Pianodemy: an Innovative Platform for Piano Learning

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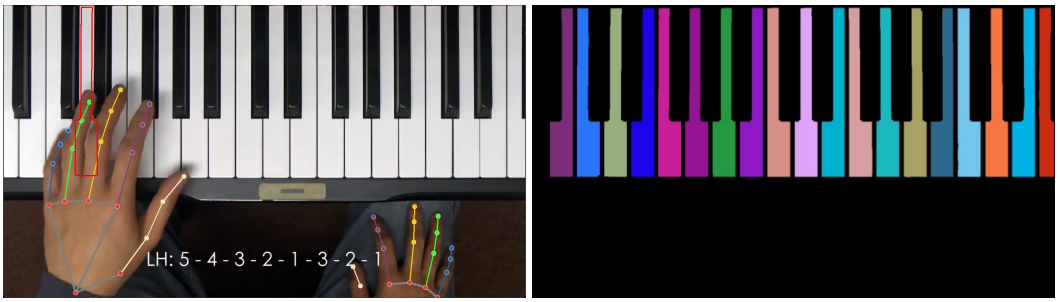

Fig. 1. Left: our method is able to detect which of the fingers are playing the current notes to allow for interactive feedback about finger placement. Right: top-down piano view preprocessing. Notes are detected and labelled. Their position and outline are stored to be later used by the finger-to-note detection algorithm.

Abstract. We introduce *Pianodemy*, an innovative online piano learning platform designed to enhance the learning experience through interactive features. One key component of the platform is a real-time method for detecting finger placement to improve piano technique. This algorithm processes a top-down view of the piano to classify notes and combines hand gesture detection with these classifications, along with inputs from the piano, to predict which fingers are playing the current notes. We show that our platform can improve learning efficiency by facilitating better practice habits.

1 INTRODUCTION

Piano learning is a skill that requires not only understanding musical theory and reading sheet music but also mastering correct finger placement and technique. Proper finger placement is critical for developing speed, precision, and fluidity in playing, yet it remains a challenge for beginners to monitor and adjust their technique in real-time. Traditional piano instruction methods, whether through in-person lessons or online tutorials, often rely on a teacher's feedback or self-assessment, which can be slow and inconsistent.

To address these limitations, we introduce Pianodemy, an innovative online piano learning platform designed to enhance the learning experience through interactive features. Pianodemy integrates two key functionalities to assist both teachers and students: real-time feedback and finger-to-note detection.

The real-time feedback feature highlights the notes currently played on a digital piano layout, making it easier for teachers to monitor and guide students during lessons. Meanwhile, the finger-to-note detection algorithm leverages computer vision techniques to analyze a top-down view of the piano, classify notes, and combine this information with hand gesture detection and piano inputs to predict which fingers are playing each note.

By providing instant feedback on finger placement and technique, Pianodemy aims to accelerate the learning process, foster better practice habits, and promote correct technique from the outset. This report details the development of the platform, focusing on its methodology, implementation, and the potential impact on learning efficiency.

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2 RELATED WORK

Recent advancements in technology have facilitated the development of interactive tools to enhance music education, particularly for piano learners. These tools leverage techniques such as augmented reality (AR), visual feedback, and real-time motion analysis to address challenges in traditional and online learning settings.

[Simion et al. 2021] introduced an AR-based piano learning tool that overlays visual cues on a physical piano, helping learners associate keys with notes and providing interactive feedback. Their approach demonstrated how AR can enhance the learning experience by reducing the cognitive load on beginners. Similarly, [Weing et al. 2013] proposed P.I.A.N.O., a system that uses interactive projected augmentation to guide learners by displaying finger placement instructions directly on the piano. These works highlight the potential of visual feedback systems to bridge the gap between theory and practice.

Other studies have focused on combining visual motion analysis and piano key press detection to improve the accuracy of finger tracking. [Hu 2022] developed a visual motion analysis tool that detects finger movements and matches them with key presses, providing insights into a player's technique. [Özkaya and Tuncer 2021] explored piano key press detection using multiple camera views, enabling a more robust and detailed analysis of finger-to-key interactions. These approaches emphasize the importance of precise tracking in improving the quality of feedback provided to learners.

