THE 'STANZA LOGO–MOTORIA': AN INTERACTIVE ENVIRONMENT FOR LEARNING AND COMMUNICATION

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ABSTRACT

The *Stanza Logo-Motoria* is a multimodal interactive system for learning and communication developed by means of the EyesWeb XMI platform. It is permanently installed in a Primary School where it is used as an alternative and/or additional tool to traditional ways of teaching. The *Stanza Logo-Motoria* is used by all the pupils of the school - from the first to the fifth grade - including the children with disabilities. This paper describes the system and a presents a first assessment of the teaching activities carried out using it.

1. INTRODUCTION

Today, the European Education System consists of an extremely heterogeneous environment: there is a significant diversification in levels of learning, a high proportion of foreign children and a growing number of children with disabilities [1]. In particular, the educational process of students with disabilities is a long and complex one, which is faced in different ways by various European Union countries. The European Agency for Development in Special Needs Education affirms that the trend in this field is to implement education policies which place disabled students in mainstream schools providing different types of support to teachers in terms of additional staff, teaching materials, in-service training and technical equipment. Technology can play a particularly valuable role in promoting greater adaptability of the Education System and, on the other hand, increasing the level of cultural demand [2].

Back in 1983, H. Gardner studied the different types of intelligences developing the Multiple Intelligences Theory [3]. This theory suggests that the traditional notion of intelligence, based on I.Q. testing, is far too limited. Instead, Gardner proposes eight different intelligences to account for a broader range of human potential in children and adults. These intelligences are: linguistic, logical-mathematical, spatial, bodily-kinesthetic, musical, interpersonal, intrapersonal, naturalist. Gardner says that our schools and culture focus most of their attention on linguistic and logical-mathematical intelligence. We should also place equal attention on individuals who are gifted in the other intelligences: artists, musicians, designers, dancers, and also disabled students. Unfortunately, many children who have these gifts do not receive much reinforcement for them in school. The theory of multiple intelligences proposes a major transformation in the way our schools are organized. It suggests that teachers ought be trained to present their lessons in a wide variety of ways using music, cooperative learning, art activities, role play, multimedia, field trips, inner reflection, and much more. It is very significant to recognize and nurture all human minds and all their combinations in order to encourage interaction with the world, global growth of the person, and the achievement of the highest possible level of learning [4].

In this framework, this paper presents a multimodal interactive system, *Stanza Logo-Motoria*, offering an alternative and/or additional tool to traditional ways of teaching that often do not adapt to the individual learning ability. In real-time the system analyzes the full-body movements and gestures of the children within a sensorised environment and maps them onto real-time manipulation and processing of audiovisual content. A particular focus is placed on expressive gestures, i.e., gestures containing and conveying emotional, affective information. In this way, the *Stanza Logo-Motoria* can be exploited by teachers either to convey content by means of an alternative method or also to verify the level of knowledge in children who better express their capabilities using the visual, spatial, or bodily intelligence.

The rest of this paper is organized as follows. In Sec. 2 theoretical foundations and related works are briefly introduced. Sec. 3 describes the system architecture of *Stanza Logo-Motoria*. Sec. 4 presents the feature extraction component and the description of the features the system uses. Sec. 5 describes how the system and the features extracted are used in a concrete instance of *Stanza*: the *Resonant Memory* application. In Sec. 6 details of *Stanza* activities are presented together with the first results from system assessment. Conclusions are drawn and future plans are laid out in Sec. 7.

2. THEORETICAL FOUNDATIONS AND RELATED WORK

The *Stanza Logo-Motoria* grounds its theoretical foundations on the Enaction theories and Embodied cognition, finding a neurophysiological basis on the discovery of the mirror neuron system. Mirror neurons constitute the neural substrate for the recognition and comprehension of actions performed by other individuals. Rizzolatti and Vozza [5] emphasize the motor aspect of cognition, claiming that learning is behind the action and that the basis of knowledge is the fact that "we do things". There are two kinds of knowledge: one is scientific and objective, the other is experiential which is our primary knowledge based on our motor system and our experiences; embodiment is the necessary condition for the development of cognitive processes. This approach [6] is grounded on multi-sensory coupling of perception and action, motor imitation and issues concerning emotions and subjectivity. Each cognitive activity is always "situated", it is inextricably associated with 'what we are doing physically' and on the structure and dynamics of the environment [7]."Learning by doing" is an important theoretical dimension also for Enactive theories of cognition; Enactive knowledge is based on motor skills (such as manipulating objects) where Enactive representations are acquired by doing [8].

