LODE: Global Reasoning on E-Stories for Deaf Children

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Abstract. Due to a limited exposition to the language in its spoken form in their first years of life, deaf children lack the primary means of acquiring literacy skills. In this paper, we present LODE, a web-based interactive tool for the literacy of Italian deaf children. LODE proposes written e-stories and elicits children to globally reason on them through interactive exercises, developed with the support of an automated reasoner and a natural language processor. The LODE's users are also invited to collaborate and exchange their productions in an interactive manner.

Keywords: e-learning; automated temporal reasoning; adaptive technology.

1 Introduction

In the last years, research in deaf studies and computer science seems to mainly concentrate on applications for sign languages; 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. Less attention seems to be paid to e-learning tools for improving the literacy of deaf children in verbal languages. Our LOgic-based e-tool for DEaf children (LODE) belongs in this latter class. Due to a limited exposition to the language in its spoken form in their first years of life, deaf children lack the primary, natural means of acquiring literacy skills [20]. Deaf people tend to reason on single episodes but show difficulties in formulating coherent global relations, such as temporal relations, between episodes of narratives in a verbal language [3,15]. As reported in [3], 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". An innovative literacy e-tool for them should thus focus on eliciting global deductive reasoning on narratives.

LODE aims at taking this challenge over. LODE proposes written e-stories and solicits children to globally reason on each e-story; to assist the child in inferring coherent global relations between events, possibly distant in the e-story, LODE employs an automated reasoner, namely, a constraint programming system. In this paper, we focus on specific type of relations which seem problematic for deaf children [3], namely, temporal relations. LODE is structured as an e-learning web

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application to reach as many children as possible and promote their exchange of information.

In Sect. 2, we provide the necessary background on automated temporal reasoning; LODE is expounded in Sect. 3, and related to other e-tools for deaf children in Sect. 4. This paper concludes with an assessment of LODE in Sect. 5.

2 Automated Temporal Reasoning

Temporal Reasoning is a branch of Artificial Intelligence. 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 still brooding, also the the big eggshell cracks and an ugly grey duckling peeps out... *Do the small eggshells crack* before *the big eggshell cracks?*

Solving a temporal reasoning problem in an automated manner means choosing a formal representation of time and a computational reasoning system for it.

Time Representation. In LODE, we adopt intervals as the primitive entities for representing time; each interval is uniquely associated with an event. Between any two pairs of events, there is an *atomic Allen* relation, namely, a relation rel of the form before, meets, overlaps, starts, during, finishes, equals or rel^{-1}, where $^{-1}$ is the inverse operation. See Fig. 1 for an intuitive graphical representation of the atomic Allen relations. The Allen relations are usefully 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

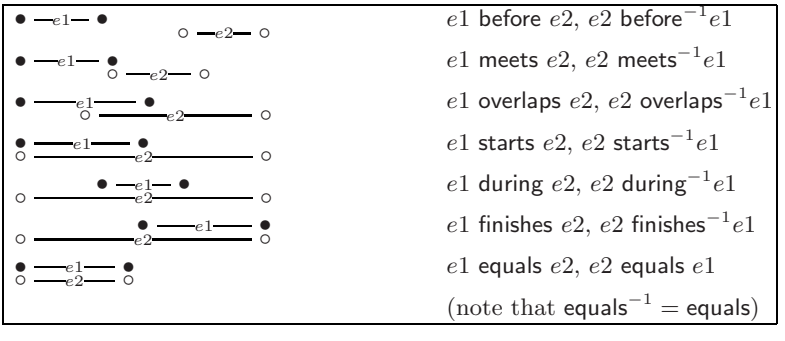

Fig. 1. The atomic Allen relations

relations, the sentence states that the relation during holds between the event "the small eggshells cracks" and the event "Mammy duck broods". Disjunctions of the atomic Allen relations represent uncertain information.

Constraint Programming. A temporal reasoning problem with the Allen relations can be formalised into a so-called *constraint problem*, as done in [1], using a suitable constraint programming language (e.g., CLP). Then a a constraint programming system (e.g., ECL^{i}PS^e) can be invoked to *solve* it. In this setting, to solve a problem means: to decide on the consistency of a relation with the story, e.g., before between "the big eggshells crack" and "the small eggshell cracks"; or to infer an/all the Allen relation/relations between two events, e.g., "the big eggshell cracks" and "the small eggshells crack", which are consistent with the story and implicit in it. The LODE's exercises rely on both these solving capabilities of a constraint programming system. For a survey on temporal reasoning and constraint programming, see [9]; for an introduction to constraint programming, see [2].

3 LODE

LODE presents a list of tales the child can choose among. They are short versions of traditional children tales, such as "The Ugly Duckling"; their language is simplified, so as to be adequate to a 8-year old deaf child, and temporally enriched, so as to focus the attention of children on temporal events. LODE addresses specific problems of deaf children with narratives in verbal Italian, as explained in Subsect. 3.1. It is developed having deaf children as its intended users, as explained in Subsect. 3.2. LODE is a web-based interactive application, and its architecture is discussed in Subsect. 3.3.

