PROJECT PERIODIC REPORT

Grant Agreement number:258338

Project acronym: MIROR

Project title: Musical Interaction Relying On Reflexion

Funding Scheme: Collaborative Project

Date of latest version of Annex I against which the assessment will be made:

Periodic report: 1st□ 2nd□ 3rd X 4th □

Period covered: from 01/09/2012 to 31/08/2013

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Project website[1] address: www.mirorproject.eu

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[1] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

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1. PUBLISHABLE SUMMARY

The MIROR (Musical Interaction Relying On Reflexion) project is co-funded by the European Commission under the 7th Framework Programme, Theme ICT-2009.4.2, Technology-enhanced learning. MIROR is a three-years project and started on September 1st, 2010. All information regarding MIROR is available through the MIROR Portal at http://www.mirorproject.eu.

1.1. Concept

The MIROR Project deals with the development of an adaptive system for music learning and teaching based on the "reflexive interaction" paradigm. The system is developed in the context of early childhood music education. It acts as an advanced cognitive tutor, designed to promote specific cognitive abilities in the field of music improvisation, both in formal learning contexts (kindergartens, primary schools, music schools) and informal ones (at home, kinder centres, etc.). The reflexive interaction paradigm is based on the idea of letting users manipulate virtual copies of themselves, through specifically designed machine-learning software referred to as "Interactive Reflexive Musical Systems" (IRMS). By definition IRMS are able to learn and configure themselves according to their understanding of the learner's behaviour. In MIROR the IRMS paradigm is extended with the analysis and synthesis of multisensory expressive gesture to increase its impact on the musical pedagogy of young children, by developing new multimodal interfaces. The project is based on a spiral design approach involving coupled interactions between technical and psycho-pedagogical partners. MIROR integrates both psychological case-study experiments, aiming to investigate cognitive hypotheses concerning the mirroring behaviour and the learning efficacy of the platform, and validation studies aiming at developing the software in concrete educational settings. The project contributes to promoting the reflexive interaction paradigm not only in the field of music learning, but more generally as a new paradigm for establishing a synergy between learning and cognition in the context of child/machine interaction.

1.2. Objectives

The MIROR project aims primarily at developing the potential of IRMS for the benefit of *music education*. More precisely, MIROR's primary goal is to develop an adaptive and intuitive system for music education, based on the reflexive interaction paradigm. This includes:

The design and implementation of a platform, the **MIROR platform**, including the core technological modules needed to implement the reflexive interaction paradigm (e.g. modules for analysing the musical behaviour of learners, modules for analysing expressive full-body movement and gestures, modules for session and interaction management, and so on).

The design and implementation of three **MIROR prototypes** (Fig. 1), grounded on the MIROR platform, addressing different aspects of music education and exploiting different qualities of the reflexive interaction paradigm:

The **MIROR-Improvisation prototype** (MIROR IMPRO hereinafter), addressing music improvisation.

The **MIROR-Composition prototype** (MIROR COMPO hereinafter), addressing music composition.

The **MIROR-Body Gesture prototype** (MIROR-Body Gesture hereinafter), exploring how full-body movement and gesture can enhance music learning.
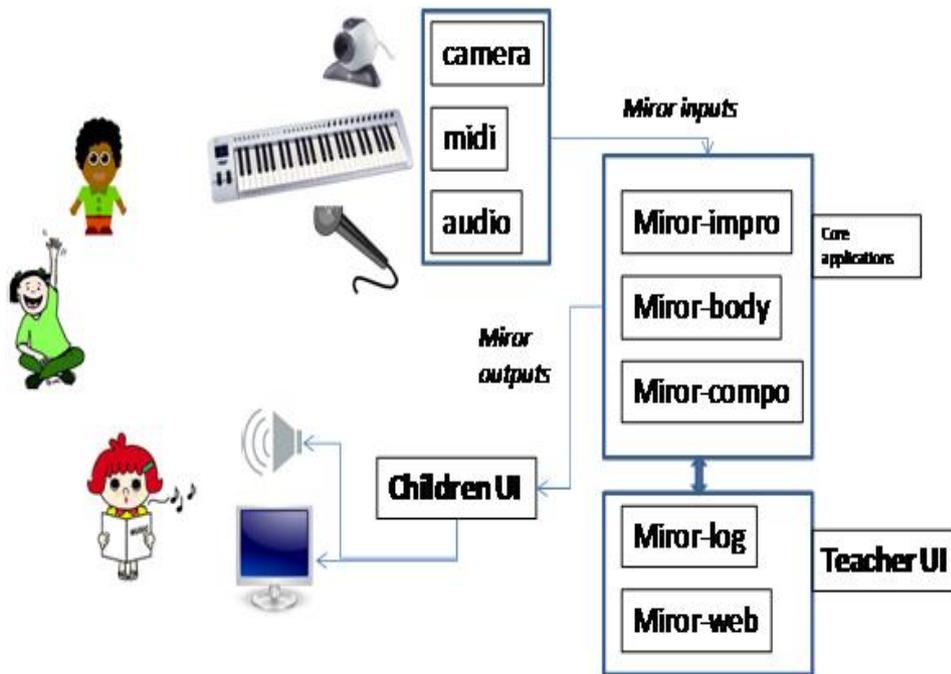

Fig. 1 – Overall architecture of the MIROR Platform

The **validation** of concrete pedagogical scenarios in which IRMS organise and stimulate the learning/teaching processes in the domains of music improvisation, composition, and body performance; the validation of the MIROR platform and prototypes in such scenarios.

The development of a detailed analysis aimed at assessing the impact of the reflexive interaction paradigm on both music learning and cognitive processes. The **theoretical framework of the reflexive interaction** will be investigated and implemented on the basis of the experimental results and of specific studies addressing the pedagogy of reflexive interaction.