In the *Stanza Logo-Motoria*, it is possible to recover the important aspect of motor knowledge and to use it to resolve situations of learning difficulties. The *Stanza Logo-Motoria* follows this approach, being an environment where the users must do things to receive a content: they have to enter the space, choose a location, listen carefully, perform activities, they have a reason for learning, ways of acting and perceiving, a significant environment. Knowledge is not imposed from above but is offered: the users must "do things" to receive it. Furthermore, the pupils learn in motion, they seek the content by physically moving within the space: ideas, thoughts, concepts, and categories are shaped by aspects of the body [6]. The *Stanza Logo-Motoria* becomes an instructional agent [2] by transferring information and instructional knowledge just as the teacher presents his/her explanation to students.

By the end of Sixties, Myron Krueger begins his experiments on interactive electronic image, immediately offering artificial environments constructed manipulating visual and audio information. He presents [9] the concept of environment linked to physical space where the observer seeks to intervene. Krueger uses spaces directly modified by the user's presence without any invasive devices. In the first experiments, using a sensitized carpet, Krueger extracts the user's location within the environment (Glowflow, Metaplay, Psychic Space) and then he directly manipulated user's gestures through video tracking. The *Stanza Logo-Motoria*, like Krueger's space, is an environment where both spatial position and user's gestures are detected by a video-camera. The coordinates of the position and the measure of open arms gesture correspond in this case to a specific audio and/or video feedback. Krueger [10] emphasizes the role of the body and considers 'responsive environments' as tools for the re-appropriation of sensory faculties sacrificed by the power of audiovisual representation. In the same way, the *Stanza Logo-Motoria* is a tool to retrieve children's attention span and concentration; the *Stanza Logo-Motoria* offers children the chance to re-experience the feeling of being good and satisfied about himself during active listening.

Another important example of the use of an interactive multimedia environment with children (and especially with disabled children) is SOUND=SPACE. In 1984 Rolf Gehlhaar developed SOUND=SPACE [11], an interactive multi-user musical environment in which visitors trigger and influence the production of sounds merely by moving about an empty space surveyed by an ultrasonic echolocation system. Since its development, this system has been displayed publicly worldwide, becoming a particularly favorite for groups with special needs. SOUND=SPACE is still being explored by visitors and participants in creative workshops for special needs groups. Further on, Gehlhaar and colleagues [12] worked on a new multi-user interactive audio visual installation: CaDaReMi. CaDaReMi addresses this problem: the user's difficulty to spatially "anchor" his/her activities; CaDaReMi answers by providing a number of visual clues designed to help the user understand "how things work", to use the "spectacle" of the installations to explain it to new users and to make the sound topologies visible. The *Stanza Logo-Motoria*, like CaDaReMi, is an environment: stimulant for users to expressively explore a wide range of different sounds; collaborative as it may be used by several persons at the same time; challenging and interesting, providing a palette of both familiar and strange sounds; visually engaging, enhancing the user's experiences and promoting their ability to locate themselves and to decode the events of others in the space at the same time; socially engaging by promoting user-user interaction, thus strengthening the sense of working together; intuitive in its functionality and use as no explanations and no special expertise are required in order to obtain a first results; learnable and master-able, being sufficiently complex so that users may, in time, enjoy the experience of "getting better" at using it and, at the same time, easy enough for beginners to quickly experience success.

