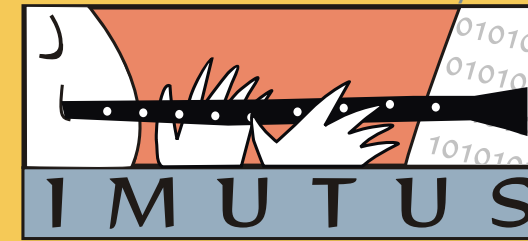


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Interactive Music Tuition System



*Interactive music tuition
multimedia system for
training users on traditional
instruments*

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IMUTUS Overview

Computers can help in making music learning and self-practising much more efficient, effective and fun! Computers have gone further from just displaying on the screen the contents of a music-teaching manual. Music tuition material has come to life interacting with the user, offering tools to the students for tuning their instruments and viewing music scores while listening to their teachers playing them. Additionally, students can watch dynamically generated 3D animations of the movements of hands and fingers, they can participate in amusing learning activities and electronically communicate with fellow students and teachers for exchanging experiences and learning resources.

But, above all, computers have started to actually listen, recognise, and evaluate the musical performances of students, providing constructive information on the aspects of the students performance that require improvement and indicating specific ways for achieving this. With these capabilities, a computer can actually become a "virtual assistant teacher", always available to offer valuable support to a student while practicing.

IMUTUS (Interactive Music Tuition System) is a project partially funded by the European Commission under FP5. IMUTUS aimed at the development of an open platform for training students on traditional musical instruments. The recorder was chosen as the target instrument because it is an instrument that cannot be directly connected to a computer, widely taught in European schools. The IMUTUS platform is designed to address the needs of beginners (first level) who are usually at the age of 9 to 14 years old. However, users of any age may use the system to improve their musical skills and acquire music knowledge.

IMUTUS is clearly not aimed to replace traditional forms of teaching. On the contrary, like all music tuition software, IMUTUS is expected to be most successful when it is used as an aid to complement traditional music lessons with a teacher and will be valuable for making practising at home much more constructive and enjoyable. IMUTUS can be particularly useful for teaching the more repetitive, yet essential, aspects of learning music.

A practicing session with IMUTUS, exploits a rich set of technological components developed by the project, aiming to provide innovative and more effective types of feedback focusing on performance skills.

The technologies involved include: real-time and off-line audio music recognition and feature extraction customised for the recorder; real-time score following for tracking the current position in the score and supporting automatic page-turning during a student performance; score matching for identifying the mapping from the overall performance to the score; and automatic performance evaluation for extracting higher-level information from the student performance and for providing prioritised structured feedback adapted to the student's skill level.

The IMUTUS environment is complemented by a set of additional tools including: a 3D fingering viewer dynamically generating and showing animations; an optical music recognition tool for scanning music sheets and converting them to electronic form; and a simplified pupil score editor mainly intended for games and student learning activities.

According to teachers experience, providing a mere report of the mistakes of the student's performance, such as wrong notes or durations, is not enough for ameliorating the students performance. Thus, IMUTUS takes evaluation one step further, providing clues on the specific points that actually caused the error and, more importantly, suggesting how to correct it. IMUTUS also tries to identify and provide positive feedback to well-performed aspects of the student's session- a pedagogically well motivated behaviour.

Validation activities and field tests have provided strong evidence for the positive impact of IMUTUS on practising with the recorder. It can safely be expected that enhancing and extending IMUTUS technology to cover additional instruments can meet with the same success.



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Using IMUTUS: Features and Capabilities of the Assessment Environment

Studying educational material



Logging on IMUTUS

IMUTUS can be used by different students and even in different languages using the same computer. It keeps separate records of each student's profile, progress and results. So, the first thing to do, is to log on!

The student is provided with a list of all the available content that is locally stored on the computer: theory units to study, exercise melodies to practise on, and educational games to play. More educational material is always available for downloading at the Distance Learning platform.

Theory units are comprised of text and rich media. The embedded pictures, images, diagrams, music scores and video provide the student with a hands-on experience for comprehending and mastering the given material. The student may also listen to performances, music samples and examples, or even examine closely and understand the fingering techniques and the correct position of the hands by observing from different angles the 3D animations that are dynamically produced by IMUTUS.

Exercise units constitute the heart of IMUTUS. The exercise units are musical pieces for the student to practise on. A number of IMUTUS modules cooperate to facilitate a student when practicing, and to provide assessment results. Specifically, the audio analysis and recognition module keeps track of the performed notes, the score following and matching module continuously detects the current position in the score and performs automatic page turning when necessary and, the performance evaluation module provides the necessary feedback for the student.

The Games are simpler than exercises and their main goal is to train the student on aspects such as music dictation, musical hearing, and playing by ear. Games may involve questions in true/false or multiple choice form, tasks involving filling-in or editing simple scores, or tasks where the student uses the recorder.



