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KRDB Research Centre Technical Report:

LODE
A Logic-based E-learning Tool for Deaf Children

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Abstract

Research carried out on deaf subjects point out that deaf people achieve verbal language literacy with difficulty, as demonstrated by the many and common mistakes that could be found in their written productions. In this paper, we present our preliminary proposal of a web-based interactive tool for Italian deaf children: LODE. The users of LODE are exclusively Italian children, with a scarce mastery of verbal Italian; in fact, deaf children are essentially visual learners, and a tutoring tool intended for them should take their specific needs and learning strategies into account. Deaf children will learn through meaningful tales and interactive exercises, with the support of an automated reasoner and a natural language processor. Last but not least, web users are invited to collaborate and exchange their productions in an interactive manner. LODE has also a specific focus: it aims at targeting reading comprehension issues, problematic for deaf children, related to global relations in fables written in verbal Italian. Here we focus on *temporal* relations and the creation of a coherent temporal network. We conclude with an overview of related e-learning tools for deaf children; to the best of our knowledge, LODE is the first tool for Italian deaf children tackling global comprehension issues of narratives with the assistance of an automated reasoner.

Contents

Chapter 1

Introduction and background

1.1 Introduction

LODE, a LOgic e-tool for DEaf children, is an e-learning web-based application for Italian deaf children. The proposal of LODE stems from the experience matured by the first author within the e-LIS project of EURAC (electronic bilingual dictionary Italian Sign Language–Italian) [14] and by the second author within PARLING (a CALL system for children) [23].

Deaf people seem to have problems in the comprehension of global relations in texts written in a verbal language; this is the case of temporal relations connecting temporal events spatially distant in a narrative. LODE aims at tackling such kind of issues related to the comprehension of global temporal relations. The envisioned user of LODE is an Italian child with a scarce mastery of verbal Italian. To assist the child in inferring the "correct" temporal relations between events in a narrative, LODE employs an automated reasoner, namely, a constraint programming system.

In the following sections, we provide the essential information on problematic issues related to verbal Italian encountered in the written productions of deaf children (Section 1.2), and background information on automated temporal reasoning with constraint programming (Section 1.3). We discuss LODE in Chapter 2 and relate it to other tools for deaf children in Chapter 3. We conclude this technical report with an assessment of our work in Chapter 4.

1.2 Literacy issues

Learning to read and write effectively is an extremely difficult task for deaf people. As they have no access or a very partial access to the verbal language in its spoken form in their first years of life, they 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" [29]. Therefore, they hardly acquire that competence of the language, which is almost intrinsic, and which would allow them to recognise between well-formed and ill-formed sentences.

Researches carried out on deaf subjects in Italian and English speaking countries point out that deaf people rarely achieve verbal language literacy, as demonstrated by the common mistakes traced in their written productions [11]. Their vocabulary is rather poor and characterised by lexical rigidity. They typically write short sentences and employ very simple syntactic structures; relative, subordinate and pronominal clauses are problematic for them, e.g., "the dog chased the girl had on a red dress" omitting "who", reported in [8], p. 82.

Given that information interchange via language is scarce in the first years of life, deaf people also seem to have problems in expressing global relations, formulating hypotheses and drawing inferences in verbal Italian. A reason for these difficulties regarding textual organization and conceptual coherence can be traced to their "poor knowledge of linguistic structures for verbal and written language" that "may interfere with their ability to organise ideas conceptually when producing [oral and] written narrative discourse" [4]. Obviously enough, this problem also involves the global comprehension of written texts to the effect that their ability of reading does not often go beyond that of a eight-year old child [24].

Taken that limited literacy skills is an obstacle to the plain integration of deaf minority into our society, our purpose is to develop an e-learning tool for deaf children, tackling the comprehension of global relations in narratives written in verbal Italian. More specifically, here we deal with global temporal relations.

1.3 Qualitative Temporal Reasoning

Temporal Reasoning is a branch of Artificial Intelligence (AI) at the intersection of planning, discourse analysis, natural language processing and understanding, knowledge representation, constraint programming,... As such, Temporal Reasoning involves the formal representation of time (see Subsection 1.3.1) and a computational reasoning system for reasoning about time (see Subsection 1.3.2). An instance of a 'simple' temporal reasoning problem is provided in the following excerpt from a LODE fable, 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 the big eggshell cracks and an ugly grey duckling peeps out... *Does the big eggshell crack* after *the small eggshells crack?*

1.3.1 The Allen Interval Algebra

Here we adopt intervals as the primitive entities for representing time; each interval is uniquely associated with an event—no distinction is made between events, intervals or fluents. Between any two pairs of events we have precisely one *atomic Allen* relation, namely, a relation of the form

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

or rel^{-1}, where rel is one of the above relations and rel^{-1} is the *inverse* of rel. See Figure 1.1 for an intuitive graphical representation of the atomic Allen relations. In his 1983 seminal paper,

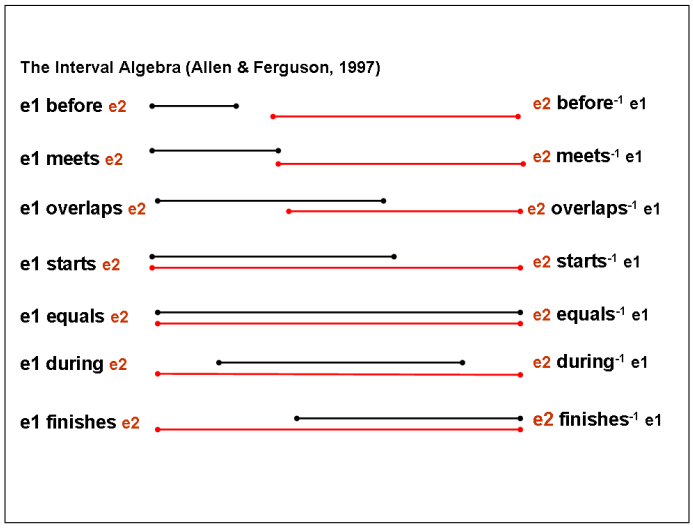

Figure 1.1: The primitive Allen relations.

Maintaining Knowledge about Temporal Intervals, Allen so motivated his representation of time:

> This representation is designed explicitly to deal with the problem that much of our temporal knowledge is relative, and hence cannot be described by a date (or even a fuzzy date).

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 relations, the sentence states that the relation during holds between the event "the small eggshells cracks" and the event "Mammy duck broods". As Allen arguments,

- his representation of time allows for "significant imprecision"; it is often the case that temporal knowledge is relative without relations to absolute dates;
- "uncertain information" can be represented by means of unions of the primitive Allen relations.

