VEMUS - FEEDBACK AND GROUPWARE TECHNOLOGIES FOR MUSIC INSTRUMENT LEARNING

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ABSTRACT

VEMUS is a european research project that aims at developing and validating an open music tuition framework for popular wind instruments such as the flute, the saxophone, the clarinet and the recorder. The system will address students of beginning to intermediate level. It proposes an innovative approach both at technological and pedagogical levels. This paper presents the project with a specific focus on the feedback technologies developed to extend the instrumental and pedagogic practices.

1. INTRODUCTION

VEMUS [1] stands for "Virtual European Music School". It is a project funded by the European Commission under the Information Society Technologies (IST) Programme of the Sixth Framework Programme (FP6). VEMUS aims at extending music pedagogical practices in several directions:

1. at instrument practice level, the goal is to improve the student practice effectiveness with an automatic performance evaluation, taking account of the music instrument played and providing structured comments, adapted to the student , and to give aural and visual feedback in order to support a better perception and consciousness of the instrumental performance,
2. in the context of the classroom, the system will explore and validate innovative tools to support music teaching in group settings, be it teaching aids to support the teacher, or tools to support collaborative learning and group activities,
3. finally, the VEMUS environment will provide distance learning extensions; maintaining and managing an open content repository, offering authoring tools to augment it, providing communication tools and allowing remote coaching of students and monitoring of their progress through time. These features will help to further build on the student-teacher relationship, also allowing the participation of students which might else be impossible due to geographic or other constraints.

We'll first present all the aspects related to the instrument practice: the system may be viewed as a *virtual teacher*; it includes a module for performance analysis and evaluation [18] but we'll focus on the pedagogic approach, based on a *mirror metaphor* and on new technologies. We'll next present the tools for the classroom and group activities.

2. THE MIRROR METAPHOR

From instrument practice viewpoint, the pedagogic approach developed by VEMUS is centred on an *extended music score*, intended to facilitates the learning process by mean of new feedback forms. This approach could be summarized with a simple metaphor: the music score behaves like a *visual and aural mirror*, helping the student in getting a better consciousness of his instrumental performance.

Part of the feedback is provided under the form of an annotated music score, including graphic shapes, text, emoticons, hand-written annotations and sound annotations. This approach, initially developed in the context of the IMUTUS project [5], has been extended to also include various graphic representations of the music performance (frequency curves, sonograms, envelope curves, etc.) that are displayed in parallel of the score. In addition, VEMUS introduces real-time aural feedback using audio processes that users can dynamically put on the music score.

2.1. Existing approaches

First approaches to visualize music performance have been developed more than 10 years ago: applied to the MIDI piano, linked to the symbolic music score,

[1] IST-27952

Smoliar [19] proposes in 1995 a pedagogic oriented system for representing music performance. Dynamic, tempo, articulation, left and right hand synchronization are graphically associated to the music score. The system limitations are mainly due to the MIDI data limits.

More recently, technological evolutions have enabled the development of real-time approaches applied to acoustical instruments, whether for performance analysis or for visualization. The feedback issue in the music performance domain has been thus renewed [10].

Several of the recent research propose real-time visualization of sound characteristics, directly computed from the audio signal, but disconnected from the music score. In the singing voice domain for example, spectral representations, wave forms, frequency curves and energy ratio have been used in a pedagogic context [9] [20]. A similar work from McLeod [14], but without targeting any specific instrument, proposes real-time representations of pitch, harmonics and envelopes.

Symbolic representations have also been developed, mainly for analysis purpose [7] [8] [13], and more recently for instrumental practice [3]. Study and representation of music expression and emotion also constitutes a recent research domain. Visualization is approached using shapes and colors [6] [2].

Finally, in the music education domain, there are very few research concerning real-time aural feedback: applied to the performer music style and addressing young children, experiments have been conducted that are relevant to the mirror metaphor [1]; some other research, recently presented by Ferguson [4], present pedagogic applications based on music performance *sonification*.

2.2. An extended music score

The concept of extended music score has been initially developed in the context of the IMUTUS [17] project. The basic idea is to enforce instrument practice efficiency by mean of a structured feedback, immediately available after each performance and adapted to each student level. This feedback is in charge of a performance evaluation module, that detects errors, builds a prioritized list and gives a specific feedback under the form of score annotations and comments. The music score has been thus extended with a set of annotations including graphic shapes (rectangles, ovals, lines, arrows) and text as well.