The Fingering Viewer



The Tuner



The main interface of the IMUTUS practicing environment

Performing and receiving evaluation

When the student decides to proceed to a practice session, the practicing environment appears on the screen, in which the score viewer has the central role. The student views a score that s/he is requested to perform in order to be evaluated. Some useful material always accompanies the score such as a standard performance of the piece (MIDI) and a 3D animation of the fingers and hands of a virtual performer playing the piece. Additional relevant material may also be available, such as a reference performance by a teacher or musician, the image of the original score, a video of a real performer etc.

Having grasped the basic characteristics of the piece, the student picks up the recorder, moves near the microphone, presses the "Start Performance" button and starts playing.

At the same time, the real-time score following algorithms built into IMUTUS ensure that the score cursor is always positioned on the last note played by the student. Score following can also handle performance errors, such as a wrong note, a missed note, an inserted note, or a pause and can follow the student even if s/he restarts the performance from a different position in the score.

An efficient look-ahead strategy is employed for the case of scores that span into more than one pages. When the student reaches the last visible line of the score, a preview of the next line appears at the top of the score. This feature is smoothly combined with the automatic page turning feature to ensure a seamless performance.

When finished performing, the student clicks on the "Stop Performance" button to notify the system. The student can then request the evaluation of his/her musical performance or discard it and start a new one.

A number of components are involved in the performance evaluation for the recognition of the performance audio with high accuracy and resolution, for matching it efficiently to the score and, of course, for assessing it. At the end of this process, the environment is updated to include the evaluation results and a grading in the range of 1 to 3.

The evaluation results take the form of feedback messages. A feedback message may relate to a specific note or group of notes, or it may concern the performance as a whole. Furthermore, it may point to errors or it may be rewarding feedback, giving credit to the students for a positive aspect of their performance. To avoid overwhelming the student with too much feedback, an error prioritisation and selection algorithm chooses up to three messages each time.

Each message belongs to a specific category and is composed of a hint providing a short description of the error and a help text including further details and suggestions. When the error refers to specific notes in the score, the student is provided with a direct way to listen to that phrase.



Starting, finishing and evaluating a student performance



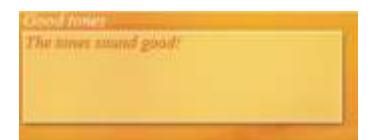
Indications during the student performance



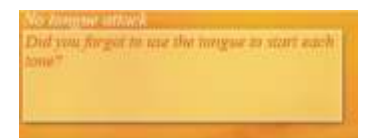
The grade in the range 1-3



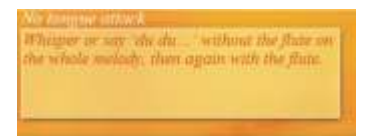
Presenting the evaluation results as feedback messages



A positive feedback message.



The hint text for a feedback message from the "No tongue attack" category...



...and the corresponding help text

Eliciting User Requirements for IMUTUS

IMUTUS has devoted considerable effort in identifying the needs and requirements of the field, especially because it addresses both a very young audience and an area of particular idiosyncrasy. Specifically, the area of music education is characterised by traditional teaching practices, emphasis on the student-teacher relations, very low computer penetration, and lack of widely available prior knowledge on the principles and on the best practices for applying technology enhanced learning. To cope with those, a set of questionnaires has been designed and employed for students, teachers and experts, supplemented by free and structured teacher interviews during meetings and discussions taking place in different countries.

Reference
For more information, please refer to the full User Requirements document available on-line at the IMUTUS website.

The following three methods have been employed for capturing user requirements for the IMUTUS project:

- Questionnaires, filled-in at sessions in the presence of a project contact person, who provided assistance and guidance.
- Direct feedback from teachers/experts through structured interviews during meetings or discussions taking place in different countries.
- Outlines of user scenarios to capture the gist and the overall feeling that was envisaged for the IMUTUS system.

The following table provides information on the number of persons that have filled-in the questionnaires.

Table. Number of people involved in filling-in the questionnaires.

	Italy	Sweden	France	Public schools	Private schools	Totals
Students	146	14	69	114	115	229
Teachers	18	10	6			34
	164	24	75			

A large part of the actual functionalities of IMUTUS could not be fully specified in advance, based solely on the feedback from students and teachers. Very limited information was available in respect to the exact principles on which the design of the system should be based. Such information could not be fully acquired from the persons involved in the current teaching procedures since they lack prior experience on the subject. Specifically, the majority of the teachers interviewed never used computers or any software in the process of teaching music or for preparing teaching material for their students.

It should be stressed that the aim of IMUTUS was not to simply copy traditional teaching procedures, but also to exploit the potential offered by technology for introducing innovative learning settings and for enabling the application of new pedagogical approaches. Thus, teachers were often unable to relate to questions involving technical aspects of the system, since they could not imagine how it would be like to use a system such as IMUTUS.