As for the latter, formally, let A denote the class of the Allen primitive relations. Then the class

$$2^A := \{\cup_{\mathsf{rel} \in S} \mathsf{rel} \mid S \subseteq A\}$$

form a relational algebra with the operations of *union* $\cup$, *composition*[1] $\odot$, and inverse. In particular, the composition operation lays at the basis of inferences among Allen relations. For instance, the composition before $\odot$ before is before; this means that

if event1 happens before event2 *and* event2 happens before event3
then event1 happens before event3.

[1] In database terms, composition corresponds to the natural join of two relations.

1.3.2 Constraint programming in a nutshell

Constraint programming originated from the logic programming community and has become a flourishing programming paradigm implemented in a number of heterogeneous environments, e.g., $\mathsf{ECL}^i\mathsf{PS}^e$ [3], a Constraint Logic Programming (CLP) system. The central notion of constraint programming is that of constraint (that is, a relation) involving finitely many variables each ranging over a domain of possible values. Given a reasoning problem, such as the temporal reasoning problem above, the constraint programmer formalises it as a *constraint problem* which is given by

- finitely many *variables*, $x_1, \ldots, x_n$,
- each ranging on a *domain* D_i of values (infinite or finite),
- and a set of *constraints*, namely, relations of the form $C \subseteq D_{i_1} \times \cdots \times D_{i_m}$. Then $s := i_1, \ldots, i_m$ is the *scope* of C.

Once a problem is formalised as a constraint problem in a suitable programming language, e.g., CLP, the problem can be "solved" by the chosen constraint programming system, e.g., $\mathsf{ECL}^i\mathsf{PS}^e$, by using general or domain specific methods. For an introduction to CLP and $\mathsf{ECL}^i\mathsf{PS}^e$ we refer the reader to [3].

In particular, $\mathsf{ECL}^i\mathsf{PS}^e$ can be used to solve a temporal reasoning problem involving the Allen relations, such as the problem of the fable in Subsection 1.3.1. To this end, first the fable is formalised as a constraint problem in CLP; then this and the CLP program encoding the Allen composition and inverse tables are loaded in $\mathsf{ECL}^i\mathsf{PS}^e$; finally $\mathsf{ECL}^i\mathsf{PS}^e$ is triggered to decide for us on "the big eggshell cracks after the small eggshells crack", or to generate the Allen relations between "the big eggshell cracks" and "the small eggshells crack" which are consistent with the fable.

For a survey on temporal reasoning and constraint programming, we refer the reader to [13].

Chapter 2

LODE

Our LODE tool has two precise goals: first, it is exclusively intended for deaf children, as explained more in detail in Section 2.1; second, it addresses specific comprehension problems encountered by deaf children with narratives in verbal Italian, as explained in Section 2.2. For each different task of LODE related to global reasoning with the Allen relations, we propose a different visualisation strategy as explained in Section 2.3. LODE is a web-based interactive application, its architecture is discussed in Chapter 2.4. An evaluation plan of LODE is described in Section 2.5.

2.1 Our users

The users of our tool are children, thus LODE narrates famous fables for children. The tool aims at being entertaining, goal oriented and highly interactive; visual effects accompany and stress the different educational tasks, without hiding the main message.

Contrary to other tools, such as Carotino [7] or Articoli [5], LODE does not rely on verbal Italian as the primary language for assisting users in their educational tasks. The rationale behind our choice is that the envisioned users of our tool are deaf children, only. Deaf children are *essentially visual learners* [26], with specific needs and (visual) learning strategies of their own. A tutoring tool intended for them, such as LODE, should take those needs and strategies into account; e.g., narratives are illustrated as sequences of animated images, and written text is be added subsequently to illustrate and enrich the narratives. Thereby cartoons are heavily employed to illustrate the narrative but also to assist children through the different educational tasks of LODE, as in [25, 30]. Note that the visual information is essential also because we cannot rely on any prior knowledge of the fables: deaf children usually do not know children fables[1].

As highlighted by Stokoe, quoted in [26], 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 verbal Italian, its users should be solicited to reason "in" verbal Italian; for instance, instructions are not provided in LIS, else our users may get confused and apply constructs and "reasoning patterns" typical of LIS to verbal Italian. LIS videos can instead be exploited for the feedback,

[1] Private communication with ENS, Italian National Institute for the Deaf-Dumb.

as a verification means of the users' productions.

In this way, children will learn in an inductive and implicit manner.

2.2 Educational tasks

2.2.1 Aims

As discussed in Section 1.2, deaf children (and adults as well) tend to have difficulties with global relations in texts written in verbal Italian, such as the formulation of coherent hypotheses and valid entailments. In particular, as experimented[2] in [4], written texts of deaf subjects are "causally less coherent than those of their hearing peers"; according to their findings, "deaf students seem generally sensitive to the causal organization of events in the narration but also unaware of the importance of a global organization for discourse or unable to organize events within a global causal discourse structures".

LODE aims at tackling such kinds of issues; more precisely, it aims at soliciting the comprehension of a narrative at a global level and the organisation of events, even 'distant' in the fable, in a coherent network. Here we focus on *temporal* Allen-like relations, hence on the creation of a coherent temporal network out of the fable. Thus children are not invited to reason on isolated sentences but on the global story, as explained in Subsection 2.2.2 below.

As mentioned above, deaf children are likely not to know the fables LODE proposes; thus a by-product of LODE will be that of teaching deaf children famous children fables.

Children are assisted and guided by LODE in all the exercises; e.g., they are shown the discourse elements they may use to compose their hypotheses or inferences. Feedback will be essential in motivating our users and maintaining their attention. Word games or other interactive games integrate the different sessions of LODE which are described below.

2.2.2 Exercises

LODE presents a list of fables the child can choose among. The fables are short versions of traditional children tales, such as "The Ugly Duckling". The child has to choose a fable from the list in order to start his/her work session.

Memorising difficult words

The work session starts with an exercise presenting the most unusual words for deaf children, used in the chosen fable; they could be (abstract) nouns, adjectives, or adverbs of the narrative. In this manner, the level of comprehension of the fable is simplified: single words are proposed on the screen together with an image explaining their meaning. Example sentences based on these

[2]The written narratives of 17 deaf high school students were compared with those of 2 groups of hearing writers: 17 high school students and 16 second graders. Participants were then asked to produce a written narrative on the basis of a picture book.

words could also be shown. This preliminary phase facilitates also the association grapheme-meaning in beginner 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 (see Section 1.2 above).