Unlike the environments described above, the *Stanza Logo-Motoria* is an interactive space, permanently installed at a school, which allows the assimilation of content by learning through movement. It is a container of knowledge that can be filled with any topic from History to Math, Geography or Science. The system creates a communicative interactive environment, a place where the user, moving the body in space and through a simple arm gestures, causes the production of information that, in absence of the usual modality of communication (the word), would not be possible to convey.

The *Stanza Logo-Motoria* has been developed by using the EyesWeb XMI platform (www.eyesweb.org). It addresses the following areas in the SMC Roadmap: Interactive Multimedia Systems and Augmented Action and

Perception.

3. SYSTEM ARCHITECTURE

Fig. 1 shows the overall system architecture for the *Stanza Logo-Motoria*. It consists of three major components:

- The *input component*, receiving the video stream captured by one or more video-cameras observing the space and the information gathered by possible further environmental sensors (e.g., microphones, pressure sensors on the floor). This component is also responsible for data pre-processing (e.g., denoising, background subtraction techniques to extract the silhouettes of the users).

- The *feature extraction component*, which analyzes the input data in order to get information about (i) how the user occupies the space (e.g., where they go; how long they remain in a given area), (ii) the expressiveness of their gestures. More details on this component are provided in Sec. 4.

- The *component for real-time processing of audiovisual content*, which is responsible of the real-time control and processing of audio and video material and depends on the features extracted by the *feature extraction component*.

The components of the system architecture will be described in detail with reference to *Resonant Memory*, a specific instance of the *Stanza Logo-Motoria* .

4. FEATURE EXTRACTION

In *Stanza Logo-Motoria* a video-camera is used to capture body and arm gestures. The image stream is processed and a number of features are extracted. The focus is on so-called non-invasive approaches. Analysis is grounded on a multi-layered model for expressive gesture processing [13] which aims at extracting features characterizing both the occupation of space on the part of the users and the expressive quality of their gestures (e.g., whether a gesture is smooth or impulsive, determined or hesitant, etc.). Analysis of both space occupation and gesture is usually based on the input video stream which is pre-processed in order to extract the silhouette of the users.

Space analysis starts from the trajectory followed by each user within the space (e.g., computed as the trajectory of the center of mass of the user). It is possible to define regions within the space and identify those that are currently occupied by the users (this information may be used for example to trigger possible audiovisual content). The occupation rate for each region is also computed. This can be used for characterizing the visiting behavior of the users with respect to the space. For example, if an audiovisual content is associated with a specific region, a high occupation rate of that region may indicate a high interest of the users for a specific content.

The analysis of the gestures is based on features that are extracted at different levels, from relatively simple (or low level) ones to more complex features (high-level) describing gestures in terms of categories inspired to theories and experiments from psychology and humanities.

Low-level features include basic kinematical features (e.g., position, velocity, and acceleration of the center of mass of the silhouette), and silhouette-based features, i.e., features directly computed on the silhouette of the user. Silhouette-based features include, for example, the Motion Index (i.e., the amount of movement detected by the video-camera), the Contraction Index (an index measuring the contraction/expansion of the body computed as the ratio between the area of the silhouette and the area of the bounding rectangle), the orientation of the body (computed as the orientation of the major axis of an ellipse approximating the body).

High-level features are computed from low-level features on the basis of theories, models, and experiments from psychology, biomechanics, and humanities. For example, according to Rudolf Laban's Theory of Effort [14] a gesture can be quick (impulsive) or sustained (smooth), direct or flexible, heavy or light. Relevant sources from research in psychology include the works by Wallbott [15], De Meijer [16], and Boone and Cunningham [17]. Examples of high-level features include: the Directness Index, measuring whether a gesture is direct or flexible; the Impulsivity Index, measuring whether a gesture is quick or sustained; Fluidity, measuring whether a gesture is bounded and hesitant or unbounded.

The instance of *Stanza Logo-Motoria* described in the following - *Resonant Memory* application - uses mainly low-level features that can be extracted directly from the image stream: the overall movement of a human body (Motion Index), represented as the movement of the centre-of-mass of the body, and the open arm gesture represented as the variation in the size of the body bounding box (Contraction Index). The focus here is on low-level features because they are relatively fast and easy to calculate, and at the same time, sufficient for defining a rich set of gestures for control. Low-level features are also inspired by studies on visual perception, and are used to build computational models inspired by perception [18].

