P.I.A.N.O.: Enhancing Instrument Learning via Interactive Projected Augmentation

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Abstract

P.I.A.N.O. aims to support learning to play piano with a steep learning curve. In order to achieve this, traditional, hard-to-learn music notation is substituted for an alternative representation of a composition, which is projected directly onto the piano. Furthermore, we propose three different learning modes which support the natural learning process, incorporate live feedback and performance evaluation, as well as the augmentation of the system with aspects of gamification to achieve early experiences of success and prolonged motivation.

Author Keywords

augmented reality; piano; instrument learning.

ACM Classification Keywords

H.5.5 [Information Interfaces and Presentation]: Sound and Music Computing; K.3.1 [Computers And Education]: Computer Uses in Education—*Computer-assisted instruction (CAI)*.

Introduction

The basis for playing piano is learning the music notation, and mapping it onto the keys. Hence, the time that must be spent practicing in order to achieve an adequate level of skill is tremendous, regardless of the musician's age. Therefore alternative ways to achieve playing skill, such as video tutorials or music games, enjoy increasing popularity.
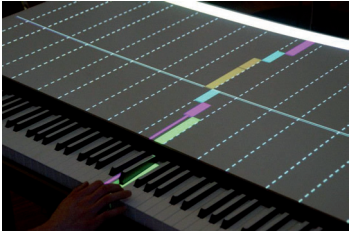
Figure 1: The alternative representation of sheet music is projected directly onto the piano.

Figure 2: The current and next keys are highlighted on the piano's keyboard while the additional area also shows several upcoming notes.

In the popular *guitarHero* game [1] users have to press colored buttons on a guitar-shaped controller to hit notes scrolling down the screen. *Synthesia* [6] is a similar system for learning to play the piano. Unfortunately, the offered information is quite simplistic and offers only the very basic information that is encoded in music sheets, i.e. which note and its duration. Therefore it is not helpful in practicing piano above a certain level. In the field of computer-assisted musical instrument tutoring (CAMIT), a recent project is *MirrorFugue* [8]. A monitor is placed directly in front of the keys of the piano, and shows the hands of a player (e.g. a teacher). Therefore, the user is able to see in detail how a certain song is to be played. Unfortunately it is necessary for someone to play the song correctly for the recording, and no feedback is provided for the user. Other projects use augmented reality to show the music sheet directly on the instrument. *guitAR* [2] projects the correct finger positions and the user's mistakes directly onto the guitar and thereby offers an alternative note representation on the guitar, but loses the depth and overview of a traditional music sheet in terms of upcoming notes. Takegawa et al. [7] use a video projector mounted above a piano's keyboard to display the traditional music notation on a projection surface, as well as additional information and mapping onto the keys; however this approach upholds the teaching of traditional music notation, instead of reducing the inherent complexity of this notation.

In all these related works, the necessity of learning traditional music notation and its mapping to the keyboard remains, and most systems provide little or no feedback. Therefore we propose the P.I.A.N.O. system, which offers an alternative sheet representation to ease the introduction to piano playing, without losing the information detail level found in traditional music sheets.

To further facilitate the learning process, the system provides different learnings modes, feedback, and aspects of gamification.

The P.I.A.N.O. System

We developed the P.I.A.N.O. system and created a respective prototype. In order to reduce the complexity for the prototype, we decided to teach users to play only right-handed music pieces, since this is an appropriate start for beginners. Our alternative note representation allows us to show not only basic elements of musical notation, but also information regarding dynamics, as well as different ornaments and playing techniques. Instead of displaying our note representation on a monitor in front of the user, we project playing cues directly onto the instrument, including the piano keys and an adjacent area above (see Fig. 1). Furthermore, our system enables learning to play piano without pre-knowledge of music sheet notations.

Projected Note Representation
As it is difficult to map symbolic notations to analogous actions [4], we used pictorial analogies instead of symbols or speech to represent notes and their features in order to reduce the extraneous cognitive load for the user [5]. We further refined our visualizations through iterative user tests, as described later on.

On the keyboard itself, we highlight the current keys to signal the user what to play. Moreover, upcoming keys are highlighted with a thin line to indicate where the user's fingers should move next (see Fig. 2). The area behind the keyboard provides a projection area to display an overview of more upcoming notes. Each upcoming note is represented by a rectangle which moves downwards toward the user. The horizontal position of the rectangles
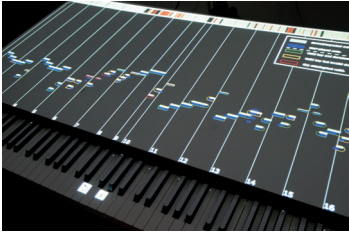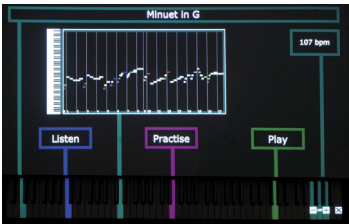
Figure 3: Detailed result screen feedback.

Figure 4: P.I.A.N.O.'s main menu.