Reasoning on the narrative

Then the chosen fable is presented, split across different pages. There are two or three sentences with an explanatory image on each page. 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. Sometimes the image is totally absent.

Every few pages, the child starts a new exercise session in which he/she is invited to tackle an exercise. 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 narrative. 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.

We have two main types of exercises for reasoning on the narrative, described as follows.

Comprehension. In comprehension exercises, the child is presented with possible temporal relations connecting 'distant' episodes in the narrative. More precisely, the child is proposed four temporal relations (e.g., one of them is "the small eggshells crack after the big eggshell cracks"); each relation corresponds to an Allen relation and is visually represented as explained in Subsection 2.3.1 below. 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 automated reasoner $\mathsf{ECL}^i\mathsf{PS}^e$ to determine which temporal relations are (in)consistent with the narrative.

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 given narrative; then he/she is asked to compose a grammatically correct sentence with these words, forming a temporal relation consistent with the narrative. 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 given narrative. The first one 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 automated reasoner $\mathsf{ECL}^i\mathsf{PS}^e$ and a natural language processor for Italian.

Concluding remarks. As mentioned above, the difficulty of the exercises increases with the length of the fable the child has to read. In both comprehension and production exercises, LODE first proposes the 'simpler' exercises: these relate two temporal events which occur in the portion of the fable, temporally rich, that the child has just read. If the score of the child is

reasonably good with the simpler exercises, LODE proposes the 'more complex' 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. Finally, note that the comprehension exercises focus on stimulating global inferences between events spatially distant in the fable; the production exercises ask children something more, that is, to compose parts of the fable. Therefore the production exercises also aim at teaching Italian grammar.

Blog

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

2.3 Visualisation

2.3.1 Visualisation of the Allen relations for the comprehension exercises

In the following, we propose two visualisation methods for representing the Allen relations (see Section 1.3) which may hold between two events of a LODE fable. In both cases, each event is represented by means of an image. The chosen visualisations should allow a child watching the image to understand immediately which is a relation that holds between the two considered events. These types of representation are used in the comprehension exercises described above.

The textual method

According to the *textual method*, two events are represented by means of two images. The images must be chosen carefully, because each must unambiguously represent the respective event in order to avoid misunderstandings with the user. Connecting the images is an arc labelled by one of the atomic Allen relations. In the comprehension exercises described above, children are presented with four arcs each labelled by a distinct atomic Allen relation; then they need to choose which relations are (in)coherent with the part of the fable they have read. For instance, the relation "Mammy duck broods before the ducks swim" is represented as in Figure 2.1.

The envisioned advantages of the textual method are:

- it is easy to implement;
- it is compact in size; this feature is useful in case of multiple choices exercises.

The envisioned limitations of the textual method are:

- users must have precisely understood the semantics of the Italian transcription of the Allen relations;
- the selection process may not be intuitive.

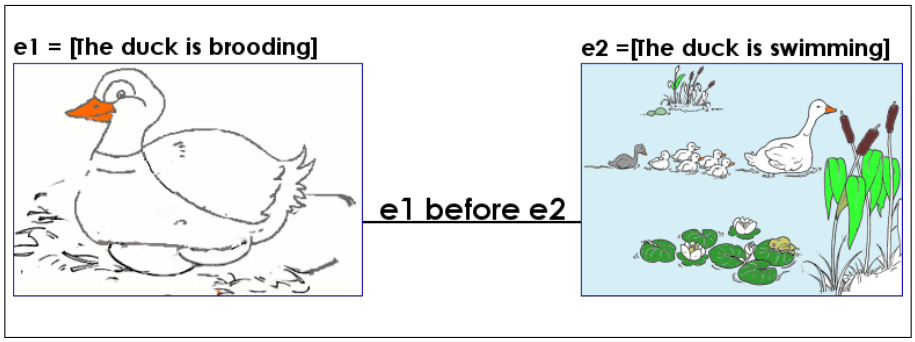

Figure 2.1: An instance of the visual representation of an Allen temporal relation using the textual method.

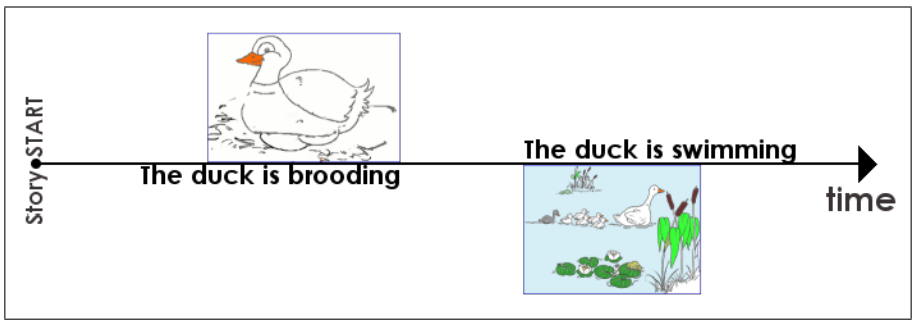

Figure 2.2: An instance of the visual representation of an Allen temporal relation using the graphical method.

The graphical method

The *graphical method* is still based on the use of an image for each event. However, in this case, the temporal relation between the two considered events is rendered by means of the relative position of images along a time line. For instance, the relation "Mammy duck broods before the ducks swim" is represented as in Figure 2.2. For the general picture, see the left image in Figure 2.3.

The envisioned advantages of the graphical method are:

- it is not necessary to read any text to select an Allen relation between the two considered events;
- once the children get familiar with the representation, the semantics of the relations is more visual hence likely to be more intuitive for deaf children.