The promotion of an **active approach to musical culture**, based on "music making" rather than on "music consuming". The promotion of the social-cultural perspective with regard to music education and creativity, integrating embodiment into technology-enhanced learning.

1.3. Consortium

Alma Mater Studiorum - Università di Bologna (UNIBO), Italy – Coordinator.

Sony Europe Limited acting through Sony France Computer Science Laboratory (SONY), France.

Università degli Studi di Genova (UNIGE), Italy.

Goeteborgs Universitet (UGOT), Sweden.

National and Kapodistrian University of Athens (NKUA), Greece.

The University of Exeter (UNEXE), United Kingdom.

Compedia Software & Hardware Development Ltd. (COMPEDIA), Israel.

1.4. Work performed and major results achieved so far

1.4.1 The First Year of the Project

The first year of the project was mainly devoted to the integration of background knowledge from partners, to the definition of the requirements for the MIROR platform and prototypes and for their interfaces, to the development of the initial version of the MIROR platform and prototypes, to the performance of a first series of experiments in concrete pedagogical scenarios. Early results include the following:

- UNIBO, UGOT, NKUA, and UNEXE (psycho-pedagogical partners) investigated several **theoretical aspects** dealing with IRMS, both in the context of music education and cognitive sciences of music, and in the more general field of learning in an interactive scenario. A review of relevant literature was carried out and the theoretical background concerning the cognitive and creative processes, which are implicated in IRMS, was discussed. In particular, the following topics were considered: the mirroring interaction; the theory of Flow in reflexive scenarios; the cognitive processes of music improvisation in children; the learning/teaching processes in a reflexive and interactive scenario; music therapy and community music settings.

- The **initial version of the MIROR platform** was developed to provide the Consortium with running prototypes as soon as possible. SONY and UNIGE (technological partners) carried out this work in close loop with the psycho-pedagogical partners - who provided feedback on the outputs needed for the experiments, manipulation of musical parameters involved (rhythm, dynamics, texture, etc.), and development of specific settings -, and with COMPEDIA who also provided feedback on exploitation issues. The following major results were achieved:

  ● New algorithmic solutions such as the novel musical sequence generation algorithm with constraint satisfaction scheme (SONY) and the techniques for extraction and processing of movement and gesture features (UNIGE) were developed, successively tested, and integrated into the prototypes.

  ● Several core technological modules such as session management, session visualisation, music score display, and export functionalities were developed and integrated.

  ● Future integration abilities were addressed in particular by developing various independent software libraries, which will be used in MIROR prototypes through evolving, but clearly defined APIs (Application Programming Interface).

  ● Hardware needs and compatibilities were studied and hardware selection was made.

- Tools for connecting the MIROR prototypes were investigated, and an initial proof-of-concept of such a connection to generate musical outputs by gesture analysed in real time, was developed and tested.

- The **initial versions of the three MIROR prototypes** were developed (SONY and UNIGE) and provided to the psycho-pedagogical partners for early feedback. In particular:

- SONY developed the initial MIROR IMPRO prototype. Its focus is the basic musical level (notes, clusters, and sequences thereof). Since the early stages of the project eleven different versions were delivered to the consortium, and many new features, bug fixes, and comments, in particular concerning the user interface, were progressively integrated, including a session management tool to record, save, retrieve, and visualise the musical information exchanged during each session in an easy way.

- SONY developed the initial MIROR COMPO prototype. MIROR COMPO grounds on MIROR IMPRO and aims at teaching children how to reflect on a larger scale than the basic musical level.

- UNIGE developed the initial version of the MIROR-Body Gesture prototype. This prototype mainly enables children to perform exploration of sound and of musical concepts by means of their body movements and gestures. The framework integrates customisable exercises, with different levels of complexity, spanning over different dimensions of sound and over different music concepts.

- SONY and UNIGE developed the initial versions of the interfaces for the MIROR prototypes, with particular reference to the MIROR IMPRO prototype (Fig. 2). Following the feedback by the Consortium, COMPEDIA developed a mock-up for an improved version of the teacher interface for the MIROR IMPRO prototype (Fig. 3).

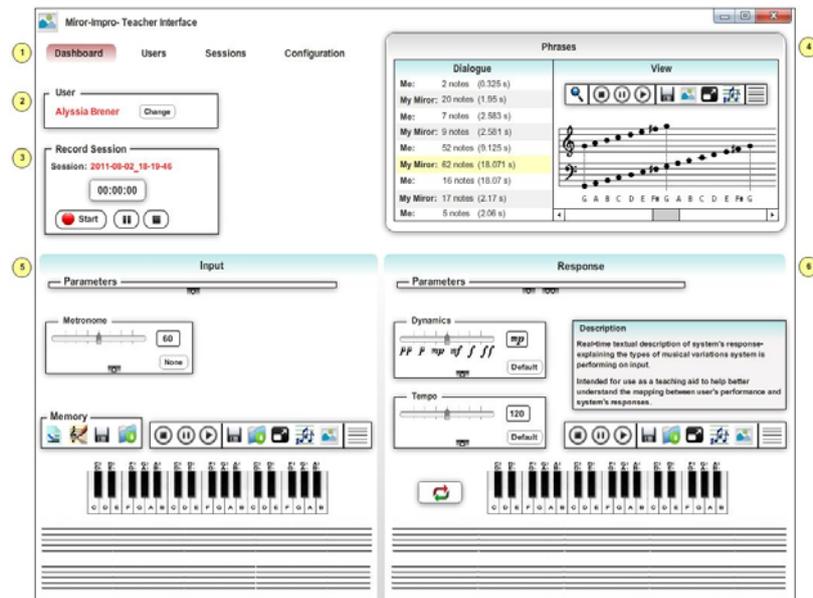Fig. 2 - Initial version of the MIROR IMPRO interface
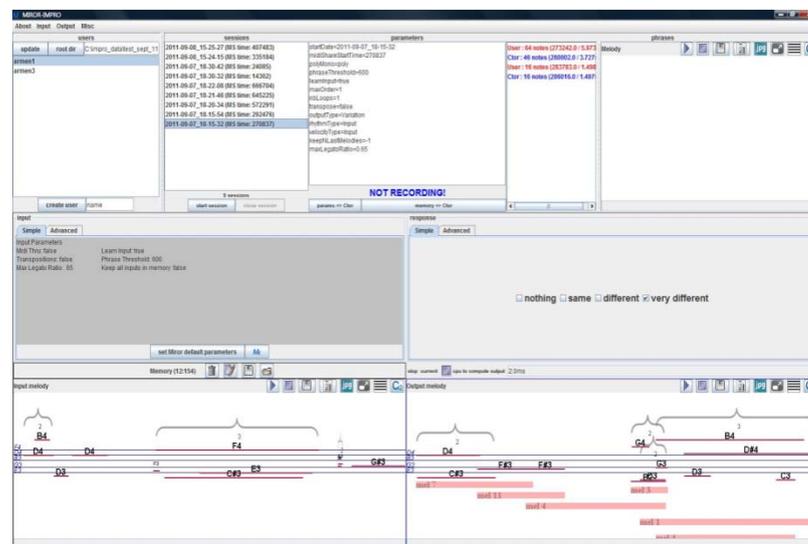
Fig. 3– MIROR IMPRO. Sample of the new suggested UI design

