Enhanced Learning of Jazz Chords with a Projector based Piano Keyboard Augmentation

Frode Eika Sandnes[1,2][0000-0001-7781-748X] and Evelyn Eika[1]

[1] Oslo Metropolitan University, Oslo, Norway
[2] Kristiania University College, Oslo, Norway
frodes@oslomet.no, evelyn.eika@oslomet.no

Abstract. Learning jazz piano is considered technically difficult. Most people cannot afford private piano tuition and there are many freely available video tutorials on the Internet. This study identified a set of challenging topics associated with learning jazz piano based on popular YouTube jazz piano tutorials. The results suggest that learners are struggling to understand the construction of complex chords in the 12 keys. Most tutorial videos show two parallel keyboards, one physical with the real hands and one virtual keyboard, which the viewers must map onto their own keyboard. Based on these results a series of visualization approaches were explored through a low-fi prototype by augmenting the physical piano keyboard with voicing instructions using a projector.

Keywords: augmented reality, projection, music, piano, jazz, chord voicing.

1 Introduction

Judging from the large number of tutorials available on the Internet, the learning of jazz and especially jazz piano is a popular undertaking. Unlike traditional popular music and classical music, jazz is known to be less bound to the way music should be performed. Often a jazz musician will only use lead sheet music to get a rough indication of the tune and its chord structure or simply play by ear. In jazz, more of the decisions on how a piece of music is played is left to the musician, and jazz is thus often associated with improvisations. In contrast, with classical music the musician simply follows the detailed instructions outlined in the sheet music.

With increased freedom and responsibility for how a piece of music is played, the player needs to understand the basic system of music that determines what will sound right in each context. In this study, we explored the content of online jazz tutorials to identify the topics that are capturing the main interest of jazz piano learners and teachers. Our results suggest that how to construct various chords is a key topic. The construction of chords involves several important decisions that greatly affect how the result sounds. Factors include the type of chords (major, minor, dominant, diminished, extended, suspended), which upper extensions (7ths, 9ths, 11ths and or 13ths) and how these should be voiced, i.e., where these components should be played, which inversions to use (the order of the components) and fingering (mostly affecting

chord transitions). In addition, the physical realization of a given chord on the keyboard depends on the key in which the chord is played.

A trained pianist should have internalized these structures and produce such chords instinctively without hesitation as part of the muscle memory. To get to this level much practice is needed. In order to get started with the right practice, the music students need to understand the space of valid decisions.

Traditionally, jazz piano was taught on a one-to-one basis with the guidance of an experienced musician. However, most hobby music students are unable to afford one-to-one tuition and some schools are experiencing budget cuts [1]. The Internet and online video services such as YouTube have made jazz learning much more accessible. The structure of a typical instruction video is the explanation of a given concept with the teachers' own anecdotes which can be important for learning. A common trend for such videos is to divide the viewing area into two where the bottom part shows the teacher's physical keyboard and the teacher's hands from above, while the top part shows a virtual keyboard with the depressed keys highlighted. Some tutorials also contain live sheet music. This makes it easier for students to see all the keys that are depicted simultaneously, which otherwise may be obstructed by other parts of the hands. The videos also often contain additional annotations such as chord names and textual explanations. Clearly, such videos can be paused, played again, and slowed down. However, a video is a passive medium analogous to reading. Viewers must translate what they see in the video to their own keyboard. This is easy for simple tunes and chords but becomes more challenging with more complex structures.

The goal of this work was to make the jazz piano learning process more immersive and interactive. Instead of having to look at the chord information on a screen and then reconstruct the structures on the physical keyboard, we augmented the physical keyboard with the chord structures directly. In addition to augmenting the keyboard with specific chord structures, we explored ways of visualizing the valid chord space on the keyboard using sketches [2]. The purpose was to train the students' ability to construct their own voicings. Rhythm [3] is not addressed herein.

2 Related work

The idea of augmenting physical piano keyboards and other instruments such as the Chinese Guqin [4] is not new. There are even commercial products such as Casio's LK-280 keyboard with lit up keys to help learn the piano. There are also patents that describe similar ideas [5]. Still, augmentation is often associated with wearable display that superimposes virtual imagery on top of the physical worlds [6]. Trujano, Kahn and Maes [7] implemented a learning system for HoloLens where the learners wear the head-mounted AR-display. Their system includes a piano roll system where the notes of a tune appear in a stream training both the temporal and spatial aspects of music. They also show chords structures and extra functions such as augmented visualizations of mistakes over time. Unfortunately, current head-mounted AR-displays are relatively expensive and inaccessible. More importantly, the field of view is small which limits the user experience. A somewhat more stripped implementation also

based on HoloLens was reported one year earlier by Hackl and Anthes [8]. A system employing the Epson BT300 augmented reality headset has been reported [9]. Birhanu and Rank [10] implemented a HoloLens piano tutoring system using an "in the air" virtual piano. Liang et al. [11] implemented an "in the air" virtual piano with the focus on a visual system for detecting the finger motions.