The envisioned limitations of the graphical method are:

- it takes too large a part of the navigation window;
- it could be necessary to have a short training before the user can confidently tackle the LODE exercises, that is, the user may have to spend some time in order to get acquainted

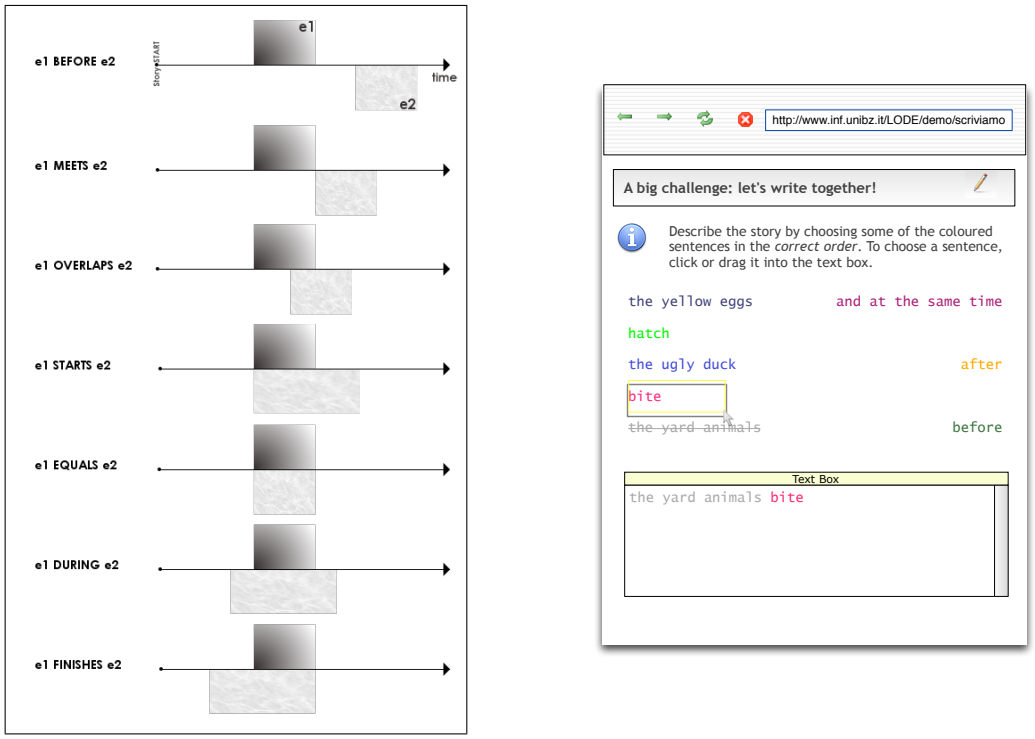

Figure 2.3: Visual representation of the Allen atomic relations using the graphical method on the left. An instance of a production exercise on the right.

with the visual representation of the Allen relations, illustrated in the left image in Figure 2.3.

2.3.2 Visualisation of the production exercises

A visualisation of the production exercises is in the right image in Figure 2.3. The child composes a sentence describing the fable by selecting some of the coloured sentences; he/she can select each coloured sentence by clicking it or dragging it into the text box. In case of mistakes, feedback will be presented in the same window.

2.4 Architecture

LODE has a web-based client-server structure (see Figure 2.4.1). We opt for this architecture for several reasons. First, it allows for the design of a system independent of the computer Operating System (OS). Therefore, users are free to run LODE on the preferred OS with their preferred web browser. Second, it makes easier the updating of the entire system; new features can be implemented in LODE without involving the users (e.g., no need of installing new versions of LODE). Third reason for using a web-based structure is that this promotes collaborative study: LODE users can work together when are on-line and exchange their own stories, comments or

feedback on LODE.

2.4.1 Client-server

The client, a graphical user interface, in short a GUI (see Figure 2.4.1), is an AJAX application compatible with most web browsers, e.g., Firefox-Mozilla, Internet Explorer, Safari, Opera. It works as the interface between the LODE user and the real system, the server, which runs on a remote machine.

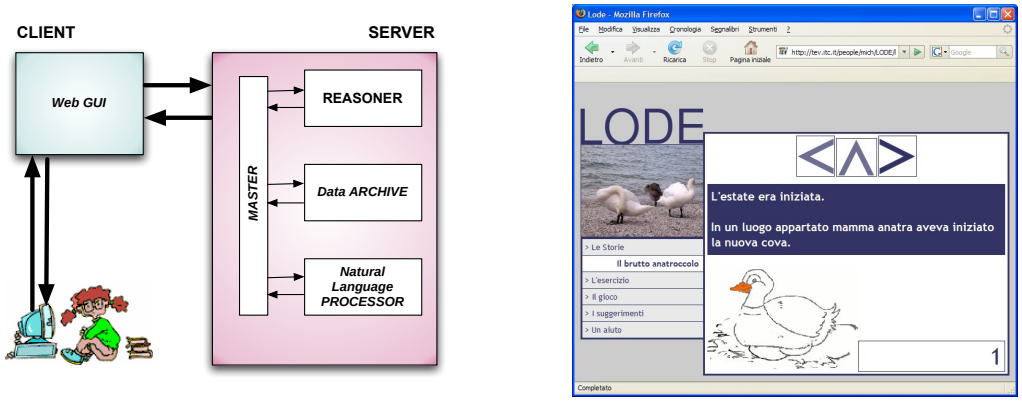

Figure 2.4: LODE: the architecture on the left and a screen-shot of a client session on the right.

The server has a modular structure. The main modules are: 1) the *fables' database*; 2) the *Automated Reasoner* and 3) the *Natural Language Processor* (see Figure 2.4.1).

In the first LODE prototype, the fables' database is a simple textual file repository, structured as a file system. In future and richer versions of LODE, the database may be organized as a relational database, if necessary.

The *Automated Reasoner* is composed of three main parts: a) ECL^{i}PS^e, the CLP system; b) an ECL^{i}PS^e program with the inverse and composition tables for the Allen relations; c) a knowledge base, consisting of constraint problems formalising the temporal information of the fables from the database.

The *Natural Language Processor* is under development at ITC-irst, Trento.

Working together, these modules serve to construct the exercises and elaborate the user's productions as explained below.

2.4.2 The automated reasoner, the natural language processor and the exercises

Children find in LODE simplified versions of famous children fables, such as *The Ugly Duckling*. Each fable is simplified so that the language is more suitable to 8-year old deaf children. Besides, the fable is enriched with explicit temporal relations. Then this simplified 'temporally-rich' fable has to be formalised as a constraint problem.

In this manner, we can use a constraint programming system to reason on it. The automated reasoner, that is, ECL^{i}PS^e is employed in the composition and production exercises to decide on the correctness of the inferences drawn by children. To explain the formalisation into a constraint problem, we consider a simple instance of a temporal reasoning problem from the LODE excerpt of Subsection 1.3.1.

> The big eggshell cracks after Mammy duck broods all her eggs; the small eggshells crack while Mammy ducks broods all her eggs. *Do the small eggshells crack after the big eggshell cracks*?

The above problem consists of 3 temporal events:

- G standing for "the big eggshell cracks",
- P standing for "the small eggshells crack",
- M standing for "Mammy duck broods all her eggs".