- **Experiments with children:** UNIBO, UNEXE, UGOT, and NKUA prepared and carried out experiments with children and the MIROR IMRPO prototype. From September 2010 to April 2011 the psycho-pedagogical partners planned, in strict collaboration with the other Partners SONY, UNIGE, and COMPEDIA, two protocols and several exploratory studies to be carried out with children in kindergarten and primary schools. In April-August 2011 the experiments and further minor exploratory studies were performed in Athens (NKUA), Bologna (UNIBO), Gothenburg (UGOT), and Birmingham (UNEXE). Almost 100 children were involved in the experiments. Initial considerations can be made as follows:

- The collected archives represent a rich data collection.
- The results obtained so far show that the MIROR IMPRO prototype works and can have a positive effect on the level of Flow of the child while improvising, providing a rich interaction context.
- The results indicate several suggestions in order to further improve the system, the interface, the equipment and the setting, and suggest new experimental hypotheses to be tested.
- The results suggest new interesting experimental ideas to be implemented with the next versions of MIROR IMPRO and with the recent MIROR COMPO prototype.
- The results raise interesting theoretical aspects concerning perceptual and cognitive issues on the reflexive scenario with young children, music perception and music analysis, music therapy, and different socio-pedagogical contexts.
- An overview of the data and results that partners collected underlines how carrying out different protocols in a range of contexts was positive and enriching for the project.
- During months 9-12, starting from the results of the experiments carried out with MIROR IMPRO and analysing the literature about composition with children, the Consortium started the preparation of the experiments with MIROR COMPO and MIROR-Body Gesture that were delivered at the end of August 2011. Experiments will be carried out in year 2.
- The Consortium organised **two workshops** (Paris, November 2010; Gothenburg, March 2011) to work on experimental designs, requirements of the platform and

prototypes, hardware and technical equipment. The goal was to transfer the results of user testing to the prototype implementation and vice versa.

- The **MIROR website** has been delivered on Month 3 (UNIBO) (www.mirorproject.eu).
- The **logo of the project** was created by UNIBO on the basis of a writing made by a 5-year-old child who was asked to write the word "MIROR" on a yellow and a red line (as from the medieval musical score). In a spontaneous way, the child wrote the last letter "R" in reverse, giving the idea of the mirroring effect and of the reflexive paradigm.

- **Secured video sharing service** was enabled by COMPEDIA and is used for sharing videos and comments among researchers. It also includes a sub-set of approved videos for demonstration and exploitation purposes.
- The project was **disseminated** to the scientific community through presentations at conferences. Initial research results were published or submitted for publication. A special issue of the journal "Musicae Scientiae" on MIROR topics is planned for publication at the end of the project.

1.4.2 The Second Year of the Project

The second year of the project was mainly devoted to a deeper definition of the theoretical framework of the reflexive interaction paradigm in the field of childhood technology-enhanced learning, to the performance of experiments with particular attention to the children's and teacher's interaction with the platform in concrete pedagogical scenarios, to the methodological implementation of quantitative and qualitative research supported by a "mixed method" approach, to the refinement of the requirements for the MIROR platform and prototypes and for their interfaces, to the implementation of the spiral process of specification leading to the development of the second version of the MIROR platform and prototypes. The second year was mostly devoted to the implementation of MIROR COMPO and MIROR-Body Gesture, and to the integration of the three MIROR components. Exploratory studies on composition and embodiment were realised with MIROR COMPO and MIROR-Body Gesture. Finally, the Consortium designed and implemented studies addressing usability and user experience aspects with the MIROR platform and related components (Impro, Compo, and Body Gesture), to be carried out in the 3rd year of the Project. The initial step for market analysis was implemented and a survey has been launched aiming at identifying and evaluating the demand for the MIROR platform among different segments and users.
Results include the following:

- **The theoretical framework of reflexive interaction paradigm** has been defined more deeply. In particular, the theoretical framework focuses on reflexive interaction, also including children's developmental models in improvisation, composition, and body gesture. The theoretical framework of the reflexive interaction paradigm has been developed from a

systematic perspective. It starts from the theoretical and technical background of the IRMS and follows with an attempt to explain the human behaviours involved in the reflexive interaction, starting from the behaviours observed in children interacting with the "Continuator", the first prototype of IRMS. These highlighted elements have been proposed to support the fundamental hypothesis of the MIROR Project, that reflexive interaction enhances teaching/learning processes and musical creativity. This places the theoretical basis for a pedagogy of reflexive interaction and for exploiting IRMS in the field of technology-enhanced learning and therapeutic/rehabilitative actions. Starting from IRMS and the experience with children, some fundamental requirements have been identified in order to implement new interactive reflexive musical systems. The background on children's improvisation, composition, and dance education is considered, and related to the reflexive interaction.