Within the framework of VEMUS, the score has been enriched with new annotations: in addition to graphic shapes and text, the score includes also emoticons, hand written annotations, audio annotations and real-time audio processes (see figure 1).

The emoticons can be used to draw the student attention on a specific point, or to communicate a performance expression [11]. Hand written annotations are provided to the student and teacher and take naturally place into existing music score annotation practices.

2.3. Objective performance representation

Objective performance representation corresponds to the annotation of the music score with graphic curves build using the audio signal or derived data. The underlying idea that has conducted our investigations in this domain was to establish the best correlation between aural and visual perceptions of a performance. The basic questions to be solved were: how to display basic audio data like fundamental frequency, RMS values, spectral data, to give an objective, accurate and intuitive representation of a music performance? what are the music characteristics that can be made visible and in what extend? and for each characteristic, what are the graphic representations that stick the best to the auditory perception?

Taking account of the above goals, a whole set of different curves has been developed, focusing on various music dimensions like articulations, nuances, pitch, timbre, intonation, pitch and volume stability. Table 1 presents these curves and the hypothesis we made on their expected efficiency along each music dimension. A curve may also combine several sound characteristics as illustrated by the figure 2.

Figure 2. Pitch, envelope and harmonics combined in a single curve.

These graphic objects are intended to make some of the sound characteristics visible, which could otherwise be difficult to describe orally. They constitute an additional tool at the disposal of the teacher, to communicate music ideas or to point out sound defects. They are also expected to be a good substitute to the teacher comments during home work and to virtually relay these comments by a shape recall. Finally these curves are also intended for an objective comparison of different music performances, between a teacher reference performance and a student performance for example.

To evaluate our hypothesis concerning the curves efficiency, a web inquiry will be presented, where users are asked to associate a curve to a performance recording and to discriminate between a fake curve and a good one (see figure 3). Results of the inquiry are not yet available.

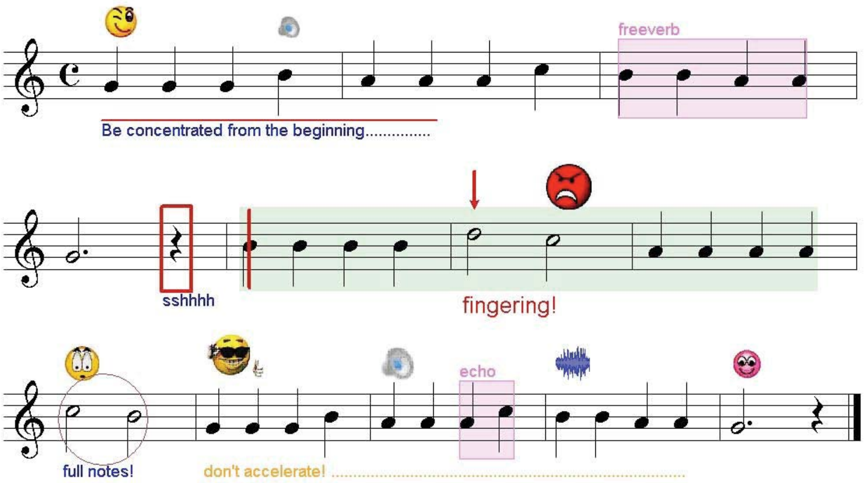

Figure 1. An annotated score.

Table 1. Curves design vs. music dimensions: the more '+' the best the curve is expected to cover the music dimension.

curve symbolic name	articulation	nuance	pitch	timbre	intonation	stability pitch	stability volume	timing
MelodicPitchCurve	+		++++		+	+		+
FinePitchCurve	+				++++	++++		
PitchStability	+					++++		
SymmetricStackedHarmonics	++++	+++		+++			+	+++
PitchSymStackedHarmonics	+++	+++	++++	+++	+	+	+	++
SpectroCurve	+++	+++	+	++++				
ArticulationCurve	++++	+++					+++	+++
DynamicsCurve	+++	++++					+++	+
ArticulatedPitchCurve	+++	+++	++++		+	+	+++	++

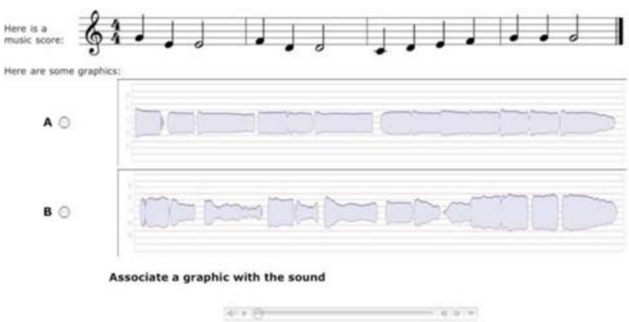

Figure 3. A web page for evaluation of feedback curves efficiency.