The corresponding constraint problem has three variables

- X_{GM} whose domain D_{GM} is the set of all temporal relations between **G** and **M**,
- X_{PM} whose domain D_{PM} is the set of all temporal relations between **P** and **M**,
- X_{GP} whose domain D_{GP} is the set of all temporal relations between **G** and **P**.

and constraints of two types:

1. constraints formalising the temporal relations in the above statement are $X_{PM} = \mathsf{during}$ and $X_{MG} = \mathsf{before}$;
2. for each ordered triple of the events G, P, M, a constraint, say $C(G, P, M)$, on the variables X_{GP}, X_{PM}, X_{GM}. For instance:

$$C(G, P, M) := \mathsf{allen\_composition} \cap \big(D_{GP} \times D_{PM} \times D_{GM}\big).$$

The question/relation "the small eggshells crack after the big eggshell cracks" is formalised as the constraint $\mathsf{before} \in x_{PG}$. ECL^{i}PS^e can then be invoked, loading a CLP program encoding the Allen composition and inverse relations (e.g., see [2]); given this and the knowledge base consisting of the temporal constraints above, ECL^{i}PS^e can state that $\mathsf{before} \in x_{PG}$ is consistent with them, that is, the relation "the small eggshells crack before the big eggshell cracks" is consistent with the narrative. While ECL^{i}PS^e detects that "the small eggshells crack after the big eggshell cracks", formalised as $\mathsf{after} \in x_{PG}$, is inconsistent with the narrative.

The formalisation is also used by the natural language processor to assist children in the production exercises.

	Phase 1	**Phase** 2	**Phase** 3
Users	30 deaf and hard of hearing children; 30 hearing children	15 deaf and hard of hearing children, aged 8–12	15 or more deaf and hard of hearing children, aged 8–12
Method	the two user groups use a demo of LODE employing the different visualisations of the exercises	a LODE prototype is tested with a compact yet effective test	pre-test and post-test design
Evaluation	video, log files, questioners	video, log files	log files

Table 2.1: Evaluation of LODE.

2.5 Evaluation

The LODE system will be evaluated into three different phases—see Table 2.1.

The first evaluation phase will check which is the most effective way of visually representing the Allen relations and the exercises in general (see Section 2.3). The second evaluation phase will test the usability of LODE. The third evaluation phase will test the effectiveness of LODE.

Chapter 3

Related work

Artificial Intelligence (AI) methodologies and tools offer great opportunities for hearing impaired children. Current research in computer science seems to mostly focus on applications related to sign language, such as Italian sign language (LIS, *Lingua Italiana dei Segni*); e.g., for its transcription, writing, recognition and teaching see [6, 17]. Considerable less attention seems to be devoted to the development of e-learning tools for improving the literacy of deaf children. Our first analysis of the scientific literature confirmed our impression: we could find references only to eight e-learning applications of that sort currently available in Italy.

In the remainder of this chapter, we overview these e-learning applications and several non-Italian projects which are relevant for our work. Alas, we could not find for all assessments of their effectiveness with respect to their goals. Therefore, ours is not a technical review; rather, it is a compact description of those tools and their respective aims—see also Appendix A, p. 24, for their detailed list.

3.1 Italian Tools

Three systems were developed in between 1997–1998 to overcome specific problems with verbal Italian grammar:

- *Articoli* [5], which aims at teaching Italian articles and their use (e.g., gender agreement);
- *Carotino* [7], an interactive tool for teaching simple Italian phrases; the child is shown an image (e.g., a flower) and is prompted with simple questions such as what-questions (e.g., "what is it?"); in case the child writes an ungrammatical answer, he/she is invited to reformulate it;
- *Pro-Peanuts* [25], which aims at teaching the correct use of pronouns.

Furthermore, we have found references to a tool developed in 1994, *Corso di Lettura* [10]; 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* [12], a collection of famous fables for children narrated using text and images, based on gestures and LIS signs.

Another application born at school is *Nuvolina* [22], the result of a project realised in a fourth class of an Italian primary school. Also in this case, the project aimed at integrating a deaf girl into the class. *Nuvolina* is a multimedia tale with contents in Italian, English and French, written and spoken. The version in verbal Italian is also presented in LIS by means of short 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. The child can also answer questions and record his/her notes on a personal notebook page.

A more recent and ambitious project is *Tell me a Dictionary* [28, 16], the purpose of which is to offer both deaf and hearing children an interactive and enjoyable instrument to discover and compare two very different languages, LIS and Italian. *Tell me a Dictionary* is a multimedia series of six DVDs plus book volumes. The vocabulary is presented "through stories and sentences that project both languages as living languages, thanks also to a lively 8-minute animated cartoon, signed and spoken narration, Italian with subtitles, vocabulary building games and a glossary that takes you back to the vocabulary items in the DVD" [16]. The first volume is the only one developed so far and currently in use.

3.2 Non-Italian Projects

In this section we introduce some non-Italian projects which aim at improving the literacy of deaf or hard of hearing children in the verbal language of the country of origin. The goals of these tools are closer to the LODE's ones.

3.2.1 ICICLE

ICICLE (Interactive Computer Identification and Correction of Language Errors) [15, 20] aims at tutoring deaf students whose native language is American Sign Language (ASL). ICICLE has been developed from the NLP/AI Group at the CIS Department of the University of Delaware, USA.

The primary goal of the ICICLE researchers 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 to be reviewed by the system. The system then performs a syntactic analysis on this writing, determines its errors, and constructs a response in the form of tutorial feedback. This feedback is aimed towards making the student aware of the nature of the errors found in the writing and giving him or her the information needed to correct them. ICICLE's research areas include:

- the development of the user model [18, 19];
- the use of machine learning to train a text planning model to replace the canned explanations;
- the implementation of a dialogue interface;
- the development of a spell-checker algorithm with rules modified by those in "aspell" in order to capture the unique spelling behavior of the user population;
- the integration of explanatory material as video-recorded ASL performed by an ASL interpreter, and the investigation of "signing avatars" to incorporate sign language instructions generated by the tutorial component of the system.

3.2.2 CornerStones

The second project we overview is CornerStones [21], developed at the Carl and Ruth Shapiro Family National Center for Accessible Media (NCAM), a research and development facility dedicated to the issues of media and information technology for people with disabilities in their homes, schools, workplaces, and communities.