Additionally, [Chen 2022] investigated the integration of AR with the Internet of Things (IoT) for interactive piano training. Their system combines visual guidance with real-time monitoring to create a connected learning environment, which aligns with the goals of our proposed method. [de Rooij 2022] also addressed the challenges of online music education by designing a piano visualizer that enhances digital lessons with visual feedback, improving accessibility for learners with varying levels of digital literacy.

Building on these existing solutions, our project combines top-down piano view preprocessing, hand gesture detection, and note classification to provide real-time feedback on finger placement. By integrating this system into Pianodemy, we aim to address the limitations of current tools and offer a comprehensive solution for piano learners.

3 REAL-TIME FINGER-TO-NOTE DETECTION

Our algorithm consists of two main stages: a preprocessing step that extracts and labels notes from a top-down piano view and a real-time detection algorithm that identifies the fingers closest to the active notes.

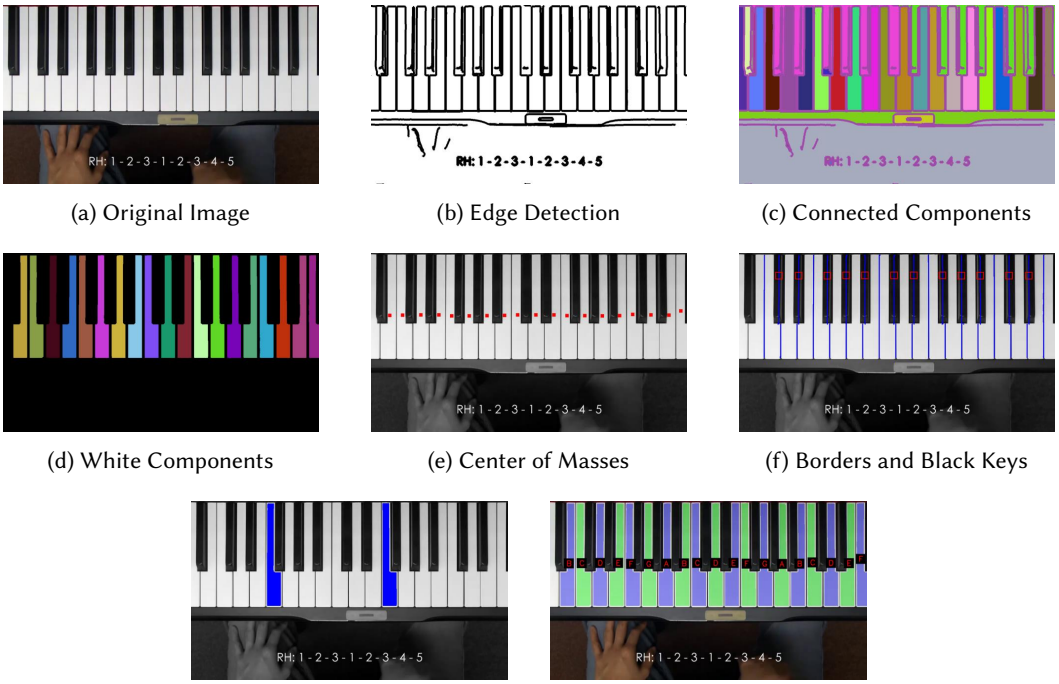
3.1 Preprocessing

The preprocessing pipeline is inspired from PyPiano [Babayof 2017] and employs several OpenCV-based operations to analyze the piano's top-down view. The goal is to identify the position and outline of each piano key, both white and black, and associate them with their corresponding musical notes. The key steps are as follows:

- **Edge Detection and Thickening:** We first apply edge detection to the input image to highlight the contours of the piano keys. The edges are then thickened to enhance connectivity between adjacent key components.
- **Connected Components Analysis:** Using connected component analysis, we segment the image into distinct regions corresponding to individual piano keys.
- **White Key Detection:** The white connected components are identified based on their size, shape, and position relative to the keyboard layout.

