Learning to play musical instruments through dynamically generated lessons in real-time based on adaptive learning system

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Abstract. *Learning to play musical instruments is something many people have interest in. Along with musical schools people tend to try to learn how to play themselves. In order to aid them in this process various learning tools and games have been developed. Usage of such tools has shown positive impact on person's learning process. All of these kind of tools function on post-playing analysis to decide on future lessons. In this paper a concept that includes real-time tracking and adaptive learning aspects is proposed and described.*

Keywords. Music, education, playing musical instruments, adaptive learning

1 Introduction

There is no need to state that music is popular media in the whole world. Millions of people listen to music every single day. As a consequence many people want to learn how to play one or more musical instruments. However, learning to play musical instruments is for many people rather demanding task that asks for a lot of time and proper guidance. People are frequently considering musical schools or private lessons to learn how to play. Many of them also try to learn how to play themselves. Learning how to play on one's own is obviously harder way since the person wanting to learn how to play has to search for bits of information here and there and the whole process largely depends on one's personal talent.

In order to enable people to learn how to play some musical instruments on their own in a way that is guided and aided a computer technology in a form of various learning tools and games has been developed. However, this kind of learning has had limited effects although research shows positive impact of this kind of technology.

Most of this kind of tools are based on analysis of played musical patterns after the person has played them and on decision process that determines if the player shall proceed on the next level or will be held at the present level. This kind of functioning has limited effect since there is no real individualization of this process and there is no real-time tracking of person's playing that would result in adapting of lesson being played as well as in adapting of overall lessons plan.

In this paper a musical instruments learning system that includes adaptive learning and real-time tracking of one's playing patterns is proposed. This kind of system would adapt a lesson that is currently being played considering player's performance. The system would also individualize the lessons plan taking into considerations player's abilities.

2 Computer technology in music education

Computer technology is used for 20 years in music education [2]. There are three main areas of interest where computer technology is used in the field of music education: (1) to improve teacher's work with students, (2) to increase motivation and (3) for individual practice [25].

Most of computer programs are in the first category (and partially in the second). They are used to teach some aspects of music theory or for acquisition of basic musical skills such as writing sheets, recognition of melodic and rhythmic patterns, harmonization, etc. [9][12][15][20][21][30]. In this category there are also computer programs that create virtual environments in order to achieve better teamwork and collaboration in the process of learning basic musical knowledge and skills [1][8][19][42].

Computer programs that are in the third category (and partially in the second) are programs that assist students in learning how to play musical instruments. These programs should be able to "listen" students' playing through specific interface, analyze playing and give proper feedback that helps in better self-evaluation and improves skills and knowledge acquisition. In the scientific literature there are several systems that meet these criteria. For violin playing (and other string instruments) there are two such systems: Violin Tutor [43] and i-Maestro [22][23][36], for piano there are pianoFORTE [39] and Piano Tutor [3][4], and for brass instruments playing there's platform that was developed on IMUTUS project [10][29][37] and continued to be developed on VEMUS project [11][41] with the goal of creating a virtual music school. There are also many commercial products that have been developed for this purpose. Most of them are products that teach piano playing [26]. Roland Company developed software for drum playing [34] for their electronic drum products.

There are also many computer games that simulate instrument playing mechanics. Examples of such games are Band Hero [14] and Rock Band [32]. These games simulate guitar and drum playing. Mechanics in these games are similar to real mechanics in instrument playing. Rocksmith [33] is a computer game that enables the player to learn guitar playing. It analyzes audio signal and gives out feedback weather player played correct notes or not.

Studies have shown that computer technology can have also very positive impact on the motivation of students [2][9][27], especially if the systems incorporate certain concepts that appear in computer games [6][16][17]. Since these computer programs can improve skill acquisition and can boost students' motivation, these computer systems are becoming more relevant and interesting for use in instruments playing education. Cultural and social aspects are changing. In order to keep the interests of students for playing music new technologies must be incorporated into existing music learning systems [2].