Cornerstones is a technology-infused approach to literacy development for early primary children who are deaf or hard of hearing. Academic experts in literacy and deafness, along with teachers of deaf students participated actively in developing an instructional tool that is demanding, engaging, research-based, and flexible for use with children who have a range of backgrounds, communication needs, and skills. Cornerstones developers are 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, such as Signing Exact English and cued speech. Other materials include a hypertext version of the story, an electronic storybook where children can click on a word to see a picture, an example, or an other meaning; clip art of target words; and supplementary games and activities. A guide for teachers includes a day-by-day sequence of rigorous learning objectives and lessons, with recommended instructional practices. Cornerstones developers evaluated their system with children and teachers. Results of their evaluation demonstrated an increase in students' knowledge of selected words from pre-test to post-test. Teachers participating in the evaluation's phases also judged Cornerstones effective for improving literacy skills.

3.2.3 FtL

Another interesting project aiming at improving students' literacy is the Foundations to Literacy (FtL) project, developed at the Center for Spoken Language Research (CSLR, University of Colorado) in collaboration with other research centres.

FtL has not been developed for deaf or hard of hearing children, but this type of users has also been considered [9]. FtL is a comprehensive computer-based reading program that has

been designed to teach beginning and early readers to read accurately, fluently and with good comprehension. It provides the pedagogical foundation for effective learning experiences for ELL students through the following features.

- Marni, an engaging, lifelike animated character, instructs and supports the student through a sequence of learning activities. Marni produces natural (recorded) speech accompanied by accurate lip movements, head movements and facial expressions.
- The program proceeds through a set of learning exercises that build on each other, and the sequencing of learning tasks are based on scientific research. The program teaches foundational reading skills until accuracy is assured, and then presents speeder tasks so these skills become automatic and unconscious.
- The program emphasises phonological awareness and decoding skills, which research shows are just those skills that require extra intensive practice for many children with reading challenges.
- The program's study plan continually modifies pacing, presentation of material, and progress through the program based on the student's performance on the learning tasks. Thus, students who learn quickly can move rapidly through the program, with periodic "reviews" to assure that skills have been retained and generalise to new stimuli, while students who have difficulty learning will receive continued practice on a focused set of skills within a variety of complementary learning exercises and books. The program continuously adjusts the pacing of activities and the number of response alternatives provided based on the student's performance.
- Children spend significant time listening to and reading interesting books that are aligned with the learning exercises in terms of both vocabulary and content, so that skills learned in the exercises are practiced and reinforced in books.

FtL 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, providing the foundation for fluent reading;
3. Interactive Books, which represent the state of the art in integration of 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 significant learning gains for letter and word recognition for all measures for kindergarten students. Surveys administered individually to students demonstrated that students were able to produce informative and discriminative responses to the program. Overall, students were highly enthusiastic about the program and their interactions with Marni. In general, also teachers participating in the evaluation phase were positive about the program.

3.2.4 Comparison

According to our survey of Italian and non-Italian projects for deaf children, LODE is the first web-based e-learning tool tackling literacy issues of deaf children which go beyond the syntax and grammar of the verbal language of the country of origin; in fact, LODE aims at stimulating global deductive reasoning—in particular temporal reasoning—on narratives. This is a distinguishing feature of LODE that is made possible through the use of an automated reasoner in the form of a CLP system, namely, ECL^{i}PS^e(see Chapter 2).

Table 3.1 offers a comparative analysis of LODE with the principal and assessed tools for the literacy improvement of deaf children.

	ICICLE	**Cornerstones**	**FtL**	**LODE**
Content type	user's input	famous stories	interactive books	famous stories
Use of sign language	yes	yes	no	planned
Dialogue interface	yes	no	yes	yes
Reading comprehension	no	no	yes	yes
Active feedback	yes	no	no	yes
Syntax/grammar analysis	yes	no	no	planned
Speech recognition	no	no	yes	no
Global deductive reasoning	no	no	no	yes

Table 3.1: Tools for literacy improvement: a comparative synthesis

Chapter 4

Conclusions

In this paper we overviewed problematic issues encountered in the written productions in verbal Italian of deaf children and related to global deductive reasoning (Section 1.2). Here we cannot analyse further problems or studies concerning the written productions of deaf people; for issues related to this, and the differences between written and oral productions of deaf people, the interested reader may consult the related literature [8, 27].

Then, in Chapter 2, we presented our proposal of an e-learning web-based application for deaf children: LODE. The tool is exclusively intended for (Italian) deaf children, and we motivated why it is relevant to have it tailored to their specific learning strategies and needs in Section 2.1. Our LODE tool addresses specific global reasoning problems encountered by deaf children with narratives in verbal Italian. In this report, we focused on temporal reasoning problems; in the future, we may extend LODE to other kinds of global reasoning problems on narratives, which are critical for deaf children. Section 2.2 presents the tasks LODE proposes and their expected learning outcomes. For the most difficult tasks of LODE we propose different visualisation strategies, explained in Section 2.3.

LODE is a web-based interactive application relying on automated reasoning and natural language processing tools; its architecture is discussed in details in Section 2.4. An evaluation plan of LODE is described in Section 2.5.

Finally, in Chapter 3, we overviewed and compared e-learning tools addressing literacy problems of deaf children, currently available in Italy and abroad. 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 Italian verbal narratives.

Currently, we are involving more actively logopaedists, LIS experts and deaf children in our work in order to test and improve the 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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Appendices

Appendix A

This appendix is a list of e-tools for improving the literacy of verbal Italian of Italian deaf children.

Tools for learning Italian grammar

ARTICOLI

- **Aim**: to teach Italian articles and their correct use.
- **Description**: it consists in a sequence of exercises.
- **Demo**: `http://www.anastasis.it/AMBIENTI/NodoCMS/CaricaPagina.asp?ID=36`.
- **Year**: 1997.
- **Users**: Italian deaf children.
- **Design and development**: ASPHI in collaboration with Coop. ANASTASIS, Azienda USL - Città di Bologna, Regione Emilia Romagna.

CAROTINO

- **Aim**: to teach user the proper use of some function words.
- **Description**: a cartoon helps user in navigating through linguistics interactive exercises, with the support of images.
- **Demo**: `http://www.anastasis.it/AMBIENTI/NodoCMS/CaricaPagina.asp?ID=40`.
- **Year**: 1997.
- **Users**: 7-year to 14-year old Italian deaf children.
- **Design** and development: by G. Guidicini (Club Insieme), ASPHI, Anastasis, Italy.