2.4. Aural mirror

The extended music score concept also includes sound aspects. The system actually records the student performances and automatically computes the mapping between the recording and the music score. Then the music score plays the role of user interface to trigger the recording: the student can listen to what he has just played, he can reach any location of the record using the score, listen to a single note or to any part of the record with a simple mouse click on the corresponding notes or score section. We may consider that the music score is extended to become a *sound mirror*.

New aural feedback elements are also added to the score under the form of real-time audio processing annotations (see figure 1, *freeverb* and *echo*). These processes are triggered in real-time during the performance and when the student enters the corresponding time section. These processes can modify the audio signal, apply filters or audio space transformation for example. The system thus provides sound feedback expected to carry pedagogic properties, but interactive music capabilities as well.

Finally, the score also includes audio annotations, which represents a way to associate an audio file to any time position of the score. These annotations are intended to insert teacher comments or music excerpts, to illustrate a difficult section for example, or to give different performances.

2.5. Experiments

Results of experimentations in the framework of the Vemus project are still pending. However, those carried out during the Imutus project proved very promising. Imutus has been evaluated in 3 different swedish music schools with pupils aged 9 to 14. The students have been distributed in 2 groups by their teachers: a control group and an Imutus group. Each pupil of the Imutus group was twinned with an equivalent skills level in the control group. During 3 weeks, each group has trained like they usually did in the normal teaching cursus: the only specific part is that each practice session was recorded by the Imutus system or using mini-disks for the control group.

The whole set of recordings for the 2 groups have been evaluated using Imutus. In addition, questionnaires were given to the teachers and students at the end of each evaluation week in order to complement the results with users point of view on usability and usefulness.

The results exhibit a significant difference between the Imutus group and the control group. According to the teachers and concerning the Imutus group:

- the improvement has been stable during the 3 experimentation weeks and the positive effect on musical abilities has been persistent up to one month after the end of the session.
- the students have significantly increased their self confidence at instrumental expression level.

Finally one of the student comments exhibits a non-intentional dimension of the feedback given by the system: *"It has been fun. I have had to think a little on my own without a teacher breathing down my neck, I get a little nervous from that. There has not either been any particular inflection to the comments so I can interpret them by myself a little."* [2]. The system is perceived as neutral, which facilitates the analysis and the self criticism of the student [15]. This is an important point, generally part of the instrument practice gaps: the young students' lack of self analysis and criticism.

The feedback related technologies developed in the Vemus framework clearly aim at filling the *pedagogic gap* that appears when the student is left to his

[2] comment made by a 12 years pupil

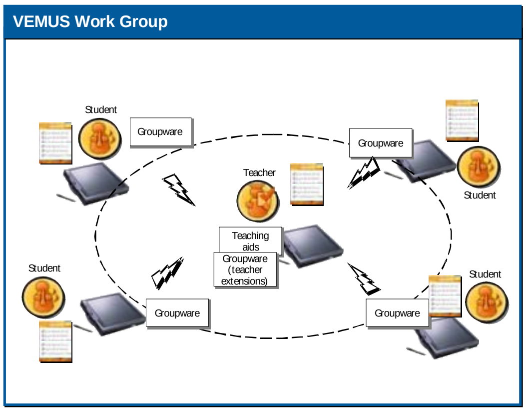

Figure 5. Organization of a work group making use of Tablet PC

own devices [16], between two lessons, during home work.

3. GROUPWARE FEATURES

Vemus approach could be viewed as an *enactive* approach of the learning process and the groupware features have been developed in this prospect. They aim at strengthening the interactions and feedback loops that take naturally place in the music classroom, and to propose new one (see figure 4). The underlying idea is also to see home work as an extension of the classroom work.

With the scenarios described below, we'll see that the underlying principle is to use the music score as a shared working space. For example, two or more participants can modify the same score in parallel, which become an interaction and communication space for the group; the teacher can add hand written comments or audio comments directly on the student score.