Therefore, although the number of students and teachers that filled-in questionnaires was large enough for obtaining substantial and valuable input in respect to teaching practices and significant points of music tuition, the obtained information related to more technical questions was limited. Thus, the input from user requirements in respect to the technical issues and features of the IMUTUS system could not be used as the only basis for technical decisions. IMUTUS has been given enough freedom at the technical level to exploit additional potentials. It was the validation activities that shaped the various features of the system based on hands-on experience with the students and teachers.

IMUTUS adopted the use of frequent prototypes and iterative development cycles. This approach was considered as the most efficient way to gradually acquire the necessary information. This implies that the acquisition of user requirements was a process that remained active almost throughout the project, until the final prototype of the system had been developed. The validation activities and the user feedback were the actual tools used to continuously refine and revise, whenever necessary, the formal user requirements and system specifications.

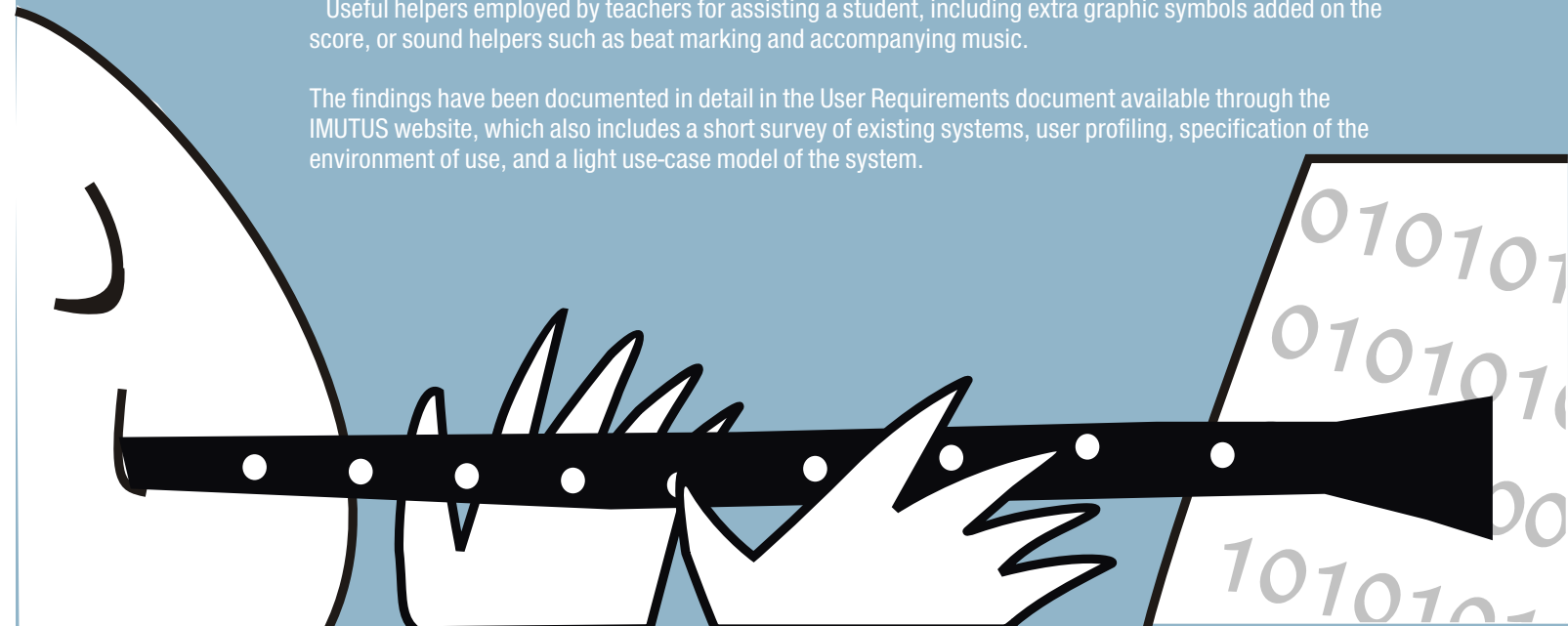
The requirements acquisition process of IMUTUS aimed to identify a number of issues such as:

- the target audience and age range
- the level of computer penetration in elementary music schools
- the level of computer usage at home
- the perceived value of a system such as IMUTUS as an assistive tool for studying music
- the aspects that students considered to be important when studying
- the aspects that teachers considered to be important when evaluating a student performance
- the perceived value of distance learning and communication through the internet in the context of music tuition
- the combination of learning and fun
- general guidelines for teaching music to beginners
- recommended practicing schedules

common teaching practices, including ways to approach a new piece, ways to correct the student and steps for progressing

Useful helpers employed by teachers for assisting a student, including extra graphic symbols added on the score, or sound helpers such as beat marking and accompanying music.

The findings have been documented in detail in the User Requirements document available through the IMUTUS website, which also includes a short survey of existing systems, user profiling, specification of the environment of use, and a light use-case model of the system.



Automatic Performance Evaluation in IMUTUS

The IMUTUS system is mainly aimed at training musical performance skills on the recorder, but the system also facilitates training of fundamentals of music and simple composition. The following discussion focuses on systems for training performance skills in general, and the specific approach of IMUTUS.