- **Performance of experiments** with particular attention to children's and teacher's interaction with the platform in concrete pedagogical scenarios and methodological implementation of quantitative and qualitative research supported by a "mixed method" approach. Several exploratory and experimental studies have been carried out by UNIBO, NKUA, UGOT and UNEXE with MIROR IMPRO, MIROR COMPO, and MIROR Body Gesture prototypes. Results with MIROR IMPRO support the hypothesis that reflexive interaction and MIROR IMPRO enhance children's Flow emotional state and several kinds of listening conducts and behaviours, enhancing music learning and creativity. The results indicate that children's ability to improvise in dialogue with a computer depends on their previous experience and the cultural tools they have already acquired by participating in other musical settings. Computational music analysis revealed specific repeated patterns that children use when they play the keyboard. In the first sessions these are indicative of various gestures that children use when they play (such as repetition of one note, movements up and down the keyboard, oscillations between two notes, etc.). After some sessions with the system, however, the playing becomes more focused and exploratory, and children use their fingers more, rather than big arm movements. Three levels of interaction with MIROR IMPRO were observed and differences between girl/boy and 4-8 year olds were observed as well. The experiments with MIROR COMPO raised interesting reflections about children's music composition and suggest that the system acts as a "musical scaffolding" (the "actions" system) that allows children to develop the ability to create new ways to combine each other's actions, i.e. to "compose" music. The results of the studies in therapeutic settings showed that there is a clear enjoyment of the sessions with the system, proving that it is an appropriate and fun tool to use for therapeutic purposes. The experiments with MIROR-Body Gesture drafted the methodological process of designing MIROR-Body Gesture, focusing on the new issue of reflexive interaction in the body gesture system, designed the pedagogical framework of MIROR-Body Gesture, collected several pedagogical scenarios, and deeply analysed the Laban' Effort Weight boundaries (heavy/light) in children movement and music performance. Researchers had the opportunity to share ideas and pedagogical issues with the teachers of the primary and kindergarten schools regarding the ecological setting for the experiments and the teachers training activities.

- **Refinement of the requirements and implementation of the spiral process of specification** for the MIROR platform and related components, and for their interfaces. During project year 2, two workshops have been carried out. Different psychological tests executed by the psycho-pedagogical-partners have contributed to the development of new and improved versions of the MIROR platform by SONY and UNIGE. By applying the spiral process between

user testing and MIROR prototypes design and implementation, the results of user testing were transferred to prototype implementation. Psycho-pedagogical partners provided feedback to technological partners, including lists of recommendations.

- MIROR Libraries: The second year was mostly devoted to the implementation of MIROR COMPO and MIROR-Body Gesture, and to the integration of the three MIROR components. This included the development of the final versions of the core technological modules on which the MIROR prototypes are grounded on, and of the support modules for connecting the MIROR Prototypes. SONY and UNIGE conducted this work in close loop with the psycho-pedagogical partners -who provided feedback on the types of system output needed for the experiments, manipulation of musical parameters involved (rhythm, dynamics, texture, etc.), and development of specific settings-, and with COMPEDIA who also provided feedback on exploitation issues. The following major objectives were achieved:

- Algorithmic solutions such as the novel musical sequence generation algorithm with constraint satisfaction scheme (SONY) were improved and adapted to the context of MIROR COMPO prototype

- New and extended techniques for the analysis of expressive qualities of movement and gesture (UNIGE) were developed: in particular, the framework of Laban's Theory of Effort was addressed (Space, Time, and Weight) and machine-learning techniques were developed for the analysis of Laban's quality on a selected gesture vocabulary. Recognition is grounded on techniques for extracting 3D features from movement trajectories provided by the Kinect sensor. Features developed in MIROR and added to the EyesWeb XMI libraries include, for example, 3D curvature and sphericity.

- Various core technological modules such as session management, session visualisation, music score display, tagging and export functionalities were extended and adapted to MIROR COMPO prototype

- Integration of MIROR IMPRO and MIROR-Body Gesture prototypes has been further investigated.

- MIROR prototypes (IMPRO, COMPO, and Body Gesture). Major achievements in the reporting period are summarised as follows:

- Development of the final MIROR IMPRO prototype (SONY). Intensive specification and development was conducted during year 2 (10 versions along Year 2). The prototype was evaluated with experiments;

- Development of the final MIROR COMPO prototype (SONY). Intensive specification and development was conducted during year 2 (10 versions along Year 2). The prototype was evaluated with experiments;

- Development of the second version of the MIROR-Body Gesture prototype (UNIGE). Intensive specification and development was carried out during year 2. The prototype is being evaluated with experiments.

- The Consortium planned **studies addressing usability and user-experience** to be carried out in the 3rd year of the Project with the MIROR platform and related components (IMPRO, COMPO, and Body Gesture). The studies address the child's particular relationship with technology on the one hand, and the child's experience on the other hand. The results of these studies should lead to a clear and explicit list of recommendations that are useful for

further technological development. Further validations of the interfaces are being discussed (video observation, experience with small group of teachers).

- The initial step of market analysis was implemented and a survey has been launched by Compedia in collaboration with the other Partners, aiming at identifying and evaluating the demand for the MIROR platform among different segments and users.

- Dissemination of results: This includes (i) update of the project website, (ii) giving the project visibility with respect to the scientific community, the stakeholders, and the general public, (iii) publishing results from the project, (iv) creation of the MIROR newsletter.