5. THE *RESONANT MEMORY* APPLICATION

Resonant Memory is an instance of the *Stanza Logo-Motoria* installed in the Primary School where it is experimentally in use. In *Resonant Memory*, the space captured by a web-camera is divided into nine areas: eight of these are peripheral areas whereas the ninth is central; in this case the zones are nine but the number may vary depending on the didactic needs. Sound or visual information corresponds to each area. The trajectory of the centre of mass is used to match a sound to a specific position in space. A child explores the resonant space in which he/she can freely move without using sensors:

- Noises, sounds, and music are associated with peripheral zones and are reproduced when the child reaches and occupies a peripheral zone;

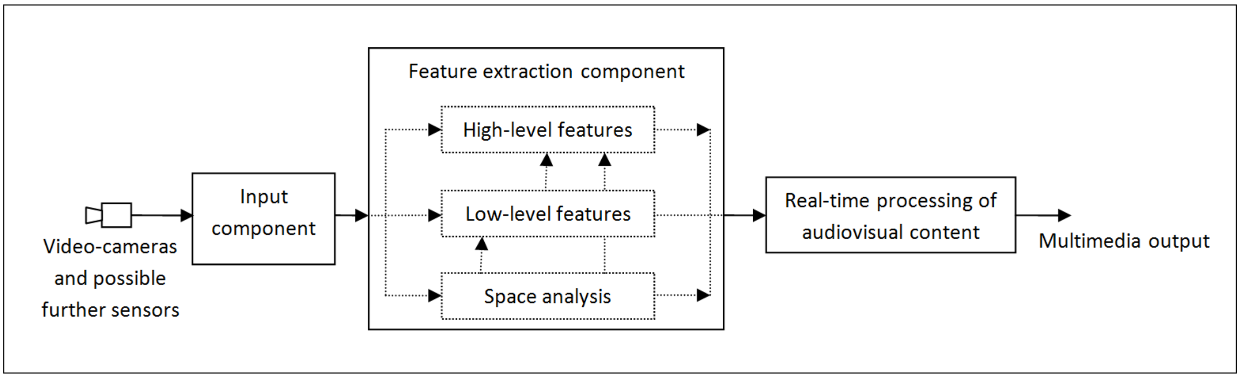

Figure 1. System architecture.

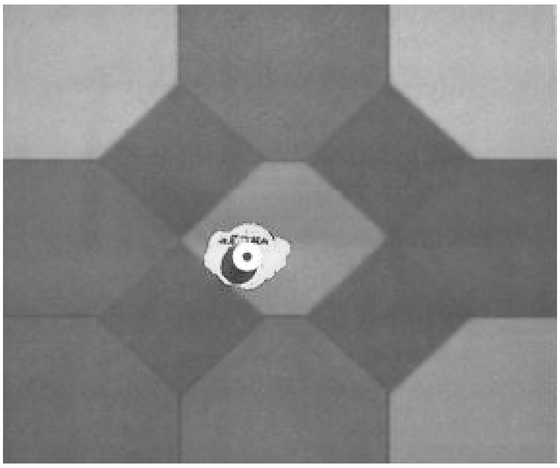

Figure 2. The sound reproduction of a story starts when the child enters the central area.

- Audio reproduction of a story is associated with the central zone (see Fig. 2); the story provides references to the various sounds located in the peripheral areas. The child, listening to the story, enjoys searching for the sounds heard before and, at the same time, he/she creates the soundtrack of the story.