Automatic performance evaluation plays a key role in the student-system interaction. The purpose is not only to inform the student about his/her achievements, but also to make the practising sessions more efficient by providing structured feedback immediately after each performance. The Performance Evaluation Module (PEM) identifies typical errors in the student performance and gives constructive feedback on the three top-ranked errors as output.

Reference

For more information please refer to the paper "IMUTUS - an interactive system for learning to play a musical instrument" E. Schoonderwaldt, K.Falkenberg Hansen & A. Askenfelt Dept. of Speech, Music and Hearing, KTH, Stockholm, Sweden Available on-line at the IMUTUS website.

Table 1

Basic performance skill categories, average ranking, and performance aspects. The ranking refers to the relative importance of the errors during the first four terms of playing the recorder. Aspects of instrument control as well as musical performance are represented. Instrument control is considered to be the most important to develop in the early stages of learning.
IC: Instrument control
MP: Musical performance

Basic performance skill category	Average ranking	IC/MP
1 Airflow	1.7	IC
2 Fingering	1.7	IC
3 Rhythmic performance	2.0	MP
4 Attack	2.0	IC
5 Melodic performance	4.2	MP
6 Tempo	5.0	MP
7 Intonation	5.3	IC
8 Phrasing	6.0	MP
9 Articulation	7.5	IC/MP

Basic performance skills

The performance evaluation module in IMUTUS is based on a model of novice student performance skills, covering different aspects of recorder playing. Errors in a student performance can be classified according to a set of basic performance skill categories. In this approach, performance errors are closely related to performance skills.

The basic performance skill categories and their relative importance were determined using questionnaires and interviews with 40 music teachers from France, Italy and Sweden. The results are summarized in Table 1. A set of 9 basic performance skill categories was considered to capture the essential characteristics of the students performances. The teachers were also asked to rank these categories in order of importance. The ranking is also reflected in the development of a student. For beginner students, the main focus is placed on aspects of instrument control, while with more advanced students, more attention is given to aspects of musical performance.

Typical performance errors

More detailed and specific knowledge of typical performance errors was obtained in a case study. For this purpose recordings were made of recorder students at varying skill levels. A representative selection consisting of 8 recorded performances was given to five Swedish recorder teachers who were asked to provide a structured analysis of the performances. The teachers also received the scores of the performed melodies. The main parts of the structured analysis consisted of a description of the most important errors in the performance, the feedback they would give to the student, and a grading of the performance on a scale from 1 to 5.

The performance errors reported by the teachers were classified according to the basic performance skill categories, resulting in a detailed overview of typical student errors. This overview formed an important basis for the development of error recognition algorithms in the performance evaluation module.

The collected teacher evaluations were entirely based on auditory information. This implies that, in principle, all the information needed for the evaluation is coded in the audio recording of the student performance, provided that the score is known. Consequently, performance errors should be able to be recognized by letting the computer search for characteristic symptoms of errors in the acoustical signal, combined with a comparison of the identified notes in the performance with the score.

A major advantage of this approach is that the identified performance errors also represent a higher level interpretation of symptoms. Recognition of typical performance errors provides the key to more adequate feedback.

Design of the Performance Evaluation Module

The IMUTUS strategy of finding and classifying performance errors, a strategy derived from a thorough research with expert musicians and music teachers, is reflected in the design of the Performance Evaluation Module. The recorded audio signal is analysed and the extracted performance information is scanned for typical errors defined by the categorisation in the Table. The PEM sorts them in order of priority according to the basic performance skill categories. The most important errors are selected for feedback to the student. PEM does not only look for errors, but also tries to identify and praise well-performed aspects. For example, if no error is found in a certain basic performance skill category, a positive comment referring to this skill is generated.

Feedback

Immediately after the performance, an overall grading is given. This gives a rough estimation of how well the student performed, and could be useful as a momentary stimulus or reward to the student. A set of twinkling stars appear on the screen, with three stars symbolising the top grade.

The detected errors in a performance may be numerous. For pedagogical purposes the errors need to be prioritised, and a small selection (typically 3) have to be made before presenting the feedback to the student. Except for reporting errors, it is also important to inform the student about the strong points of his/her performance. Rewarding feedback is important to keep the student motivated.

The feedback is communicated to the student via a user interface displayed on the screen. The student is guided through the feedback process following the priority of the feedback. When one of the three error buttons is pressed, the location of the error is displayed in the score and an initial, short descriptive message is displayed.

There are two levels of feedback, which can be shown on request by the student. The first, light level is 'Get hint' and the second, deeper level is 'Get help'. Each category of performance error has a predefined set of feedback messages. Most messages are available in different wordings, for avoiding boring repetitions of the same phrase.

The IMUTUS Score Viewer as a mirroring user interface

The IMUTUS training system may be viewed as the interaction between the user and a virtual teacher by the means of an extended score viewer. The virtual teacher is in charge of the performance evaluation and provides the results under the form of score annotations. During a training session, he helps the student by showing the next note to play, by turning the page when necessary and by providing aural feedback. Score processing is at the heart of these interactions.