1.4.3 The 3rd Year of the Project

The results of the 3rd Year include the following:

- Spiral process of specification
Two final workshops took place in Exeter (September 2012) and Bologna (March 2013). In Bologna SONY and UNIGE held technical presentations of the final software of MIROR IMPRO, COMPO and Body Gesture, including practical tests by all the participants. This was connected to a summary of the pedagogical experiments carried out within WP6 by UNIBO, UNEXE, UGOT and NKUA. The collaborative activities concerning the results of the final pedagogical experiments further contributed to the discussions in the spiral process. These activities also involved members of the Advisory and Liaison Board, and the Consortium decided to give the ALB members access to prototypes.

- Core technological modules
SONY and UNIGE continued to implement new features to improve the software. SONY achieved the implementation by introducing several new core features, among which:

- Added a cycle detection/avoidance feature in response generation (solves the sticky note problem),

- Added a melody randomizer feature for U. Athens experiments.

- Accuracy of phrase segmentation algorithm (phrase Threshold) was improved drastically (from about 100ms to 1ms),

- Export of melodies to MP3 format.

UNIGE extended the EyesWeb XMI platform by integrating new modules, both general purpose modules and modules specifically devoted to movement and gesture analysis:

- EyesWeb XMI was endowed with a new data type for floating-point operations, explicitly handling significant digits in computations involving physical measures. This allows for meaningful and more robust computations, especially on MoCap data from Kinect.

- EyesWeb XMI was endowed with new modules (blocks) for generating and processing floating-point data taking into account significant digits and using the data type mentioned above. This includes basic operations (e.g., arithmetic operations), derivatives, and statistical descriptors. Such new modules were used for improving feature extraction for movement analysis.

- The EyesWeb blocks for Kohonen self-organising maps were extended and improved in order to handle supervised classification problems, where labels of feature vectors to be classified are provided during the training process.
- Analysis of child's movement in terms of Laban's Effort dimensions was improved and refined. Use of Kohonen self-organising maps allowed for adaptation of movement analysis to the motoric behaviour of each single user. A more fine-tuned analysis on four different levels for each Effort dimension (two extreme and two intermediate levels) was achieved.

- MIROR prototypes

SONY achieved the final MIROR IMPRO prototype. MIROR IMPRO has been designed and implemented using the various new API developed in WP3 during year 2. During year 3, four different versions were delivered to the consortium, and many new features, bug fixes, and comments, in particular concerning the user interface, were progressively integrated. NKUA, UNIBO, and UNEXE contributed to the specification and design of the MIROR-Improvisation prototype on the basis of their work and research experience with children, and provided feedback to SONY.

SONY achieved the final MIROR COMPO prototype. MIROR COMPO has been designed and implemented using the various API integrated and developed in WP3. The final prototype includes a session management tool to record, retrieve, export to a webservice and visualise the musical content and user choices. NKUA, UNIBO, and UNEXE contributed to the specification and design of the MIROR IMPRO prototype on the basis of their work and research experience with children, and provided feedback to SONY.

UNIGE achieved the final version of the MIROR-Body Gesture prototype. In particular, following year 2 feedback from the initial evaluation, from psycho-pedagogical partners and from reviewers, the BeSound application was extensively reworked. Personalised and adaptive models were introduced grounding on Kohonen self-organising maps and reflecting both the motoric behaviour of the child and her movement and sound space exploration. Cross-modal reflexive music dialogue was improved and extended. An algorithm for determining the system's responses on the basis of the behaviour of the child and of the pedagogical goals of the teacher was implemented. New features were introduced (for example, higher variety of sounds, the possibility of storing session data, improved user interfaces, management of users and sessions). Five versions of MIROR-Body Gesture, including the new developments of BeSound, were released along year 3 (February, March, May, June, and August 2013). UNIBO contributed to recommendations for improving the design of MIROR Body-Gesture on the basis of their experiments with children, and provided feedback to UNIGE.

- Theoretical results related to the IRMS – creative musical processes and cognition/learning

In order to study the IRMS, the Partners present different topics concerning the theoretical study on IRMS paradigm in learning processes.

UNIBO has analysed several aspects dealing with IRMS, both in the context of music education and cognitive sciences of music, and in the more general field of learning in an interactive scenario. In particular, the following topics were studied on the basis of the experimental results: the mirroring interaction, the theory of Flow in reflexive scenarios, the cognitive constraints in children interacting with MIROR IMPRO, the processes of music

improvisation in children, learning/teaching processes in the reflexive and interactive scenario, reflexive interaction and embodied music cognition, music therapy and reflexive interaction. UNIBO carried out experiments in order to study if the reflexive interaction could enhance musical dialogue and creativity in children at the beginning stages of learning music improvisation, in particular when using the MIROR Platform during the "deliberate practices" at home. UNIBO also carried out several focus groups with university students who are undergoing teacher training, in order to extrapolate educational conceptions related to the MIROR Platform.

UNIBO has addressed specific topics as the link between the interactive reflexive paradigm, embodied music cognition and Laban movement analysis, through both theoretical insights and exploratory studies with MIROR-Body Gesture, and experimental studies, which combined MIROR IMPRO and body movements. In order to improve the child/machine reflexive interaction by means of body and creative movement and to integrate the body expression in reflexive technology, UNIBO carried out the following activities: analysis of the child's experience of the reflexive interaction, creation of an overview of reflexive interaction requirements. This list of requirements has been used as a basis for the exploratory studies with the MIROR-Body Gesture and to formulate feedback and recommendations for UNIGE in order to implement the Body Gesture component of the MIROR Platform. In particular, to measure the improvement in the quality of children's movements, we implemented an original grid, by means of the software Observer (Noldus copyright), based on the Laban Movement Analysis, created by the choreographer Rudolf Laban (1879-1958) to analyse the movements of dancers. The preliminary experimental results support the hypothesis that reflexive interaction could enhance the quality of children's movements.