The video analysis and sound rendering tasks are performed by a software patch developed in the EyesWeb environment. Fig. 3 shows an overall picture of the patch, which can be subdivided into three stages. The first is the input stage: the signal from the camera is processed in order to extract several low-level features related to the user's movements. Background subtraction is achieved via a statistical approach: the brightness/chromaticity distortion method [19]. Extracted features include the trajectory of the center of mass, the Motion Index, and the Contraction Index. In the mapping stage (see Fig. 4), the patch analyses the features and, according to the user's actions, it runs the transitions among four states: exploration, story, pause, and reset. Finally, the output stage controls the playback of a set of pre-recorded audio files.

When the application starts and the user enters in the area of activity for the first time, the application is in the exploration mode. Whenever the user reaches one of the eight peripheral zones, this information is stored by the system (see Fig. 2). If during the exploration phase the user reaches the central zone no event is triggered. Only after all the eight zones have been explored at least once and the user reaches the central area, the application turns to the story mode. When the user widens their arms during the story, the system pauses and the playback of the sound events is interrupted until the user closes their arms (see Fig. 5). If the user leaves the area of activity and does not return for over a certain time limit (which can be pre-set), the application goes back into reset state which erases the track of the visited zones. When a new user enters in the area of activity after the reset, the application starts over and he/she can begin a new exploration phase.

Currently the input modality is limited to video tracking and the only the sound modality is used as output for the following reasons:

- The path of teaching/learning by the use of *Stanza Logo-Motoria* in the school was a novelty for students and for teachers, therefore we proposed a very simple, direct and intuitive tool also considering the limited financial resources of the school.

- In agreement with teachers we thought that, in general, children need to recover the ability to listen and to experience space without any visual references. The aim is to achieve heightened awareness of space.

- Multi-modality is the ultimate goal: as children learn to control one of the modalities, the *Stanza Logo-Motoria* can evolve and several other modalities can be introduced according to their own individual paths of growth.

6. ASSESSMENT

The *Stanza Logo-Motoria* is a technological tool to enhance alternative intelligences and communication; the purpose is to promote learning motivation and develop pupils' different cognitive styles. The *Stanza Logo-Motoria* is currently installed in the "E. Frinta" Primary School in Gorizia (Italy). We are evaluating to use the *Stanza* with 10 Primary School classes, from the first to the fifth grade (a total of 170 pupils) as follows:

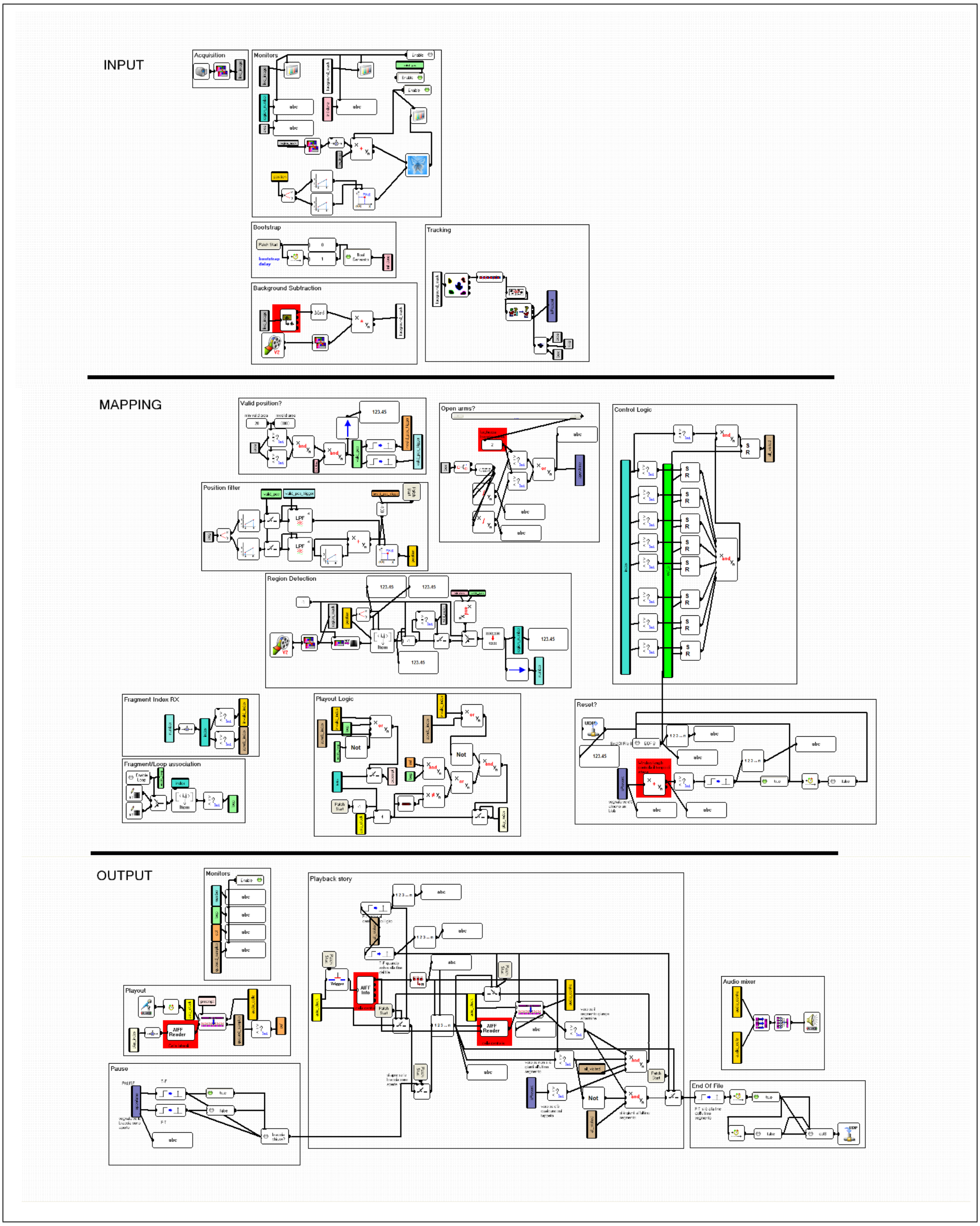

Figure 3. The patch developed in the EyesWeb environment.

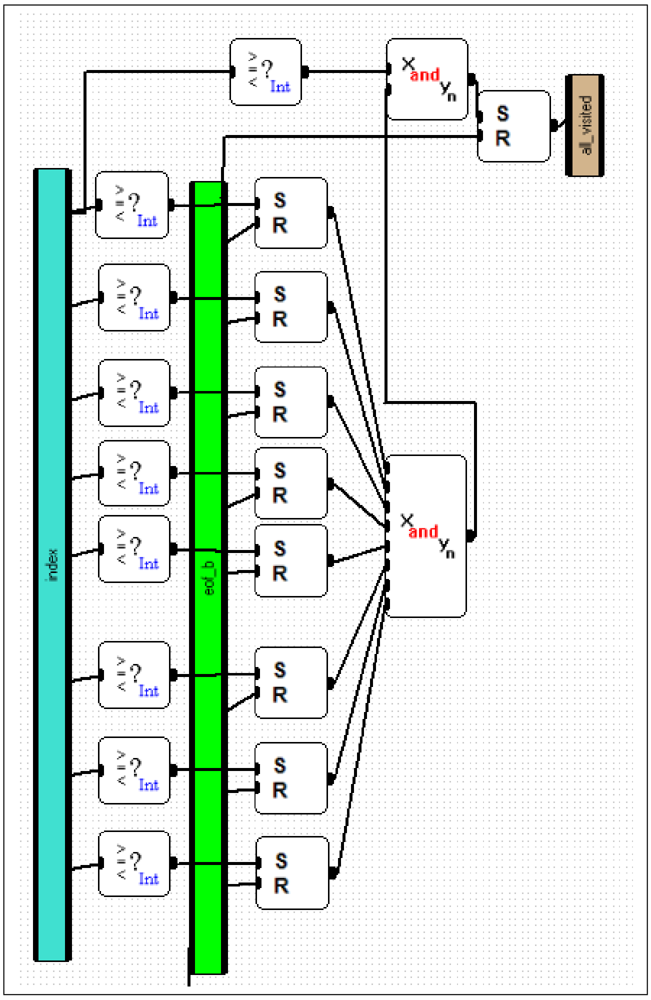

Figure 4. The subpatch that manages the transition among the operative states of the application.