Figure 5: Pressing one of the foot pedals activates a secondary menu while in *Listen*, *Practice* or *Play Mode*.

correlates with the corresponding keys that have to be played on the piano, while their length represents the duration of the note. A rectangle's shape and color offer additional information about the key, e.g. rectangles with rounded corners represent *legato* i.e. the first key is held until the second key is pressed. Furthermore, while most notes are gray, the intended fingering for important finger switches is encoded by different colors.

Supporting the Learning Process
The system offers three modes which support the user's learning process. The *Listen* mode plays the song for the user, allowing them to become acquainted with the melody, as well as the system's song visualization. The *Practice* mode provides users with an environment to practice playing, by visualizing the song and forcing the user to play correctly, i.e., the system will not continue to the next note unless the correct key has been pressed for the correct duration. To support the user in doing so, the system brightly highlights the correct keys, while at the same time, wrongfully pressed keys are highlighted in red. Finally, the *Play* mode visualizes the song at an adjustable specific tempo, which the user should match in order to learn to play at a consistent speed. While playing, the user is provided with feedback within the note visualization in the form of colored borders around the notes which have to be played at the moment. A green border indicates a correctly pressed key, while a red border indicates an incorrectly pressed key. Additionally, a note-by-note progress bar at the top of the projection is colored accordingly.

After each session with the *Play* mode, the system displays a detailed feedback screen (see Fig. 3) which allows for self-assessment by visualizing deviations between expected and played notes. Passages requiring

further training can then be selected and practiced individually at a freely adjustable speed, to enable practice at a comfortable pace.

The piano keys are not solely used to play music, but also for interaction with the P.I.A.N.O. system, as shown in Figure 4. During play, pressing any of the foot pedals pauses the current mode and activates a second menu, which is displayed on the keys (see Fig. 5) and provides various options, such as returning to the main menu, adjusting speed settings, or scrolling back and forth in the song visualization.

P.I.A.N.O. Prototype
Our prototype, shown in Figure 6, consists of an electric stage piano with a MIDI interface connected to a computer via USB. A DLP projector is mounted on a tripod at a height of 1.75 meters above the piano, allowing for a projection of about 75x120 cm (1280x800 px), despite the relatively short distance. A wooden board mounted behind the piano provides a large projection area to facilitate a more extensive preview of upcoming notes.

Our prototype was implemented in C#. It uses the midi.NET library [3] to interpret incoming MIDI signals whenever key or pedal events occur. Songs are loaded into the system as MusicXML files and converted into an internal note representation data structure for processing.

Preliminary Evaluation
In order to gain first insights into how users interact with the system, and to evaluate the system's song visualization design, we conducted semi-structured interviews and practice sessions with 4 participants. Our participants were male computer science students, aged 24-27. Two of them played an instrument (not piano) for more than 10 years, and considered their ability to read
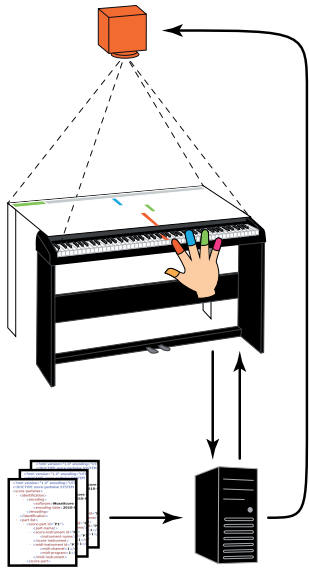
Figure 6: Prototype architecture.

music sheet notation high. The other two played no instrument and could not read music sheets.

First, participants were presented with our prototype's visualization, and asked to identify what they thought various visual features indicated. Subsequently, they were allowed to explore the prototype's modes one by one; participants were asked to practice a specific song until they felt comfortable enough to attempt the *Play* mode with a set speed. Finally, they were asked to fill out a questionnaire.

We were most interested in whether the provided fingering information was sufficient, and what scope of visual attention was adopted by the users. Regarding the former, the amount of finger information was deemed satisfactory by all participants; none felt overwhelmed by the amount of colours. Visual attention areas differed between participants. Half of them looked mostly at the piano keys, and indicated their visual scope to reach only 5–10 cm (approx. 2 notes) above the keyboard. The other half declared their visual scope to include the piano keys and about half of the extended projection area. All participants considered the preview to be adequate and not too overwhelming. While three out of four participants did feel overwhelmed during their attempt at the *Play* mode, they were also certain that they would do better given more time to practice.

Conclusion
The P.I.A.N.O. system offers assistance in learning to play piano without requiring any experience with traditional music notation. By circumventing the time necessary to learn the mapping from the sheet notation to the corresponding keys, users can concentrate on learning to play specific songs immediately, and soon begin to learn

advanced techniques. Our proposed note representation encodes a note's key and duration, as well as indicates a variety of advanced playing techniques. We are currently investigating how to extend our notation further in order to match the complexity and expressiveness of traditional sheet music notation. Furthermore, we are planning two more extensive user studies to assess the learning support of our prototype and compare it to related systems.

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