2.1 Computer programs and artificial intelligence

Computer programs that assist in the education of playing a musical instrument must have properties of artificial intelligence because they must be able to analyze students' playing and give them feedback on their playing as well as direct them in their educational process. These programs can be classified into two basic categories: (1) Computer-assisted instruction (CAI) and (2) Intelligent tutoring systems (ITS) or adaptive learning systems (ALS) [28].

Each program with artificial intelligence properties is somewhere on this scale between these two extremes: CAI and ITS. CAI programs have simple deduction mechanisms; they usually present static elements from their knowledge base and don't have elements of individual learning paths for each student. ITS programs have more complex deduction mechanisms. Based on input data from user, they can dynamically present elements from their knowledge base. Also, they can create individual learning paths for each student based on student's performance [28].

As a subdomain of intelligent systems, there are expert systems that emulate the decision-making ability of a human expert [13]. Expert module is an integral part of any intelligent learning system that extends system with additional features such as adaptability to a variety of external changes.

3 Existing solutions and proposed model

Existing intelligent tutoring systems for playing musical instruments are based on the mechanism of giving feedback to the user about his progress after finished lesson. The proposed solution extends this model with mechanism of analysis of input data in real-time and that enables lesson adaption during the lesson which results in better individualization for each user based on their performance and skill.

The process of learning is also additionally individualized by generating customized exercises after each and every lesson based on the types and number of errors in user's performance. This should have positive influence on user's motivation since lessons are constantly adapting to the user, in order to be optimally difficult. The process of learning adapts to each particular user and this should also increase the quality of the learning process. Additionally, with real-time analysis, it is possible to accelerate the learning process because the system is able to quickly react on user's performance and therefore give him more relevant content in real-time.

The developed prototype is composed of a standard ITS elements: (1) the domain model, (2) student model, (3) tutoring model and (4) user interface. The same components, only under different names are standard ALS elements: (1) the expert model, (2) student model, (3) instructional model and (4) instructional environment. Some authors prefer to use term adaptive learning, more than intelligent tutoring, considering the adaptability is integral part of the definition of intelligent systems [40]. Fig. 1 shows the basic model according to which proposed adaptive learning system is made.

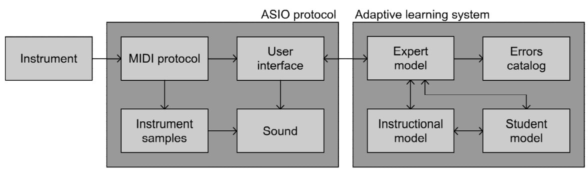

Figure 1. A model of an adaptive learning system for learning to play musical instruments

The user interacts with the system through its musical instrument. For instruments that have integrated MIDI interface the input data is directly transmitted via the MIDI protocol into the system. Instruments that don't have MIDI interface must use pitch detection algorithms to generate MIDI data from audio recording [5]. Today's algorithms work well on monophonic instruments while algorithms that deal with polyphonic instruments are still in development and are not yet practically applicable to real systems. Based on the input data from the user over MIDI interface and instrument sounds in the database, the sound of user’s playing is generated. Same MIDI data is used by the expert model for evaluation of user's playing. The final sound that the user will hear is a combination of audio signal that comes from the instructional environment and the sound of user's playing. To be able to generate sound in real-time, ASIO protocol is used. This protocol enables direct communication between software and sound card [38].

Instructional environment enables the user to interact with the system. The main part of the interface is a visual representation of interactive sheet interface where user can see what he has to play. There is also visual representation in the form of animation where user can see how to play. Video records will also be used along with audio and textual instructions. Studies have shown that in the initial stages of learning how to play musical instrument, abstract musical notation is more suitable for faster learning [18][35]. Students were able to master rhythmic patters faster and better then when standard musical notation was used. Such abstract notation is used mostly in computer games.