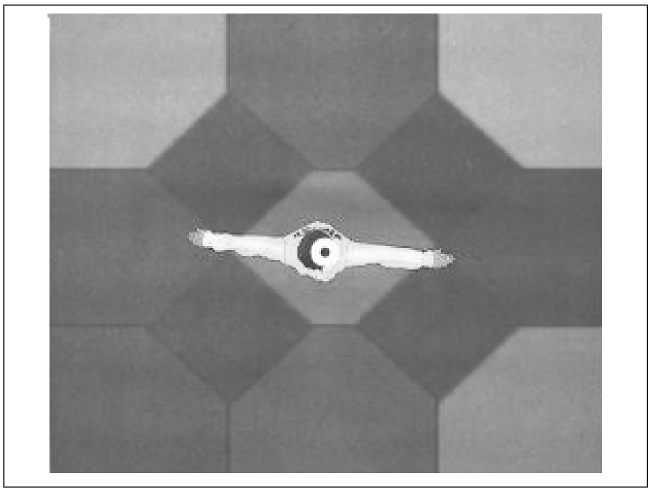

Figure 5. The Contraction Index allows the user to stop the reproduction of the story simply by opening her arms.

Figure 6. Learning English.

- in first grade classes - for a Continuity Project between Nursery School (10 hours) and Primary school and for the integration of a child with autism (3 hours);
- in second grade classes - for the Project "Infolibro" (aimed at the writing of a book for children, 6 hours) and for the development of the communication skills of a child with severe autism (5 hours);
- in third grade classes - for history (2 hours);
- in fourth grade classes - for music (6 hours);
- in fifth grade classes - for two children with dyslexia (7 hours).
- all the classes use the *Stanza Logo-Motoria* for English (40 hours).

We will now describe two particular learning pathways: learning English and the study of science for dyslexic children.

6.1 Learning of a foreign language

From March through May the school organized English language courses held by a mother tongue English teacher; the courses take place every Thursday afternoon and are organized on two levels of complexity. Teaching English through *Stanza Logo-Motoria* has one main goal: to accustom the children to listening to phonemes that are different from the ones of their own language. In this way learning a foreign language increases the awareness of non linguistic tools to communicate, e.g. body language, images, sounds, and symbols for their value across all cultures. The *Stanza Logo-Motoria*, used as a language vehicle, allows activities to be structured so that genuine connections with other disciplines are emphasized. Thus, the enhancement of cognitive skills and the Integrated Learning is encouraged. Segments of speech and phrases become part of the pupils' language knowledge simply because it is used to carry out a task. So speaking English becomes spontaneous, fun, and natural (see fig. 6).

Many languages and methodologies are involved in this system of teaching:

- musical language: enjoying music, acquiring skills to discriminate sound and timbre characteristics of musical instruments;
- theatrical language: characters animation, mime acts and conditions;
- use of new technologies;
- use of community languages to learn disciplines: C-LIL, Content and Language Integrated Learning is a teaching methodology that involves learning a discipline through a foreign language.

Children explore the eight peripheral areas and they memorize the spatial coordinates of sounds (noises, environmental sounds or music); then, entering the central area, they activate a sound reproduction of a story in English. Children must then listen carefully in order to trigger the correct sound at the right time within the story and they have to move in the space searching for the sounds suggested by the story. Sometimes, in one or more peripheral zones, we include several sequences of the story without nouns, adjectives or verbs that the child must insert by saying them aloud.

High concentration in listening and body movement in space ensure effective learning. Even after some time, children are able to recall the exact contents learnt during a particular session within the *Stanza Logo-Motoria*. From analysis of video recording, together with the teachers we observed that this method of teaching increases the motivation to listen and consequently to learn new words and phrases. The evaluation tests carried out successively by the teachers show that children master the contents assimilated through the *Stanza Logo-Motoria*.