- **Center of Mass Calculation:** For each detected key, we calculate its center of mass to facilitate later finger-to-note assignment.
- **Border and Black Key Detection:** The black keys are segmented using their relative positions to the white keys. Additional features such as borders are used to refine the classification of keys.
- **F Key Detection and Note Labeling:** The "F" key, which serves as a visual anchor, is detected to establish a reference for labeling all keys with their corresponding musical notes. Each key's position and outline are stored for subsequent stages.

The different stages are shown in figure 2. This preprocessing step is performed offline or during the initialization phase and generates a list of labeled notes with their positions and outlines.



(a) Original Image (b) Edge Detection (c) Connected Components

(d) White Components (e) Center of Masses (f) Borders and Black Keys

(g) F Key Detection (h) Notes Labeling

Fig. 2. Preprocessing steps for finger-to-note detection. Each step visualizes an intermediate result of the algorithm.

3.2 Real-time Detection

The real-time detection algorithm identifies which fingers are playing the current notes by analyzing a list of pressed keys provided by the piano. The steps are as follows:

- **Input from Piano:** A list of pressed keys is retrieved, representing the notes currently being played.
- **Finger-to-Note Assignment:** For each pressed key, the algorithm identifies the finger whose position is closest to the center of mass of the corresponding key. This is achieved by comparing the Euclidean distances between the detected finger positions and the stored center of masses.

- **Output:** The algorithm outputs a list of fingers assigned to the pressed keys, allowing for real-time feedback on finger placement.

This approach is computationally efficient and ensures that the feedback remains responsive during live piano sessions. By combining robust preprocessing with a simple yet effective detection algorithm, our method provides accurate and reliable finger-to-note detection to enhance the piano learning experience.

Accuracy Evaluation. We manually annotated several top-down view piano videos with notes and the corresponding fingers, then ran our algorithm on these videos. The overall accuracy achieved was 92%. However, detection errors were observed when fingers were partially obscured by the palm. To address this, a potential improvement would be to shift the camera angle from the top to the front of the piano, allowing better visibility of the fingers that are otherwise hidden by the palm.

4 EVALUATION AND RESULTS

To assess the usability and effectiveness of Pianodemy, we conducted an experiment involving five piano teachers. Each teacher hosted a lesson using the platform and provided feedback through a post-lesson poll. The goal of the experiment was to evaluate the implemented real-time feedback feature and gauge interest in the upcoming finger-to-note detection functionality.