3.1. Groups setting up

The system is designed for small work groups, typically a teacher and one to four students (see figure 5). The group is created by the teacher who has has administrator responsibilities. He sends the required "invitations" to join the group to the different students. A group could also be set up by a student in order to open the Vemus groupware features to the home, family or friends contexts. Wifi Tablet PC mobility makes the group functioning easier and increases the friendliness of the system.

3.2. Scenarios of use

Groupware facilities have been designed according different scenarios of use. They correspond to typical pedagogic cases. They are briefly presented below.

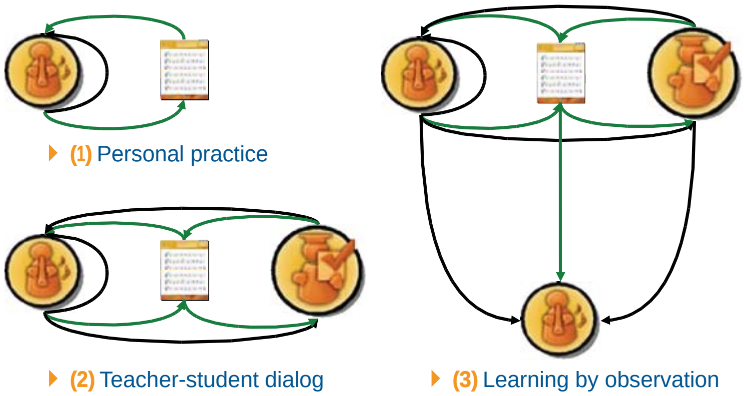

Figure 4. Strengthening of interactions and feedback loops in the classroom.

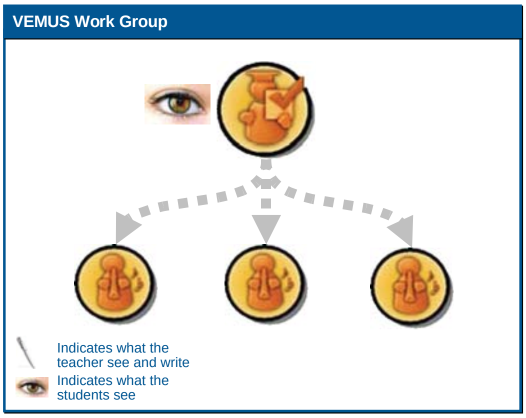

Figure 6. Demonstration case: the score and the teacher operations are duplicated on the students stations.

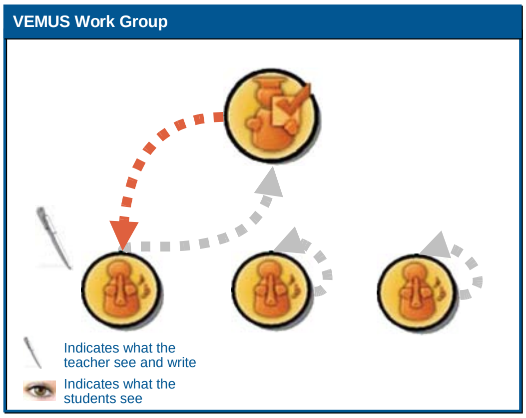

Figure 7. Teacher / student dialog case.

3.2.1. *Demonstration*

This scenario corresponds to a classic case: the teacher wants to address the whole class (see figure 6). Using his control interface, he connects all the students Tablet PC to his own station in read-only mode. All his operations are then automatically transmitted and duplicated on the students' remote stations. In particular, he can add annotations, play a section of the score, show curves etc., which gives his comments a very concrete turn. Hand written or audio annotations, cursor movements, score selections are duplicated so as to give the student the feeling of looking directly to the teacher Tablet PC.

3.2.2. *Dialog*

With this second scenario, one of the students plays in front of the teacher, who will next make some comments about the performance (see figure 7). To do so, the teacher connects to the student station in read/write mode. He can then access the student score similarly to his own score. Once the performance finished, the teacher can access both the score and the recording of the student. He can replay any section of the student performance while giving oral or written comments. When necessary, he can also makes use of the graphic feedback curves to illustrate these comments.

The teacher annotations are saved on the student station. Thus they remain available to the student even after the lesson, for instance during home work.

3.2.3. *Passive learning*

This scenario is a variation of the previous one: the rest of the class can watch and listen to the dialog between the teacher and a student (see figure 8). It proposes a situation where a pupil *learn by looking at the others learning*.