Expert model consists of: (1) knowledge base and (2) reasoning mechanism. The knowledge base is created according to the principles of instructional design model of Dick and Carrey [7]. Their view is based on the fact that a domain knowledge is related and it's not just a sum of isolated parts. The model is based on the relationship between context, content, learning and instruction. This approach is appropriate in this case because knowledge that user needs to learn is complementing and intertwined. Often, the new knowledge/skill is associated and based on prior knowledge/skill. The idea is to structure knowledge into smaller units and structure it in a way to see clear links between lessons. Based on those links, the system will dynamically generate paths to navigate knowledge base, based on user's speed and ability to acquire knowledge and skills. Fig. 2 shows a conceptual model according to which the knowledge base will be made and possible scenarios for knowledge base navigation.

Knowledge in the knowledge base is based on a standard literature in music schools, while selection of lessons is made by experts. Knowledge base consist of a lessons that are in the form of instructional multimedia sections which provides an introduction to each lesson, warm up exercises, technical exercises and a variety of rhythms and their variations. For creating adequate knowledge base, experts should go through an iterative process that will result in the knowledge base that will be adequate to educate playing of some particular instrument [13].

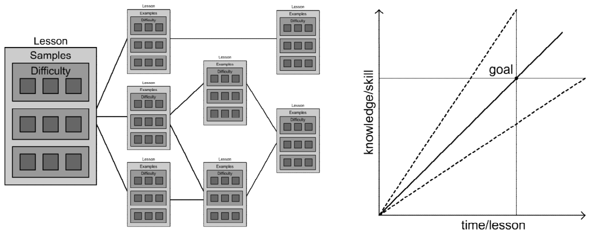

Figure 2. Knowledge base structure and paths through knowledge base

Acquiring knowledge and skills is divided into small lessons. Each lesson consists of many samples for specific knowledge and skill acquisition. Samples are graded by their difficulty. Because of this classification, system will be able to give proper samples of proper difficulty to user based on his playing. To unlock new lessons, user must master lessons that are prerequisite for some specific lessons. Sometimes user will have a choice which lesson he wants to handle if he unlocks more than one lesson. This structure can be presented to the user in a more interesting way by using concepts that are used in computer games [31]. Right part of Fig. 2 shows different scenarios of passing through a knowledge base system. A typical scenario is a straight line in the middle of the graph to reach a goal: in a certain amount of time, in a certain amount of lessons user will acquire certain level of knowledge/skills. Users that are more talented and that will make less mistakes during lessons will be able to reach certain goal much faster while those that need more time will get more lessons that will be more appropriate for their skill level.

Reasoning mechanisms are designed in such way that they can generate lessons in real-time that are individualized and customized for each user based on his skill level. Systems that were developed so far could not give feedback in real-time during the lessons. Fig. 3 shows generalized reasoning mechanics that was used in previously developed systems.

Proposed model has component that analyzes the user’s errors in real-time. Fig. 4 shows a conceptual model of such inference mechanism. After the instructional part of the lesson, comes the practical part where the user is required to play lesson. At the beginning, the initial set of samples that the user will need to play is generated. Based on the errors percentage in user's playing, more complex samples will be added or removed, based on users’ performance. After the lesson is played, based on types and percentage of errors, lesson for errors correction is generated. Studies have shown [4] that it's not good to point out too many errors to the user, so the errors are classified by importance and corrective lesson that will be generated will deal with only the most important and most reoccurring errors. After the corrective lesson has been finished the student model is being updated. In this way by using corrective lessons the user is given additional help which suits his need and his errors.