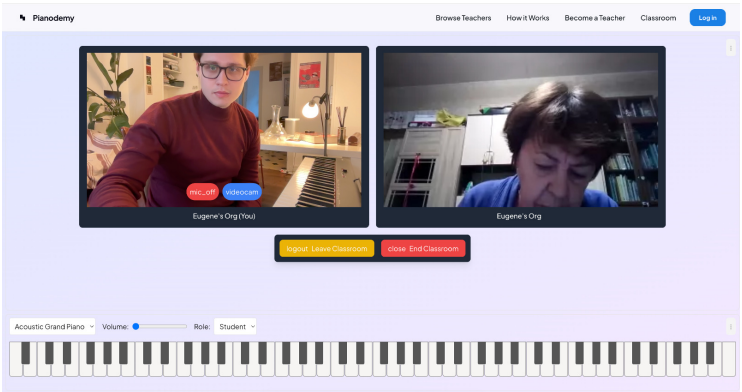
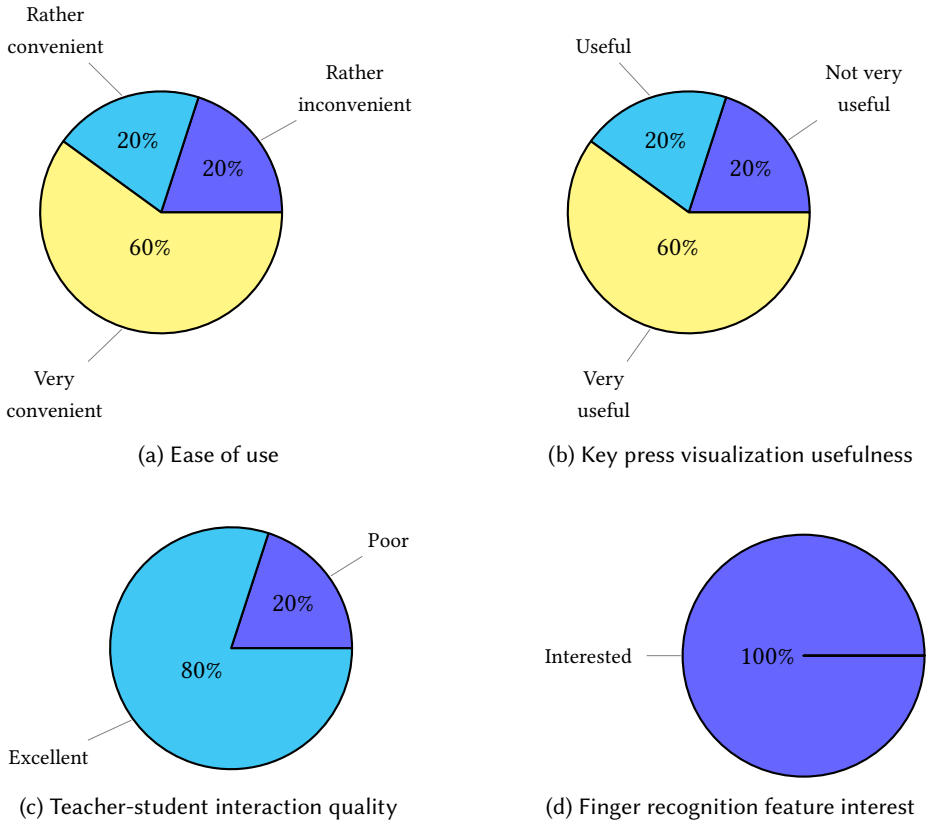


Fig. 3. Experiment setup using Pianodemy

Methodology. Each teacher was instructed to use Pianodemy during a standard lesson with their students. The real-time feedback feature, which displays a visual piano layout highlighting the notes being played, was fully implemented and operational during the sessions. However, due to time constraints, the finger-to-note detection algorithm was not yet integrated into the platform.

Results and Analysis. The feedback from the five piano teachers after using Pianodemy during their lessons is summarized in Figure 4. Overall, 60% of teachers found the platform "very convenient" to use, with 20% rating it as "rather convenient" and 20% as "rather inconvenient." The key press visualization feature was well-received, with 80% of teachers finding it useful or very useful, though 20% found it less helpful.

Teacher-student interaction quality was rated "excellent" by 80% of participants, while 20% rated it as "poor," indicating that the platform significantly improves interaction for most users but



(a) Ease of use

(b) Key press visualization usefulness

(c) Teacher-student interaction quality

(d) Finger recognition feature interest

Fig. 4. Feedback from 5 teachers after an online lesson using Pianodemy

may benefit from refinements. Importantly, all teachers expressed strong interest in the proposed finger-to-note detection feature, highlighting its potential as a valuable addition to the platform.

These results demonstrate the platform's effectiveness, particularly the real-time feedback feature, while identifying areas for improvement, such as usability and visualization enhancements.

5 CONCLUSION AND FUTURE WORK

In this report, we introduced Pianodemy, an innovative online piano learning platform featuring real-time feedback through key press visualization and the proposed finger-to-note detection algorithm. Our experiments demonstrated promising results, with positive feedback from piano teachers highlighting the platform's potential to improve the learning experience.

While the finger-to-note detection feature shows promise, its accuracy and robustness could be further enhanced by employing advanced methods such as neural networks. Additionally, this feature could be extended to various applications, including automatic finger placement on music sheets based on video recordings of performers or assisting beginners in a self-learning context by correcting hand and finger placement.

These future developments could make Pianodemy a more versatile and impactful tool for piano education, benefiting both students and teachers alike.

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