Using his control interface, the teacher connects to a student station in read-write mode. He also make a connection to the rest of the class but in read-only mode. All the teacher's operations on the student score are transmitted on the network and duplicated

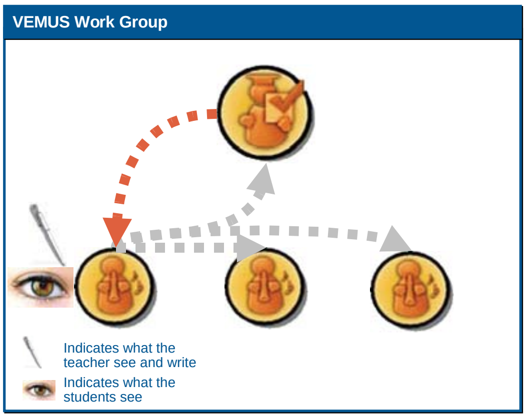

Figure 8. Learning by looking at others learning.

on all the connected stations.

3.3. Implementation principles

The implementation of the above scenarios requires information sharing and synchronization mechanisms that will be briefly described.

The implementation is based on a distributed MVC (Model-View-Controller) scheme (see figure 9). There are many interpretations of this diagram; our is quite close to the Smalltalk view [12].

The *model* corresponds to the system *state*. It exists both on disk and (partially) in memory. It includes the music score, annotations, performances recordings and a set of performance analysis.

The *view* is in charge of representing the *model*, both in visual and audio domains. A layers system allows to stack annotations and curves on top of the music score. Audio and MIDI sequencers are in charge of the sound rendering. Audio plugins can be dynamically switched on or off. Finally, the *controller* is in charge of translating the user input (mouse, keyboard, pen) into operations on the *model*. These operations will trigger possible redisplay at view level. Together, *view* and *controller* constitute the system user interface.

Instead of operating directly on the *model*, the *controller* encodes all these operations under the form of *actions*, that are next handled by the *model*, where they are finally decoded and processed. This intermediate encoding is intended to support *actions* storage, handling and transmission.

Actions are one of the two mechanisms provided for the synchronization of shared exercises. The other mechanism is a distributed file sharing system. Both are implemented above the Microsoft P2P layer.

Let's take the example of the dialog scenario presented above (figure 9) to illustrate how the system works. The student makes his model public. The teacher subscribe to the student remote model. Each action made by the student on his own local model is transmitted over the network. All the subscriber stations and notably the teacher station, are then processing the action incoming from the network in order to keep their model synchronized. Similarly, each teacher action made on his copy of the student remote model is transmitted over the network and the student station apply it to its own local model.

The model publication and subscription operations and the definition of the transmitted actions set are sufficient to implement all the scenarios considered by the project.

4. CONCLUSION

The different technologies developed in the framework of the VEMUS project, in particular feedback and collaborative technologies briefly presented above, are currently entering a first evaluation and validation period. This important phase of the project involves many users groups, distributed over 6 european countries. These groups include students, teachers and administrative people of conservatories and music schools. Results of this evaluation and validation phase should enable hypothesis and technological choices refinement. They are also intended to measure the system impact in the students progress. The promising results obtained with IMUTUS will be used as reference point.

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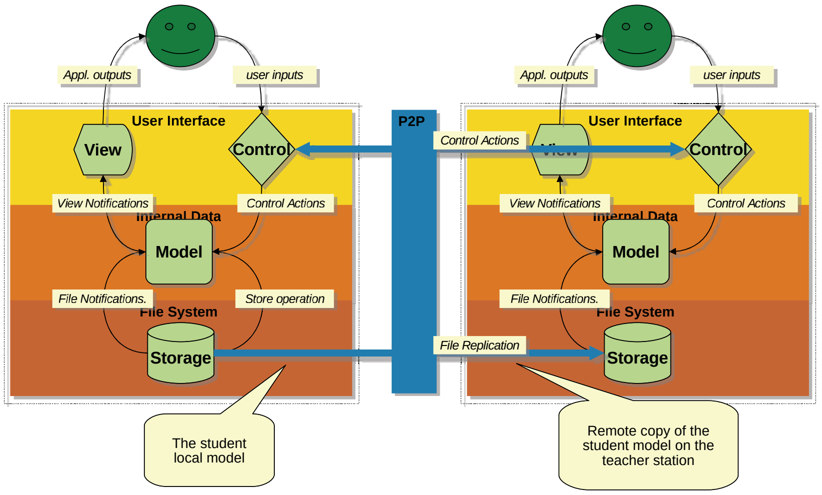

Figure 9. Relation between the student model and its image on teacher side in the *dialog* case.

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