UGOT addressed two basic issues concerning the work on the MIROR technologies, and on the background of contemporary research on children's composition. The two issues are the following: (i) Composition in the digital age, and (ii) the collaborative nature of composition. What UGOT has studied during the project is how children collaboratively compose (and also improvise) in natural settings with an analytical interest in *interaction* and *reflection.* One finding that informs the reflexive paradigm with new insight is that children's interaction with each other (and the teacher if present) takes priority over their interaction with the system, when used collaboratively. These results would confirm the pilot study and hypotheses,[2] and the more recent studies,[3] that the system positively affects the social interaction among children and between children and teachers, developing collaborative playing and joint attention.

UGOT also raised several issues as commentaries to the application of the MIROR-Body Gesture and the combination of audio and gesture communication, taking the learner's perspective into account and different concepts of variation, and what learning to use this technology may result in. A third issue that UGOT raised concerns the concept of variation

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[2] A.R. Addessi & F. Pachet, Experiments with a musical machine. Musical style replication in 3/5 year old children. *British Journal of Music Education*, 22(1), pp. 21-46, 2005; L. Ferrari, A.R. Addessi & F. Pachet, New technologies for new music education: the Continuator in a classroom setting, in Baroni et Al. (Eds), *Proceedings of the 9th International Conference of Music Perception and Cognition*, Bononia University Press, Bologna, 2006.

[3] A.R. Addessi, From Echo to the mirror neurons: Founding a systematic perspective of the reflexive interaction paradigm". In E. Cambouropoulos, C. Tsougras, P. Mavromatis, & K. Pastiadis (Eds.), *Proceedings of the 12th International Conference on Music Perception and Cognition (ICMPC) and the 8th Triennial Conference of the European Society for the Cognitive Sciences of Music (ESCOM)*, 23-28 July 2012, Thessaloniki, Greece, 9-19.

and what patterns of variation does the technology provide in interaction with the learner and hence, what does it make possible to learn. Finally, UGOT highlighted how the reflexive interactive paradigm can be related to socio-cultural theory.[4]

UNEXE has focused its attention on the application of MIROR technologies and on exploring how the children use the equipment in 'real world' educational contexts. Our questions have focused on the nature of engagement between children and MIROR IMPRO and COMPO; what children are learning from the processes of using MIROR and how this might be enhanced, either through the types of adult interactions to structure or guide their activity or through further strategies such as visualisation. UNEXE has been interested in the nature of musical thinking that is generated in play with MIROR technologies. In work with both MIROR COMPO and MIROR IMPRO we theorised that the activity of listening back immediately to musical ideas which are similar to but not the same as the child's own input requires the child to relate what has just been played bodily and heard, with what is now heard as sound only. Importantly we found that the children need to also acquire a language for talking about musical ideas with peers and adult if their learning is to be extended and consolidated.

UNEXE developed a further study with young pianists, for whom the keyboard was no longer a novelty and who already had keyboard skills. This study revealed that the children developed a number of strategies over a course of sessions to 'manage' the replies in ways they found meaningful on musical terms. The MIROR responses can be musically unsatisfying, but this then stimulated the children to find inventive ways to manage the replies. However, the balance between frustration that stimulates creativity and frustration that dampens motivation is a crucial one and the teacher needed to intervene to maintain a balance that was positive in learning terms. We looked for approaches in which the adult could develop three-way interactions between child, technology and adult that helped to guide the children's play with the equipment and stimulate the musical imagination.

Reflexive Interaction in relation to therapy setting
UNIBO carried out an exploratory study with a child with Down's syndrome and an exploratory study with children in therapeutic setting concerning music therapy as a prevention tool. From the theoretical point of view, the IRMS offer a useful paradigm to study the communicative process in music therapy, since the IRMS, through the mechanism of repetition/variation, do not exactly mimic the user's proposal, but her/his own musical style, and her/his own musical identity. Data analysis referred to: 1) an event-based analysis of musical improvisation through the *Improvisation Assessment Profile* (*IAP*) by Kenneth Bruscia, using the guidelines offered by Tony Wigram;[5] 2) an analysis of dyadic communication process through the Relational Coding System by Alan Fogel.[6] The results

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[4] B. Rogoff, *Apprenticeship in thinking: Cognitive development in social context*. New York: Oxford University Press, 1990; L.S. Vygotsky, *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press, 1978.

[5] K. Bruscia, Improvisational models of music therapy. Springfield, IL: Charles C Thomas Publishers, 1987; T. Wigram, *Improvisation: methods and techniques for music therapy clinicians, educators and students*. London: Jessica Kingsley Publishers, 2004; T. Wigram, Event-based analysis of improvisations using the Improvisation Assessment Profiles (IAPs). In R. R. Pratt & D. E. Grocke (Eds.), *MusicMedicine 3: Musicmedicine and music therapy: Expanding horizons* (pp. 211-226). Parkville, Victoria: Faculty of Music, University of Melbourne, 2007.

[6] A. Fogel & M. Lyra, Dynamics of development in relationship. In F. Masterpasqua, & P. Perna (Eds), *The Psychological Meaning of Chaos: Self-Organization in Human Development and Psychotherapy*. Washington, DC: American Psychological Association, 1997; A. Fogel, Oltre gli individui: un approccio storico – relazionale

shows that introducing the MIROR IMPRO could encourage the emerging of combined innovative actions in communicative process and enhance musical creativity.

NKUA proposed to use the MIROR IMPRO system in this kind of population with three therapeutic goals: 1) creating a sonic mirror, where the patient could regress to early infancy and find a chance to be heard, recognised and thus reconstruct his/her Self through musical reflexion; 2) proposing an interactive musical instrument as a transitional object, that would function as an intermediate between the patient and the outside world, including the therapist. The final goal would be to facilitate the creation of a relation with the therapist in pathologies where relation with human beings is very difficult; 3) enhancing a contact with the external reality, by inviting the patient to listen to his own musical reflexion and verbalise on it.