The score viewer has been designed to facilitate the learning process by providing innovative and enhanced forms of feedback. To use a metaphor, the score viewer acts as a visual and aural mirror that helps the student to become aware of his own performance. The interaction between the student and the score viewer can be divided in three main phases:

- In a first phase, the student uses the score viewer to read the score to be performed in order to listen to the reference performance and take note of the difficulties as well as any indications on how to perform the score correctly: this is the **preliminary phase**.
- In a second phase, the student uses the score viewer to perform the piece by possibly using the metronome, the automatic cursor following and the turn-page facilities of the score viewer: this is the **practice phase**.
- In a third phase, the student uses the score viewer to become aware of his own performance by the means of the automatic performance evaluation annotations as well as the possibility to listen to his/her own performance and to compare it with the reference performance. Specifically, s/he is able to directly click on a particular note or selected section on the score to listen to the corresponding audio recording: this is the **feedback phase**.

To provide the required features the score viewer is organized in several sub-modules:

- A set of player modules: The player modules are in charge of the audio, MIDI, metronome rendering. They can be triggered to play the whole piece or a specific time range. They can synchronize the graphic sub-module to display the current position in real time.
- A graphic module: The graphic module is in charge of producing and merging several graphic representations in order to draw what is actually seen on the screen according to the current position in the score.

The heart of the student/virtual teacher communication and interaction lies in the graphic module. All the information linked to pedagogical issues is related to the corresponding musical material and displayed on the score: it represents pedagogical annotations, tips for a correct performance or for improvements and graphical signs to highlight a specific section.

Reference

For more information please refer to the paper "IMUTUS - AN INTERACTIVE MUSIC TUITION SYSTEM" D.Fober, S.Letz, Y.Orlarey Grame - Centre national de creation musicale A. Askenfeld, K. Falkenberg Hansen, E. Schoonderwaldt KTH - Royal Institute of Technology

Available on-line at the IMUTUS website.

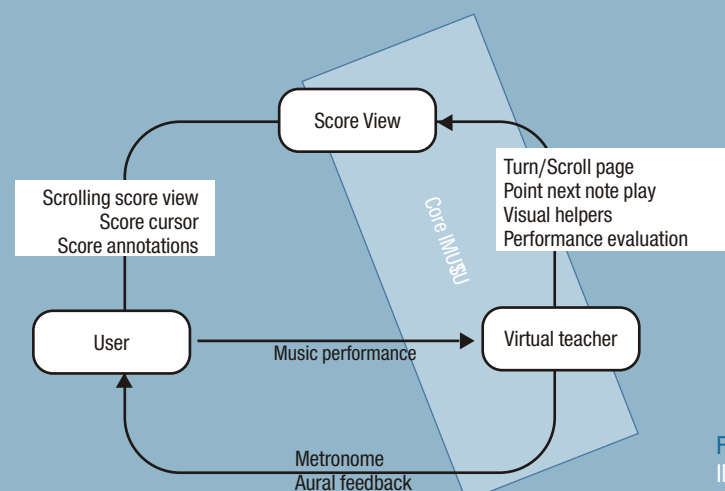


Figure
IMUTUS global architecture

The Validation of the IMUTUS practicing environment

The IMUTUS project has addressed many research topics in the development of an interactive music tuition multimedia system for training students on traditional instruments. Computer engineering has been devoted for the integration of various key technologies resulting in the final version of the IMUTUS prototype. Validation efforts have been directed to assess the benefits of IMUTUS as a tool for tuition, an issue that can not be taken for granted despite careful computer engineering. Informal validation activities have also been carried out in music schools in Italy with the participation of students and teachers, focusing on the IMUTUS practicing prototype and on different modules separately.

The validation activities in IMUTUS addressed the following topics:

- Educational needs: The content, the aim, the students' perspective on the tuition system and the teachers' knowledge and experience.
- Computer experience: The estimate of knowledge to handle the computer as a tool.
- Affect and attitude: The students and the teachers impressions of IMUTUS examined after each week of the validation period.
- Musical improvement: The efficiency of the system in teaching students to play the recorder.
- Usability: The mixture of relevance, efficiency, attitude and learnability of IMUTUS.

Method

The validation was a field trial that collected qualitative and quantitative data as they appeared in students (12) and teachers (3) self-reports, as well as performance measures from the practicing sessions stored in the computer log files. The students, between 9 and 14 years old, used the tuition system in their homes (ecological validity), during a period of a couple of weeks (longitudinal), 3-4 times a week, about 30-45 min per session but in well-defined tasks and with possibility for technical support from the research leaders (control). There were two groups of students arranged in matched pairs, one experimental group using IMUTUS, and a control group doing the same kind and amount of practice, but without access to the software using just a minidisk player (quasi-experiment). The musical material consisted of the same melodies that the teacher would select for the student during normal teaching and students in each pair used the same melodies.