PRO-PEANUTS

- **Aim**: to teach the use of pronouns.
- **Description**: an academic product for multimodal grammar learning. It is based on the use of cartoon. It has a simple help interface.
- **Demo**: `http://www.ciscl.unisi.it/persone/chesi/laurea/propeans/propeans.zip`.
- **Year**: 1997.
- **Users**: Italian deaf children
- **Design and development**: Chesi C., Tosi A., Rizzo A. - University of Siena

Tools for improving reading ability

CORSO DI LETTURA

- **Aim**: to offer a complete path for improving the reading ability of hearing impaired children that have difficulties in speaking already at the end of their kindergartens. It mainly aims at teaching the correct correspondence between phonemes and graphemes.
- **Description**: a product proposing pre-reading exercises (for developing visual attention, for image recognition, for developing logic-spatial capabilities and a good organization of the ocular-motor coordination). Other proposed exercises are related to the use of the alphabet letters and to the use of pronouns.
- **Demo**: `http://www.anastasis.it/AMBIENTI/NodoCMS/CaricaPagina.asp?ID=35`.
- **Year**: 1994.
- **Users**: 3-year to 11-year old Italian deaf children.
- **Design and development**: ASPHI in collaboration with Coop. ANASTASIS and Regione Emilia Romagna.

Tools for bilingual learning

GLI ANIMALI DELLA SAVANA

- **Aim**: to help deaf children with literacy difficulties.
- **Description**: a multimedia software based on text, images and videos, presenting an actor that translates the text content in LIS. With the help of a cartoon (a lion), the user can navigate through a series of pages, presenting the life of 10 wild animals. The child can also answer some questions and take notes on a personal notebook page.
- **Demo**: distributed by Opera Multimedia, Milano.
- **Year**: 1994.

- **Users**: deaf and hearing Italian children, of age varying from 6 to 14.
- **Design and development**: Ist. di Psicologia, CNR.
- **Review**: by Luciano Rosso. Retrieved October 24, 2006 from http://www.areato.org/noquadri/ausiliDinamici/AusDnm_00_Titolo.Asp?IDAUSILIO=106&FORMATO=G.

FABULIS

- **Aim**: to facilitate the integration of deaf children in classes of hearing children. Its aims are also: to improve the linguistic knowledge of deaf children, to help their imagination development and in acquiring a new linguistic code.
- **Description**: the tool presents some famous children tales by means of text, images and LIS signs.
- **Demo**: http://www.bonavitacola.net/fabulis/
- **Year**: 2000/2003.
- **Users**: Italian children going to the primary school.
- **Design and development**: Circolo Didattico di via Russo, Milano.
- **Review**: by Luciano Rosso. Retrieved Octorber 24, 2006 from http://www.areato.org/noquadri/ausiliDinamici/AusDnm_00_Titolo.Asp?IDAUSILIO=406&FORMATO=G.

NUVOLINA

- **Aim**: to facilitate the integration of a deaf girl into a class of hearing children.
- **Description**: a multimedia story with contents in Italian, English and French, written and spoken. The version in Italian is also presented in LIS by means of short videos.
- **Demo**: http://www.areato.org/noquadri/ausiliDinamici/AusDnm_01_Dettaglio.Asp?IDAUSILIO=229&IDSEZIONE=5&FORMATO=G&VETRINA=N.
- **Year**: 1998.
- **Users**: children of primary schools.
- **Design and development**: it is the result of a project realized in a fourth class of an Italian primary school.
- **Review**: by Luciano Rosso. Retrieved October 24, 2006 from http://www.areato.org/noquadri/ausiliDinamici/AusDnm_00_Titolo.Asp?IDAUSILIO=229&FORMATO=G.

TELL ME A DICTIONARY

- **Aim**: to offer deaf and hearing children an interactive and enjoyable instrument that allows them to discover and compare two very different languages, LIS and verbal Italian.

- **Description**: a multimedia DVD + book series; the vocabulary is presented through stories and sentences (cartoon, signed and spoken narration, Italian with subtitles, games, a glossary).
- **Demo**: `http://www.lismedia.it/demo01/home.html`.
- **Year**: 2005.
- **Users**: Italian deaf children.
- **Design and development**: Ente nazionale sordomuti [Ens] and Istituto statale di istruzione specializzata per sordi "A.Magarotto" [Isiss], with the collaboration of the Mason Perkins Institute, the contribution of Digisys and the Municipality of Rome.

Non-Italian Tools

ICICLE (Interactive Computer Identification and Correction of Language Errors)

- **Aim**: to employ natural language processing and generation to tutor deaf students on their written English.
- **Description**: the target learner group for ICICLE is native or near-native users of American Sign Language (ASL). At first they designed a user model incorporating a representation of the language acquisition process for this type of users. Then they developed the error identification module, that uses this model to determine between multiple interpretations of a sentence which may correspond to different perceived errors in the text.
- **Web site**: http://www.eecis.udel.edu/research/icicle/.
- **Year**: 2000-2005
- **Users**: American deaf children.
- **Design and development**: NLP/AI Group at the CIS Department of the University of Delaware, USA.

CORNERSTONES

- **Aim**: designing a system for literacy development of early elementary children who are deaf or hard of hearing.
- **Description**: Academic experts in literacy and deafness, along with teachers of deaf students helped us develop an instructional approach that is demanding, engaging, research-based, and flexible for use with children who have a range of backgrounds, communication needs, and skills. Cornerstones is most concerned with three key areas of literacy:1. Identification of words in print; 2. In-depth knowledge of words, and 3. Story comprehension.
- **Demo**: http://pbskids.org/lions/cornerstones/
- **Year**: 1998-2003
- **Users**: American deaf or hard of hearing children.

- **Design and development**: the Carl and Ruth Shapiro Family National Center for Accessible Media (NCAM), Boston, MA. USA.

FtL (Foundations to Literacy)

- **Aim**: Teaching Reading to Beginning Readers
- **Description**: FtL is a comprehensive computer-based reading program that has been designed to teach beginning and early readers to read accurately, fluently and with good comprehension. It provides the pedagogical foundation for effective learning experiences for ELL students.
- **Web site**: http://cslr.colorado.edu/beginweb/ftl/ftl.html
- **Year**: 2000-at present
- **Users**: kindergarten, first grade and second grade students.
- **Design and development**: CSLR (Center for Spocken Language Research).University of Colorado. USA

Appendix B

Examples of stories. The language need to be simplified and implicit temporal relations have to be made explicit.

Il brutto anatroccolo, *H.C. Andersen*

L'estate era iniziata. In un luogo appartato mamma anatra aveva iniziato la nuova cova.

