluently. It consists of three integrated components: (1) a Managed Learning Environment (MLE) that tracks and displays student progress and manages an individual study plan for each student; (2) Foundational Skills Reading Exercises, which teach and practice basic reading skills, such as alphabet knowledge and word decoding; (3) Interactive Books, which integrate human language and animation technologies to enable conversational interaction with a Virtual Tutor that teaches fluent reading and comprehension of text. Summative evaluation of FtL produced learning gains for letter and word recognition for kindergarten students.

Comparison. According to our overview of Italian and non-Italian projects for deaf children, LODE is the first web E-Learning tool that tackles literacy issues of deaf children which go beyond the syntax and grammar of a verbal language; that is, it addresses *global deductive reasoning* on whole e-stories, with the support of an automated reasoner.

5 Conclusions

This paper presented an innovative E-Learning tool for deaf children, namely, LODE: the tool aims at stimulating global reasoning on written e-stories. As outlined in Sect. 1, this is a problematic issue for many deaf children. In Sect. 3, we explained the educational exercises of LODE and the role of the automated reasoner in their construction and resolution; for a survey of the architecture of LODE, we refer to [11, 12]. In Sect. 4, we overviewed and compared E-Learning tools addressing literacy problems of deaf children. According to our overview and to the best of our knowledge, LODE is the first web-based E-Learning tool which aims at stimulating global deductive reasoning on whole e-stories in a verbal language. Currently, we are concentrating on global temporal reasoning; in the future, we are going to extend LODE to other kinds of global reasoning on narratives, addressing problems which may be critical for deaf children and that can be tackled with the assistance of an automated reasoner. LODE, now in prototype form, is being evaluated into three main phases. The first evaluation phase is almost over; a cognitive psychologist, a logopaedist, LIS interpreters and teachers for deaf children tested a preliminary version of LODE and provided us with positive informative feedback on its learning goals and strategies. The second and third evaluation phases will directly involve deaf children; the second phase will be done with the assistance of a teacher for deaf children; the third phase will involve children at home. The second evaluation phase tests the usability of LODE, in particular, it tests which is the most effective way of visually representing the Allen relations and the LODE exercises in general. The third evaluation phase aims at delivering the final design solution, focusing on the user's satisfaction.

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