Questionnaires

The questionnaires are designed to assess the overall usability as defined in the section "Main topics for validation" above. They contained a mixture of fixed response alternatives and open-ended questions. Questionnaires aimed for students are in simple style that avoids abstract and ambiguous terminology and questions.

There were three different kinds of questionnaires. The first was used to estimate (longitudinal) usability, affect and attitude changes among students during the three-week period. This questionnaire was answered at the end of each validation week. The second and third questionnaires aimed at final validation at the end of the period, with reflections on IMUTUS as well as previous computer experience. It was possible to compare the students and the teachers answers in a systematic way.

Results

Computer experience. The students are experienced computer users. They have access to computer at home and almost everyone plays computer games and is on the internet everyday. None of the teachers had used a computer program in their teaching before. They use the computer at home and at work several times a week, but none considered oneself as well-experienced. All three teachers estimated their interest for computers as “pretty small”, but they were somewhat positive for computers in education.

Affect and attitude. The teachers answered the open-ended question “When you heard about IMUTUS for the first time, what was your impression? Explain in your own words the first thought you had.” and reported that they were sceptical to the very idea of having a computer software as tutor for music.

- ▶ “Is it possible to learn music from a computer?”
- ▶ “I don't think that a computer can replace a teacher, but I am curious.”
- ▶ “I was sceptical because of my inexperience, and a bit worried that the computer should replace me as a teacher.”

Students were asked about their experience with IMUTUS. Figure 1 shows the frequency of their self reported amusement and perceived usability.

After the validation period the three teachers answered the question: “How do you believe that your students experienced the work with the computer software?”

- ▶ “Very funny, pretty easy, the program is free from demands, amusing”,
- ▶ “Very funny, pretty easy, when they can see through the software structure to gain award.”
- ▶ “Pretty funny, pretty easy, but the 10-year old students perceived it as very funny”.

To be able to compare the teachers first impressions with their attitude after the validation period the following question were answered “Explain in your own words your experience of IMUTUS now, three weeks later and how that feeling corresponds with your first expectations?”

- ▶ “I am positively overwhelmed that students found IMUTUS so funny. It exceeded my expectations.”
- ▶ “I was sceptical but now my I am curious. I think the software is under way but it is not finished yet”.
- ▶ “My sceptical thoughts disappeared, but I realize that the program needs to be developed.”

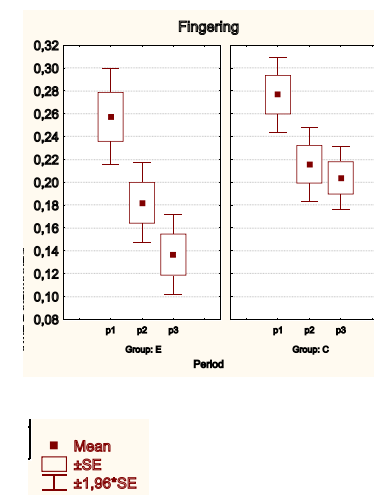
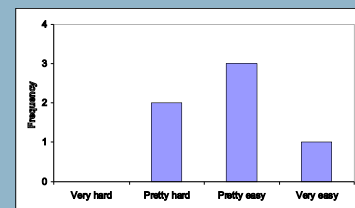
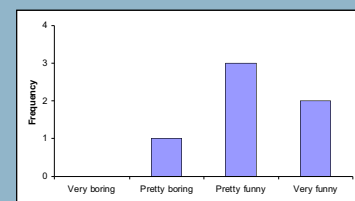


Figure 2
IMUTUS performance evaluation for fingering. Experimental group (left panel) and control group (right panel).

Musical Improvements. The students self reported beliefs about their musical improvements showed that about one third believe it to be “much better” about one third “somewhat better” and one third “as good as before” in an even distribution across the three week validation period. They also believed that their teachers had the same opinion about their improvement. The teachers judgment of their students musical progress was positive.

- ▶ “The Improvement was stable across the three weeks and there is a persistent effect in the students musical skill, even now a month later.”
- ▶ “The students have been much more secure in expressing themselves on the recorder.”
- ▶ “There were individual differences in how students improved by the software.”

However, the most objective measure would be to examine the performance data stored in the computer.

Figure 2 shows means and 95% confidence intervals for occurrence of performance error density (errors per measure) for Fingering. Data which is collapsed across three time periods (p1-p3) covering equally long practising time shows that the experimental group (left panel) decreased error density across period to a much greater degree than the control group (right panel). A similar effect was apparent in intonation, Tempo and Attacks, but not apparent for melodic issues, where the experimental group showed a floor effect with low error level in all three periods.

Usability. The students reported that they sometimes get stuck when using the software and that they need to get help many times. However, it should be noted that this was their first time using the software and that the research leaders were there to provide instructions and help when needed. The students were also asked about usability on specific tasks such as running the software, getting started, using menus, and working with the music score.