Although not strictly in the field of music therapy, UNEXE carried out a small study in a special unit for children with behavioural difficulties who cannot attend mainstream school. We hypothesised that MIROR technologies might have potential to engage children whose behaviour reveals autistic spectrum characteristics. We found some evidence to suggest that children with ASD (autism spectrum disorder) behaviours may engage more with MIROR technologies than with comparative classroom-based activities and that there would be future in developing this line of application.

- Pedagogical Experiments
UNIBO, NKUA, UGOT and UNEXE carried out several pedagogical experiments, in collaboration with SONY and UNIGE and several results were collected, as follows:

- Pedagogical aspects of IRMS have been explored, tested and evaluated in different contexts in four countries, Sweden, UK, Greece and Italy; mainly in school situations (individual, group and whole class) and also therapeutic and community situations.

- Action research procedures were developed for work in educational settings and observation protocols were devised to assess the application of the MIROR platform in educational and therapeutic settings.

- A user guide and teachers' guide have been prepared. Work has explored the integration of MIROR enhanced activities within the curriculum frameworks of the UK, Italy, Greece and Sweden.

As a result of this activity the psycho-pedagogical partners have:
- contributed to some final-stage developments of the technology and its interface;

- increased understanding of the ability of the MIROR system to enhance children's learning processes in creative music-making (both improvisation and composition) and increased understanding of its therapeutic potential;

- increased understanding of how reflexive music technologies might enable certain music-learning processes, particularly those associated with the retention of style and with creativity, and considered the notion of reflection from within a socio-cultural theoretical framework;

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alla teoria e alla ricerca sulla comunicazione. In M. L. Genta (Ed.), *Il rapporto madre-bambino*. Roma: Carocci, 2000.

- increased knowledge of how the MIROR platform might be integrated into educational contexts within systems of schooling as they differ across the European countries involved in the project;

- contributed information for the development of a marketable music technology for use in education, therapeutic and community contexts.

- Implementation and validation of MIROR systems interfaces
SONY continued to gradually improve the interface of IMPRO and COMPO. UNIGE continued to improve the interfaces for BeSound (the interfaces for the Potter were already delivered in year 2) and delivered the final version of them. Feedback was received from UNIBO, UNEXE, UGOT and NKUA. The UNIGE work focused on:

- Improvements to the teacher interface of BeSound, including new windows for managing the newly introduced working modes (transitions and music dialog), controls for simplifying the flow of the activity (e.g., skipping the introduction movies if already played), new windows for managing and controlling the adaptation of the self-organising maps modelling the behaviour of the user, new windows for managing users and sessions.
- Improvements to the children interface of BeSound, including a zoom mechanism for adapting the interface to the size of the body of the child and refinement of the selection mechanism.
- A comprehensive user manual was delivered to explain the use of the interfaces.

UNIBO and UNEXE carried out several usability tests and sent feedbacks and recommendations to SONY and UNIGE. A usability questionnaire was implemented by UNIBO in collaboration with Dr Luc Nijs and Prof. Leon Van Noorden (IPEM, University of Ghent) and was submitted to the participants of the MIROR Summer School (The Hague, July 2013).

- Dissemination of results: With reference to the dissemination and exploitation objectives, the achievements during the 3rd reporting period were the following:

- Continuous updating of the project website (www.mirorproject.eu) - News, Partner Area, Publications-, and preparation of dissemination material.

- Continuous updating of the Home page of the windows "Work in progress" and "Subscription list", and creation and updating of the page "Publications on IRMS"

- Continuous updating of the Deliverables accessible to the EU Commission and Reviewers.

- Periodical analyses of traffic on the web site.

- Periodical MIROR newsletter to inform a wider public about the implementation, the activities, the events and the results of the MIROR project.

- On the occasion of relevant international meetings, the MIROR project and its underlying ideas have been presented and the papers have been published in the Proceedings.

- Several contacts have been established with networks and associations in the field of music science and technology-enhanced learning.

- An online survey has been carried out. The main goal of this survey was

to gather attitudes of the music and dance teachers and opinion leaders in the industry, to identify needs, and define the channels for promotion and dissemination.

- The industrial exploitation plan has been carried out based on the secondary sources market overview, and the analysis of the inputs and feedbacks provided by the opinion leaders to whom the system was presented.

- MIROR project's Wiki portal. The music and video server, an associated taggable interface was implemented.

- Exploitation Agreement and the Exploitation Academic Plan were defined.

- The MIROR Summer School was held at the MERYC Conference, The Hague, Netherlands, in July 2013, attended by educators and researchers from many European countries. The participants were able to try out the equipment and to discuss its application within their own contexts.

1.5. Expected final results and their potential impact and use

The expected final results of the project are fully functional MIROR prototypes, assessed with experiments with children and grounded on solid theoretical bases. Impact is expected on education and learning, starting from music education, but possibly extending to other fields. Moreover, MIROR aims to:

- Develop a detailed analysis to assess the impact of the reflexive interaction paradigm for both music learning and general cognitive/learning processes.

- Promote an active approach to musical culture, based on a "music-making" concept, rather than "music-consuming"; promote the use of the MIROR platform in children and adults, enabling a wider access to music by experts as well as non experts; enhance the diffusion of music culture in EU society through experiments with the MIROR platform in several European countries; produce a User Guide and a Teachers' Guide.