6.2 Support for dyslexia

Every year the school is presented with cases of dyslexia. Teachers need to use compensatory and dispensatory measures in order to facilitate learning on the part of dyslexic children and apply a specific evaluation. For this reason *Resonant Memory* is used also by dyslexic children as an alternative tool for learning curriculum subjects. In this case the *Stanza* is used as follows:

- in the first session the text to study is divided into sound sequences, each sequence corresponds to an area of the room; each area of the room is set up with an empty billboard; the students enter the area, one at a time, they listen to the text sequence and put the correct images on the billboard as suggested by the text;
- in the second session the students enter the area, one at a time, they listen to the text sequence observing the images previously positioned onto the poster then they repeat the content with the help of the images;
- the teachers orally assess whether the students' performance has improved after using the *Stanza*.

The school is also attended by a child with visual impairment and one with behavioral disorders who regularly participate in activities organized in *Stanza*. These children integrate with the group of peers and they succeed in the tasks because this tool requires learning skills that they actually possess: there is no text to read, no written questions to be answered, no strings of mathematical operations to solve but there are sounds to listen to and movements to perform.

6.3 Major results

In teaching with the *Stanza Logo-Motoria* it is possible to observe immediately great involvement on the part of the children, high motivation, and extension of the period of attention. All the school children, including the disabled people, are enthusiastic to use the *Stanza*. The use of *Stanza Logo-Motoria* with disabled children offers them the possibility to:

- enhance their communication skills providing alternatives or additions to the mode of communication already in place;
- encourage interaction with others and with the environment;
- extend the time of attention;
- develop expressivity of gesture;
- improve autonomy through production of intentional actions.

In particular using the *Stanza Logo-Motoria*, as a tool for learning for dyslexic students, allows to bypass the written code which, in this case, represents an obstacle to understanding. Children show greater awareness of contents, they regain motivation to learn and they are excited to present what they have learnt to the teacher and to their classmates. Accordingly, children get top scores in the assessment tests of subjects studied in the *Stanza*. Teachers are highly motivated to carry out activities in *Stanza*, indeed they spontaneously propose topics and paths to explore.

Between January and May we have had the chance to assess that:

- Compared to the first term (from September to December when the *Stanza Logo-Motoria* wasn't in use) pupils with dyslexia improved their performance in evaluation tests as well as their approach to all other subjects showing an overall greater self-confidence. Teachers have also noticed that in the *Stanza* these children are able to summarize the contents with greater security linking the various subjects; a performance this that they were not able to do only working in the classroom.
- Regarding English learning, performed in *Stanza*, the teacher pointed out that, thanks to the total and immersive sound perception, the children have a general better understanding of English as well as an improved pronunciation and oral production.

These assessments were carried out by the teacher through:

- direct observation;
- analysis of video recording made inside the *Stanza*;
- school assessment tests.

We certainly believe that in time it is possible to gather more evaluative information; this is a goal that we aim to achieve in the coming years. We intend to create a control group that will allow us to assess over time whether there is a difference between the learning of children who use the *Stanza* and those who have never used it. We will also detect whether a change occurs between the average marks registered in the past (when the *Stanza* was not there) and those of following years (when the *Stanza* was used).

7. CONCLUSIONS

Experiments conducted on 170 pupils of a Primary School have shown that the *Stanza Logo-Motoria* allows users to gradually face many organization tasks across progressively complex experiences. To provide a more complete sensory experience, we plan to modify the system adding a visual feedback and a spatialized rendering of sound.

We are also thinking of providing further opportunities for interaction among children by designing a modality in which the mapping of the gestures of one user depend on the gestures of another. This feature is essential when the user has relationship difficulties such as those typical of autism.

Multimedia is a great opportunity for the evolution of the Educational System as the children are able to use all the elements and tools to build a positive relationship with the world and with themselves. Children who are not yet adults, bound by the self-control which is typical of written communication, are human beings in evolution that receive all the relevant information to put themselves in relation with the world.

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