Some of the students own comments on the IMUTUS software were:

- ▶ “I think that the instructions sometimes are bad. But they are good because you can improve your performance.”
- ▶ “This is good because I have learned a lot more.”
- ▶ “It has been fun. I have had to think a little on my own ... There has not either been any particular inflection to the comments so I can interpret them by myself a little.” (12 year old student)

Conclusion

The validation of IMUTUS is a typical small N field investigation involving a group of a few students and their teachers and studied their affects and attitudes, in combination with performance data stored in the computer across a limited time period of three weeks. The converging evidences of affect and attitude shows that IMUTUS is fun and believable. Students musical skills were also improved as is evident from a) performance evaluation data and b) reflected in judgements by the teachers and in self-estimations by the students. With regard to usability, it could be concluded that IMUTUS is relatively easy to use.

Meet the IMUTUS Consortium

The IMUTUS team

The members of the IMUTUS team that were present at the final review meeting!
January 28, 2005
Stockholm



Institute for Language and Speech Processing (project coordinator) Epidavrou & Artemidos 6, Marousi, 151 25 Athens, GREECE

The Institute for Language and Speech Processing (ILSP) was founded in Athens (Greece) in 1991 under the auspices of the General Secretariat of Research and Technology of the Ministry of Development. ILSP began its activities in May 1992. The goal of ILSP is to support the growth of Language Technology in Greece. For this purpose, ILSP has brought together a team of experts and has created the necessary technical infrastructure in accordance with the EU policy towards safeguarding the European cultural heritage through technology. ILSP aims to be a pole of attraction for the language industry, which will grow both in Greece and in the rest of Europe, thus contributing to the expansion of activities in this particularly important area of modern IT. The industrial direction which ILSP maintains, the experience of its researchers and its close relations with key research centres in other European countries, are the three basic elements of the ILSP profile.

ILSP carries out applied research in Speech Processing, Text Processing and Language Learning Technologies. Expertise used by the Institute includes basic fields as NLP, DSP and Pattern Recognition. ILSP has participated and is currently involved in many National and European projects in topics of language learning, web based learning, content management, video indexing, speech enhancement, music distance learning and others.

► In addition to the overall administrative and technical coordination of IMUTUS, ILSP is also responsible for the audio recognition, the score following/matching, the front-end environment, the core IMUTUS platform and the integration of the overall system.

KTH, Royal Institute of Technology KTH/TMH, Drottning Kristinas vag 31, SE-100 44 Stockholm, SWEDEN

KTH (Royal Institute of Technology) is the largest technical university in Sweden with about 13.000 students and over 3.000 in faculty and staff. The Dept. of Speech Music and Hearing - a division of the School of Computer Science and Communication teaches and conducts research in the areas of speech communication, speech technology, music acoustics and music technology, and hearing technology. With a faculty of 50 researchers and PhD students and a turnover of about 3,500,000 €, the department represents a competitive partner in major branches of speech and music research. The department has been engaged in 12 projects in EU Fifth Framework Programme (FP5), some of them as coordinator, as well as being a Marie Curie Training Site. Presently, the department is active in two IPs and a NoE in Fp6.

The Music Acoustics Group within the department is active in research on music performance, the physics and acoustics of musical instruments, and singing. While running in parallel for periods, the research areas often merge and interact. Research at KTH on musical performance by computer modelling has been a long-term project, dating back to the 70's. The KTH generative music performance grammar Director Musices has been well-known in research laboratories for more than a decade. In addition, thousands of music-interested people all over the world have down-loaded this music interpretation program since it was made accessible on the internet in 1997. More recently, models for the synthesis of emotional expression in music performance have been developed and made available on the internet <http://www.speech.kth.se/music>

► KTH's responsibility is the development of the Performance Evaluation and Skill Grading module, as well as for the controlled validation phase.



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Grame, Centre National de Creation Musicale 9 rue du Garet, BP 1185, 69202 Lyon Cedex, FRANCE

Grame is a National Center for Music Creation supported by the French Ministry of Culture, the Rhone-Alpes region and the City of Lyon. The main mission of the center is to encourage and promote contemporary music creation in a rich and pluridisciplinary environment associating artistic and research activities. The activities of Grame are organized in four main departments: music creation, concert and festival organisation, music education and research in computer music. Grame is strongly involved in international music and research activities and provides many opportunities for composers, performers and researchers to collaborate. The areas of expertise of Grame in computer music research are: real time and distributed systems, music operating systems, composition environments and music programming languages.

► GRAME is responsible for the development of the Musical Score Processing modules, namely the Score Viewer and the Graphical Score Editor.

EXODUS S.A. 6-10, Farantaton Str., Athens, 115 27, GREECE

EXODUS S.A. Is an IT company, specialising in Content Management and electronic solutions, to small, medium and large organisations. EXODUS is located in Athens Greece, founded in 1994 and since 2000 is a member of the Piraeus Bank Group of Companies, the third largest bank organisation in Greece. Currently EXODUS S.A. employs 80 highly skilled professionals.