In particular, the Consortium planned the Exploitation plan, which includes the following *Sectors of research activities:*

- UNIBO research areas include the following: Child/machine interaction, technology-enhanced learning, e-learning, reflexive interaction and creativity, children's music improvisation and composition, teacher education, music therapy, embodied music cognition, dance education, artistic performance, evolution of music language, vocal child/adult interaction, singing development in children. In particular, the UNIBO team is planning to fully realise the virtual environment of the MIROR Platform, i.e., the learning/teaching modules for using the three software applications (MIROR IMPRO, MIROR COMPO and MIROR Body Gesture): the users'/teachers'/researchers' interfaces; the learning-objects for teachers, music therapists, children of different ages, music teachers, dance educators, tutors facilitators, teachers' training tools, etc.; the two data bases (Children_Log - ,for teachers: to upload interesting children compositions, improvisations and choreographies. Work in progress, for researchers: to upload interesting practices, experiments and videos, documenting the work in progress research).
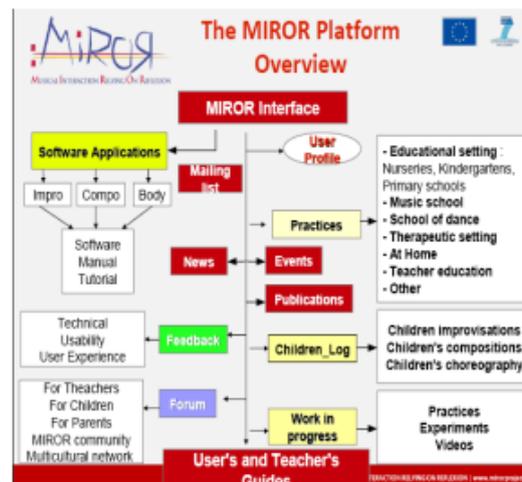
Figure 3: *An overview of the MIROR Platform architecture showing the most important parts as described in the section above (as from Addessi A.R (2013).* Child/machine interaction in reflexive environment. The MIROR Platform. In *Proc. of SMC2013, Stockholm).*

In particular, UNIBO will exploit the following knowledge:
- The concept of MIROR platform as a learning/teaching/research virtual environment exploiting the reflexive interaction paradigm not only in music improvisation education but also in the field of body gesture analysis, and potentially in other learning/teaching.
- The design and implementation of pedagogical processes and guides for teachers and children to be used with MIROR applications.
- The theoretical framework of reflexive interaction paradigm for educational purposes.
- Experimental protocols: Protocol no 1 and no2 of DoW, protocol Body-IMPRO. Protocol in music-therapy setting.
- Flow grid by software Observer.
- Laban grid by software Observer.
- Listening grid by software Observer.
- Grid of Sound/Movement connection, for MIROR-Body Gesture.
- Grid with Modes of Dialogue, for MIROR-Body Gesture.
- "Duets" grid, for the observation of musical dialogue between 2 children, by software Observer.

SONY Research areas include the following:
- [ACM Computing Classification System, 1998 H.5.2.] Information interfaces and representation: User interfaces – Interaction styles, user-centred design, auditory feedback.
- [ACM Computing Classification System, 1998] K.3.1. (Computers and education): Computer uses in education – computer assisted instruction.
- [Other sectors] Child/machine interaction; technology enhanced learning, e-learning, reflexive pedagogy, teacher education, music therapy, embodied music cognition, performing arts, sport, score visualisation, musical software handling MIDI signal.

In particular SONY will exploit the following knowledge:
- Constrained Markov Processes: Algorithm for generating Markov chains satisfying unary constraints.
- MIROR IMPRO application: Application for real-time generation of improvisation in the style of the user.
- MIROR COMPO application: Application for off-line generation of compositions in the style of the user.
- MidiShare 32-64: real-time musical MIDI operating system, providing high level services to the field of computer music and MIDI applications.
- JGuido and GlnToGmn Libraries: Full-fledged musical score notation display, which handles realtime, arbitrary MIDI inputs.
- "Style game" experiment: Analysis of preservation of individual musical style (principle of comparison between human and machine generated melodies).

UNIGE Research areas include the following (ACM Computing Classification System, 1998):
H.5.2. Information interfaces and representation: User interfaces – Interaction styles, user-centred design, auditory feedback
K.3.1. (Computers and education): Computer uses in education – computer assisted instruction.
In particular, UNIGE will exploit the following knowledge:
- Annotated archive of children performing selected gestures according to different Laban's effort qualities.
- EyesWeb applications for synchronised recordings of video and mocap.
- Extensions to EyesWeb XMI making a EyesWeb platform for scientific measurements (handling of significant digits, operations with significant digits, etc).
- Techniques for extraction movement features from full-body 3D trajectories (curvature, sphericity, and so on), developed as EyesWeb XMI modules.
- Techniques for extraction movement features from users playing a music keyboard, developed as EyesWeb XMI modules.
- Techniques for real-time analysis of Laban's Effort on 3D full-body mocap data, developed as EyesWeb XMI applications.
- Techniques for computation and adaption of models of the motoric behaviour of the child in terms of Laban's effort qualities, developed as EyesWeb XMI modules and applications.
- Methodology and techniques for real-time cross-modal reflexive dialogue, developed as EyesWeb XMI and MetaEyesWeb applications.
- A MetaEyesWeb template for developing applications involving cross-modal interaction with stories or non-linear structures.

NKUA Research areas include the following: teacher music education, community music therapy, music therapy, school music education and curricula, computational music analysis, creativity. In particular:
- Designing and implementing pedagogical processes of learning to improvise for teacher education in university curricula.
- Designing and implementing community music therapy and music therapy interventions.

- Follow up studies using MIROR COMPO in schools.
- In collaboration with the Department of Psychiatry at the University of Athens, cognitive neuroscience experiments using ECT scans while using MIROR IMPRO.
- Continue developing the methodology and system for the computational music analysis of MIROR IMPRO (PhD thesis of Antonis Alexakis).
- Possible book publication

Open access to the MIROR Applications

In order to exploit the results and implement the MIROR community of users, SONY and UNIGE give open access to the 3 MIROR applications.

1.6. The project public website, the MIROR newsletter and the wiki-portal

Relevant information and updates about the MIROR activity can be found at the **project URL**: www.mirorproject.eu.
The MIROR newsletter will be sent periodically in order to update the MIROR community about the last and near future events, studies, results, proposals, and publications. You can subscribe to the MIROR newsletter by means the project URL.
The MIROR wiki-portal has been activated: http://mirorwiki.eu.