Il tempo le passava molto lentamente ed era impaziente di vedere uscire dal guscio la propria prole. Finalmente, uno dopo l'altro, i gusci scricchiolarono e lasciarono uscire alcuni adorabili anatroccoli gialli.

Solo l'uovo più grande non si era ancora schiuso. Si mise allora a covarlo nuovamente con aria contrariata. Finalmente il grosso uovo si aprì e lasciò uscire un grande anatroccolo, brutto e tutto grigio.

Il giorno seguente l'anatra portò la sua piccola famiglia ad un vicino ruscello e saltò nell'acqua. Gli anatroccoli la seguirono tutti, compreso quello brutto e grigio. Gli anatroccoli salutarono le altre anatre.

"Oh! Guardate, i nuovi venuti! Come se non fossimo già numerosi! E questo anatroccolo grigio non lo vogliamo!" disse una grossa anatra, morsicando il poverino sul collo.

L'anatroccolo, da quel giorno, fu schernito da tutti gli animali del cortile: le galline e le anatre lo urtavano, mentre il maiale lo impauriva.

Un giorno, stanco della situazione, scappò da sotto la siepe. Dopo qualche ora di marcia, l'anatroccolo arrivò alla dimora di una vecchia donna che viveva con un gatto ed una gallina. I due animali non accolsero con piacere il povero anatroccolo, il quale decise di scappare subito.

Dopo il lungo e freddo inverno, l'anatroccolo si accorse che le sue ali battevano con molto più vigore e che erano anche molto robuste. Partì dunque per cercare nuovi luoghi e si posò vicino ad uno stagno.

Improvvisamente si accorse del suo riflesso sull'acqua:... era diventato un cigno!! Tre cigni si avvicinarono e lo accarezzarono con il becco dandogli così il benvenuto.

Il giovane gambero, *G. Rodari*

Un giovane gambero pensò: "Perché nelle mia famiglia tutti camminano all'indietro? Voglio imparare a camminare in avanti, come le rane, e mi caschi la coda se non ci riesco".

Cominciò a esercitarsi di nascosto tra i sassi del ruscello natio. I i primi giorni l'impresa gli costava moltissima fatica: urtava dappertutto, si ammaccava la corazza e si schiacciava una zampa con l'altra. Ma un po' alla volta le cose andarono meglio, perché tutto si può imparare, se si vuole.

Quando fu ben sicuro di sé, si presentò alla sua famiglia e disse: "State a vedere". E fece una magnifica corsetta in avanti. "Figlio mio," scoppiò a piangere la madre, "ti ha dato di volta il

cervello? Torna in te, cammina come i tuoi fratelli che ti vogliono tanto bene". I suoi fratelli però non facevano che sghignazzare.

Il padre lo stette a guardare severamente per un pezzo, poi disse: "Basta così. Se vuoi restare con noi, cammina come gli altri gamberi. Se vuoi fare di testa tua, il ruscello è grande: vattene e non tornare più indietro".

Il bravo gamberetto voleva bene ai suoi, ma era troppo sicuro di essere nel giusto per avere dei dubbi: abbracciò la madre, salutò il padre e i fratelli e si avviò per il mondo.

Il suo passaggio destò subito la sorpresa di un crocchio di rane che da brave comari si erano radunate a far quattro chiacchiere intorno a una foglia di ninfea. "Il mondo va a rovescio," disse una rana, "guardate quel gambero e datemi torto, se potete". "Non c'è più rispetto." disse un'altra rana. "Ohibò ohibò" disse una terza.

Ma il gamberetto proseguì diritto, è proprio il caso di dirlo, per la sua strada. A un certo punto si sentì chiamare da un vecchio gamberone dall'espressione malinconica che se ne stava tutto solo accanto ad un sasso. "Buon giorno" disse il giovane gambero. Il vecchio lo osservò a lungo, poi disse: "Cosa credi di fare? Anch'io, quando ero giovane, pensavo di insegnare ai gamberi a camminare in avanti. Ed ecco cosa ci ho guadagnato: vivo tutto solo, e la gente si mozzerebbe la lingua, piuttosto che rivolgermi la parola; finché sei in tempo, dai retta a me: rassegnati a fare come gli altri e un giorno mi ringrazierai del consiglio". Il giovane gambero non sapeva cosa rispondere e stette zitto. Ma dentro di sé pensava: "Ho ragione io".

E salutato gentilmente il vecchio riprese fieramente il suo cammino. Andrà lontano? Farà fortuna? Raddrizzerà tutte le cose storte di questo mondo? Noi non lo sappiamo, perché egli sta ancora marciando con il coraggio e la decisione del primo giorno. Possiamo solo augurargli, di tutto cuore: "Buon viaggio!".

I topi campagnoli e il gatto appeso, *Esopo*

La casa in campagna era rimasta vuota per molti anni. Alla fine i topi campagnoli decisero di occuparla. In breve furono tanti da riempire ogni buco e buchetto, crepa, fessura, e cantuccio di quella casa.

Un gatto udì la notizia e vi si trasferì anche lui. Da quel momento non ebbe più bisogno di uscire per mangiare: aveva topi a colazione, a pranzo, a cena e anche a merenda se ne aveva voglia.

I topi cominciarono a preoccuparsi. Il loro numero diminuiva di giorno in giorno.

"Bisogna fare qualcosa" disse uno.

"Sì, ma che cosa?" disse un altro. "Il gatto è troppo grosso perché si possa attaccarlo".

"Il miglior modo di attaccare è difendersi" disse il topo più anziano. "Staremo nei nostri buchi senza muoverci fino a quando il gatto, affamato, non andrà via".

Il gatto attese ore ed ore, ma dei topi non si vide neppure la punta dei baffi.

Trascorsi tre giorni, il gatto decise di indurli, mediante un tranello, ad uscire dai loro buchi per porre così fine al fastidioso digiuno. Si arrampicò dunque sul muro, si legò le zampe posteriori e si appese testa in giù ad un chiodo. E rimase lì, muto come un pesce.

“Avanti” disse uno dei topi giovani “usciamo”. Adesso non c’è più pericolo: il gatto è morto.

Ma il topo anziano scosse la testa, la sporse di un centimetro o due dal buco e disse ad alta voce: “Non serve, gatto! Fatti pur passare per morto quanto vuoi! Noi la sappiamo più lunga di te. Non ti crederemmo neppure se tu fossi appeso lassù dentro un sacco. Non usciremo dai nostri buchi finchè sarai qui!”.

Il gatto non stette a perdere altro tempo. Si sciolse dai lacci, scese dal muro e, con un miagolio di collera, se ne andò.