EXODUS S.A. designs, creates and offers the Greek and international markets software solutions and services in the area of electronic business. Exodus offers integrated solutions and services for intranets and extranets, implement systems for workflow, knowledge management, document management and business intelligence (data ware housing, data mining). In addition, Exodus develops applications for e-commerce (B2B) and e-procurement and offers powerful infrastructures for e-learning and for contemporary and efficient project management.

► EXODUS is responsible for the development of the Distance Learning platform and Communication tools, the Content Authoring modules and the content transfer between the local and the remote system. EXODUS also guides the project's dissemination and exploitation activities.

Department of Systems and Informatics (University of Florence) Via S. Marta 3, 50139 Firenze, ITALY

The Department of Systems and Informatics, DSI, Faculty of Engineering, University of Florence, Italy presents several different competencies: artificial intelligence, software engineering, multimedia, systems, automatic control, environmental aspects, operative research, speech recognition, database navigation, image modelling. At the DSI there are few research groups. Prof. P. Nesi is the co-ordinator of a group which is strongly active in the field of: software engineering, HPCN, computer music, parallel architectures, object-oriented, formal methods, visual languages, CASE tools, real-time techniques, logic languages, temporal logic, object-oriented user interface, vision, scheduling, distributed systems, multimedia, graphic user interfaces, software quality and assessment, testing, object oriented languages, verification and validation techniques, image processing, optical music recognition, simulation, and electronic design.

► DSI is responsible for the development of the Optical Music Recognition module and the Music Notation to Hand Positioning Module.



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Systema Technologies S.A. 215 Mesogeion Ave., Athens, 115 25, GREECE

Systema Technologies specialises in the development of advanced information technology applications in the areas of Multimedia Databases and Networking, Virtual Reality, and Image & Video processing and archiving.

In the area of Cultural Information Society Technologies, Systema has a long tradition and large experience in developing integrated solutions especially utilising digital 3D surrogates of physical objects (e.g. e-Islam Benaki Museum Islamic Branch Athens). In addition the company has taken up in many cases technological solutions for exploitation in the Cultural and Tourism Markets (e.g. Regnet Ontology mapping).

► SYSTEMA's responsibility is the development of the Movement Authoring Tool, the Fingering Viewer and the presentation of fingering to VRML.

Music School of Fiesole Via delle Fontanelle, 24, 50016 S. Domenico di Fiesole, Firenze, ITALY

SMF (Scuola di Musica di Fiesole - founded by M. Piero Farulli of the Quartetto Italiano in 1974) is a European Foundation musical institution that welcomes students from 3 to 90 with the core school for all instruments, the master classes, the master classes for orchestra and the Italian Youth Orchestra directed by C. Abbado, C.M. Giulini, R. Muti and G. Sinopoli.

SMF's program includes professional level seminars taught by world renowned musicians, composers and directors, but the most successful objectives of SMF are the instrument and chamber music courses that cultivate young talents from their first approach to music to active participation in one of SMF's three orchestras and numerous chamber groups.

SMF has always prided itself in experimentation of innovative teaching techniques and is in the avantgarde for implementation of computer technology applied to music instruction.

► SMF represents the user community (students and teachers) within IMUTUS, providing valuable input for the user requirements, as well as the system validation and evaluation.



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Meet the Protagonists



Testing IMUTUS in action has been an enjoyable, fruitful and rewarding experience, clearly demonstrating a very strong potential. IMUTUS has managed to amuse and attract the interest of students but also to overcome the initial doubts of the teachers.

Students and teachers from different schools in Sweden and Italy have been involved in IMUTUS working alone at home or in groups at their school. The IMUTUS Consortium would like to warmly thank all the involved students, teachers and schools for their valuable help. Special reference should be made to:

- Music School of Fiesole, Florence, ITALY
- Ghiberti Junior High School, Florence, ITALY
- Nacka musikskola, Stockholm, SWEDEN
- Solna kulturskola, Stockholm, SWEDEN
- Stockholms kulturskola, Stockholm, SWEDEN

What the students and teachers have to say about IMUTUS...

The Students

"I think that the instructions sometimes are bad. But they are good because you can improve your performance."

"This is good because I have learned a lot more."

"It has been fun. I have had to think a little on my own... There has not either been any particular inflection to the comments so I can interpret them by myself a little."

The Teachers

Explain your experience of IMUTUS now, after the three weeks of validation.

"I am positively overwhelmed that students found IMUTUS so funny. It exceeded my expectations."

"I was sceptical but now my I am curios. I think the software is under way..."

"My sceptical thoughts disappeared..."

How do you believe that your students experienced the work with IMUTUS?

"Very funny, pretty easy, the program is free from demands, amusing"

Do you think that your students which used IMUTUS improved compared to the others?

"The improvement was stable across the three weeks and there is a persistent effect in the students musical skill, even now a month later." "The students have been much more secure in expressing themselves on the recorder."



IMUTUS

An Interactive music tuition
multimedia system for
training users on traditional
instruments

Interactive Music Tuition System