3.1 Educational Tasks

The child has to choose a story of LODE in order to start his/her work session. Then LODE proposes three different kinds of educational tasks, for: building a dictionary of difficult words; reasoning on the story; exchanging information.

Building a Dictionary of Difficult Words. The work session starts with an exercise presenting the most unusual words for deaf children, used in the chosen tale; they are abstract nouns, adjectives, or adverbs; single words are proposed on the screen together with an image and an example sentence explaining their meaning. This preliminary phase also facilitates the association grapheme-meaning in beginning readers, a step which may be necessary with young deaf users as they may ignore several words (e.g., abstract ones) which are known to their hearing peers. LIS videos can also be employed here to assist LIS native speakers.

Reasoning on the Story. Then the chosen fable is presented, split across different pages. Each page contains a sentence with an explanatory image for each significant temporal event. The narrative language is as simple as possible;

the text is visually predominant in comparison with the image so that the child gets stimulated to focus on it. Every few pages, the child starts a session of reasoning exercises. The level of difficulty of the exercises is graduated. The first exercises aim at helping children in comprehending and memorising the temporal sequence of events of the story. Then, gradually, the child is asked to resolve an exercise after more and more pages. In this manner, the amount of text that the child has to elaborate gradually increases. LODE has two main types of reasoning exercises: comprehension exercises; production exercises.

Comprehension. In comprehension exercises, the child is presented with four possible temporal relations connecting two distant events in the narrative. Each relation corresponds to an Allen relation and is visually represented as explained in Subsect. 3.2 below. For instance, one of these relations is "the small eggshells crack after the big eggshell cracks". 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 constraint-based automated reasoner to decide which temporal relations are (in)consistent with the story.

Production. If in the above type of exercises the amount of text is limited, the production exercises are essentially textual: the children are shown scattered words extracted from the tale; then he/she is asked to compose a grammatically correct sentence with these words, forming a temporal relation consistent with the story. For instance, suppose that the available words are: BEFORE, AND, THE, THE, TO, TO, DUCK, NEST, LAKE, GOES. Two are the possible correct sentences the child can compose, which are consistent with the story. The first sentence is: THE DUCK GOES TO THE LAKE AFTER THE DUCK GOES TO THE NEST. The second sentence is: THE DUCK GOES TO THE NEST BEFORE THE DUCK GOES TO THE LAKE. If the child composes a wrong sentence, because it is ungrammatical or inconsistent with the given narrative, LODE will provide suggestions to correct the sentence. This will be done with the help of the constraint-based automated reasoner and a natural language processor for Italian.

Exchanging Information. Last but not least, the users of LODE are invited to collaborate and exchange their productions in an interactive manner on the web via a blog.

3.2 Our Users

The users of LODE are children, thus LODE has to be entertaining and highly interactive; visual effects accompany and stress the different exercises, without hiding the main message. The visual appeal of the tales and exercises is fundamental in LODE for deaf children rely on visual learning [17]. A tutoring tool intended for them, such as LODE, should take those strategies into account, e.g., the significant events of a story are highlighted and illustrated. The same cartoons of the e-stories are employed to assist children through the different

educational tasks of LODE. Note that the visual information is essential also because we cannot rely on any prior knowledge of the stories: deaf children usually do not know them[1].

In particular, the visualisation of the Allen relations in the LODE's comprehension exercises is a critical feature of the tool, and it is still under evaluation. Currently, LODE adopts two visualisation methods: the textual method; the graphical method. With both methods, an event is represented by means of an image; this must be informative but essential, for too rich an image in terms of information may mislead the user. In the *textual method*, the two images representing the events are connected by an arc labelled by one of the atomic Allen relations. Here, children must precisely understand the semantics of the Italian writing of the Allen relations. In the *graphical method*, an atomic Allen relation between two events is rendered by the spatial position of the relative images along the timeline. Initially the child may have to spend some time in order to get acquainted with this method, which is however the more visually appealing.

As highlighted by Stokoe, quoted in [17], a sign language and the verbal language of the same nation tend to be very different languages. This is indeed the case of LIS and verbal Italian; each has its own lexicon, syntax and grammar. As LODE aims at being an e-learning tool for 'reasoning on' stories in verbal Italian, its users are solicited to 'reason in' verbal Italian; thus instructions in the comprehension and production exercises are not provided in LIS. Instead, in the exercises for creating a dictionary of the e-stories, LIS videos can be used as a support to LIS signers.

3.3 Architecture

LODE has a web-based client-server structure. Such an architecture makes LODE independent of the Operating System (OS); thus, the user is free to run LODE on the preferred OS with the preferred web browser. Second, it makes easier the updating of LODE without affecting the users (e.g., no need of installing new versions of LODE). Third, the web-based architecture promotes collaborative study: when they are on-line, the LODE users can work together and exchange their own stories or comments on LODE.