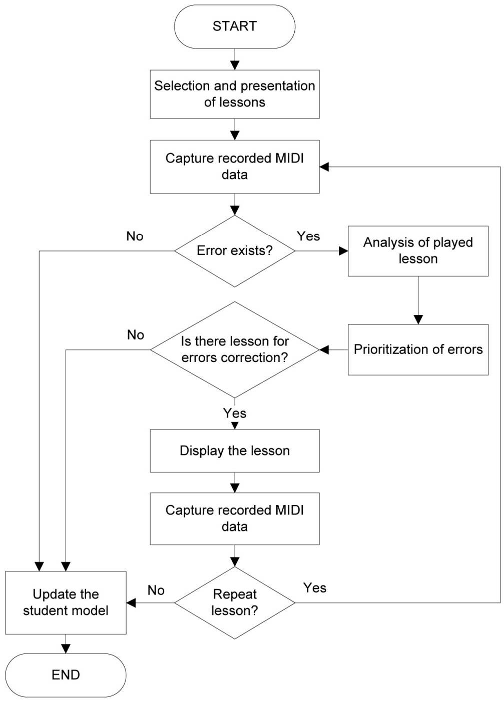

Figure 3. Model of reasoning mechanics in previously developed systems

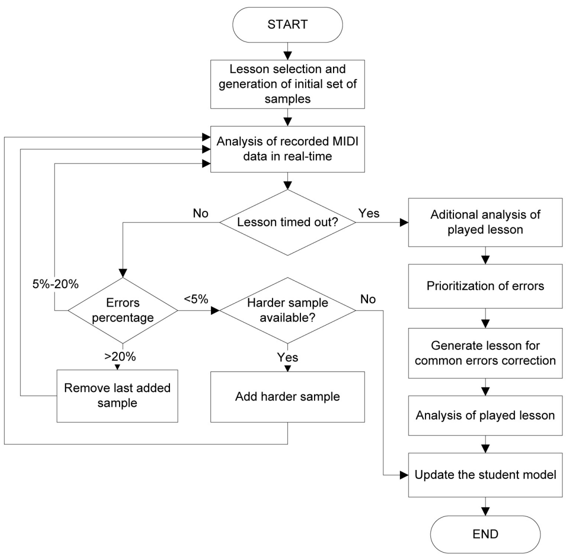

Figure 4. Proposed model of reasoning mechanics in real-time

In the student model, the progress of knowledge and skills acquisition is stored: which lessons user passed, what's the success rate for each lesson and each sample, which elements are fully or partially mastered. Based on information in the student model and knowledge base, instructional model determines next lessons that will be generated and what samples will be used. This approach enables individualized knowledge/skills acquisition for each user.

In addition, errors catalog is defined, based on Anderson's ITS model [24]. Here are specified all types of errors that the system can detect as well as their classification. First type of errors that are detected are "lower level" errors:

- is every note played at the right time,
- is note played earlier or later then needed,
- is there any note that shouldn't be played,
- is there a note that should be played but wasn't,
- is there a place where some note is supposed to be played but the wrong note was played,
- are notes played with appropriate dynamics, etc.

After the errors that are based on single notes, "higher level" errors are detected, that are based on two or more notes:

- is there a problem of hand or legs synchronization in playing (any combination of notes),
- if more notes should be played at same time, are they synchronized, what's their dynamics,
- compare dynamics of notes that are played with left and right hand, etc.

After that, errors on a sample level or lesson level are detected, such as:

- the user at certain point started to speed up or slow down with playing,
- which samples have higher percentage of errors,
- are errors more frequent at the beginning of the lesson or at the end, etc.

Based on this information, appropriate error correction lessons are generated. For example, if there are more errors at the beginning of the lesson, the user may need more time to warm up, if there is higher frequency of errors at the end, he should relax his muscles so he should repeat the instructional part about playing techniques, etc.

4 Conclusion

Computer technology is used in many ways in music education. Scope of intelligent systems for learning to play musical instruments yielded some interesting solutions, but there is still room for further development and new research. This paper proposes a new conceptual model of adaptive musical instrument learning system that has been upgraded with mechanism that can dynamically generate lessons in real-time based on number of errors and types of errors that users make while playing musical instruments and in that way this model enables better individualization of the overall learning process.

Existing intelligent learning systems in this domain haven't found their practical applications in practice, although the results of the studies indicate that they have potential for such purpose. To make them applicable, further development is needed in this area. The proposed approach provides a foundation for automated learning to play musical instruments that could be integrated into existing systems of education or that could provide a successful alternative approach in the process of learning how to play musical instruments, based on computer technology with elements of artificial intelligence.

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