The client, a graphical user interface, is an AJAX application compatible with most web browsers. It works as the interface between the LODE user and the real system, the server, which runs on a remote machine. The server has a modular structure. The main modules are: 1) the *e-stories' database*, 2) the *Constraint-based Automated Reasoner* and 3) the *Natural Language Processor*.

1) The current stories' database is a simple repository structured as a file system. It contains temporally enriched versions of famous children stories, in XHTML format. Events and relations are tagged in XHTML à la TimeML [19], the main difference being that the used Allen relations can be non-atomic, e.g., see Fig. 2.

[1] Private communication with the Italian National Institute for the Assistance and Protection of Deaf People.

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<EVENT class="E1"> The small eggshells crack </EVENT>
<EVENT class="E2"> Mammy duck watches the big egg </EVENT>
<TLINK event="E1" relatedToEvent="E2" relType="before OR meets"/>
<EVENT class="E3"> The big eggshell cracks </EVENT>
<TLINK event="E2" relatedToEvent="E3" relType="before"/>
```

Fig. 2. A sample of a tagged story in LODE

2) The *Constraint-based Automated Reasoner* is composed of three main parts: a) ECL^{i}PS^e, a constraint programming system; b) the *knowledge base*, namely, an ECL^{i}PS^e program for reasoning with the Allen relations; c) the *domain knowledge*, consisting of constraint problems formalising the temporal information of the e-stories in the database. The Constraint-based Automated Reasoner is employed in the composition and production exercises to decide on the consistency of the relations set by children, or automatically infer new relations consistent with the e-story.
3) The *Natural Language Processor* will check if the user's sentences are grammatically correct in the production exercises.

4 Related Work

Currently, research in deaf studies and computer science seems to mostly revolve around applications for sign languages, such as LIS, e.g., see [5,12]. Considerable less attention seems to be devoted to the development of e-learning tools for the literacy of deaf children in verbal languages. This impression is confirmed by our overview of this type of e-learning tools. We present the main ones related to LODE in the remainder.

Italian Tools. In Italy, three systems were developed in the '90s to tackle different 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 [16] deals with the correct use of pronouns. None of these tools were developed exclusively for deaf children. There are several tools that aim at teaching stories to deaf or hearing-impaired children. Examples are: *Fabulis* [8], a collection of famous stories for children narrated using text and images, based on gestures and LIS signs; *Nuvolina*, a multimedia tale in Italian, English and French, written and spoken, and LIS via short videos. Another bilingual tool, employing LIS and verbal Italian, is *Tell me a Dictionary* [11,18], a multimedia series of six DVDs plus book volumes [11], to discover and compare the lexicon and syntax of verbal Italian and LIS.

English Tools. The primary goal of the ICICLE [10,13] researchers was 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: the user submits a piece of writing, the system performs a syntactic analysis on this and provides tutorial feedback. CornerStones [14] is a technology-infused

approach to literacy development for early primary children who are deaf or hard of hearing; 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. FtL [7] is a comprehensive computer-based reading program for teaching beginners to read with good comprehension. Its Interactive Books integrate human language and animation technologies to enable conversational interaction with a Virtual Tutor.

According to our overview, and to the best of our knowledge, LODE is the first web e-learning tool that tackles literacy issues of deaf children which go beyond the lexicon and grammar of a verbal language, that is: LODE addresses *global deductive reasoning* on stories, with the support of an automated reasoner.

5 Conclusions

In this paper we presented LODE, an e-learning tool addressing issues encountered in the written productions in verbal Italian of deaf children, as reported in Sect. 1. More precisely, LODE aims at eliciting children to globally reason on e-stories—not on isolated sentences—through a series of exercises which are expounded in Subsect. 3.1; currently, we are focussing on temporal reasoning, but in the future we may extend LODE to other kinds of global reasoning on stories, which can be critical for deaf children and can be tackled with the assistance of an automated reasoner. LODE is exclusively intended for deaf children, and we motivated why it is relevant to have it tailored to their learning strategies in Subsect. 3.2; there, we also proposed different visualisation strategies for the most difficult educational tasks. LODE is a web interactive application relying on automated reasoning (namely, constraint programming) and natural language processing; the advantages of its web-based architecture are discussed in details in Subsect. 3.3. In Sect. 4, we overviewed several e-learning tools for the literacy of deaf people. According to our overview and to the best of our knowledge, LODE is the first web e-learning tool which aims at stimulating global deductive reasoning on written narratives.

Currently, we are involving more actively logopaedists, cognitive psychologists, LIS experts and deaf children in our work in order to test and improve the educational tasks and design of LODE. In fact, according to our own experience, this is the only effective way for developing a tool interesting for our users.

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