Several systems have experimented with projected augmentation where an overhead projector is placed above the piano keyboard allowing specific keys to be lit up in various colors. It is argued that such setups lead to more rapid learning as it eliminates learning sheet music. The area behind the keyboard can be covered in white allowing this space to be used as an extra information display. Rogers et al. [12] implemented a projector-based system with a piano roll that incorporated various additional information such as fingering information using color coding. In a related project, Weing et al. [13] implemented such a system for right hand practice using piano roll visualizations as well as projected menus associated with the piano pedals. Similar approaches with variations including games for accelerated learning have also been reported by Raymaekers et al. [14]. Chiang and Sun [15] implemented a virtual projected piano, which detects keypresses with a camera. Their system has a training mode to guide the user towards the right keys on the keyboard. Instead of highlighting keys, Gerry, Dahl and Serafin [16] overlay the videos of the teacher playing on top of the student's hands. Their system was implemented using a magic leap headset.

A totally different approach is to project a performer's hands directly on the keyboard while displaying the upper body of the performer in front [17, 18, 19], or support for remote learning by projecting a mirror image of the keyboard with the teacher's hand behind the keyboard [20]. The idea is that the student learns by playing along by copying the movements of the master. This approach is also used in other domains to visualize the craft of an expert [21]. Nemoto and Umezu reported a similar approach where they played back a mirrored version of a video, slowing the teacher playing behind the piano keyboard [22]. The same research group also explored learning through animated characters projected onto the top of the piano keyboard [23].

Most work on augmented reality for piano training focuses on visual augmentations. Some work has also addressed the sense of touch by incorporating haptic stimuli allowing the student to feel the movements of the teachers. For instance, using gloves with sensors and vibrators [24]. Fujii et al. [25] experimented using haptic feedback to guide the hands of the student as an expert while learning to play instruments. Kallionpää and Gasselseder [26] discussed the augmentation of the audio that is possible with computer technology. Augmented reality has also been used at a different level such as enhancing printed text [27] and songbooks [28].

One related approach includes Piano Genie, a system where novices are empowered to improvise on a piano using a controller with eight buttons [29]. The button presses are automatically translated into piano keypresses that musically make the most sense. Their system was built using a neural network. Other systems encourage learning by playing along with automatic comping, such as GimmeDaBlues app [30].

There have also been numerous reported efforts on visualization of music. Snydal and Hearst [31] visualized jazz improvisations and presented two types of views, one visualizing the melodic landscape and another showing the harmonic palettes used.

The visualizations allow the different improvisation styles of different musicians to be compared. Chiua et al. [32] visualized music using color where the keys were organized into a circle of thirds, i.e., a circle of an octave with three semitones between the tones assigned the colors of the color wheel. Pleasant sounding transitions are seen as gradual changes in color. Bergstrøm and Karahalios [33] implemented a system for visualizing structures in music by the means of Tonnetz which is a two-dimensional triangular representation of tonal space.

3 Method

3.1 Qualitative video study

To identify key issues faced by jazz piano learners, jazz piano tutorials on YouTube were investigated over a period of one month. The videos were reviewed for the content explained and the methods used to communicate the ideas. Higher weights were given to issues echoed in videos by several YouTube-teachers and only issues addressed by more than one teacher were included. The approach was ad-hoc as it is difficult to review YouTube videos in a systematic manner as these videos are not systematically categorized according to structure. However, as the YouTube search engine tends to return videos with many views it is likely that the findings are representative of the overall trends. Concerning content, the videos vary greatly in quality. Frequently downloaded videos were considered likely to be more correct as they are trusted and "quality assured" by more viewers.

3.2 Design cases

Based on the findings from the video study, a set of cases was selected for further exploration through a design phase. The design phase involved ideation around alternative ways to visualize the content using keyboard augmentation based on a setup with a projector and a physical keyboard. A simple low-fidelity prototype was realized using manually generated images that were projected onto the keyboard. These images were generated by first obtaining measurements of the keys of the keyboard based on an overhead image. Next, augmentations were created using various colors on a black background as the black regions are not projected while all the non-black regions are projected. The intensity of the colors in the image controls the intensity of the augmentation.

4 Results

4.1 Key issues in jazz piano learning

The results of the video analysis show that most video tutorials on jazz piano employ overhead video of the hands on a physical together with a virtual keyboard with

pressed keys above. Many of these videos also contained additional information superimposed on the video such as textual explanations, chord names, tonal information and voicing information. Some chord information was inserted manually, and some appear to be based on automatic chord recognition systems. Clearly, the manual chord labelling was generally easier to understand and clearer than the automatically generated chord names which sometimes did not match the explanations of the teacher. One key aspect of jazz piano is the notion of ambiguous chords which can be interpreted as several types of chords. Some videos only showed the teacher's hands from above. These videos were also useful, but some finger movements can be hard to observe, especially with complex chords around the black keys. A few videos showed the keyboard from other angles, making it harder to study the motions of the keys. In such situations the verbal commentary and in-video annotations are highly useful.

The videos revealed that chord voicing is a difficult and important area for learners of jazz piano. Many videos cover 7^{th}, 9^{th}, 11^{th} and 13^{th} that are used to create dissonance and ambiguity and what several teachers refer to as "modern sounding". Many videos attempt to explain how to construct higher order chords and what choices that make these chords sound good, i.e., how to spread the chords across two hands and using larger intervals in the left hand. Chord inversions and the dropping of notes (moving notes around octaves) are also a recurring topic of high importance. Another topic is the role of the tonic (root) and guide tones (the 3^{rd} and the 7^{th}) which are used to communicate if the chord is a major or a minor. In fact, having great freedom in how to voice the chords is something that may be overwhelming for learners. Some videos therefore explain tricks such as slash chords and stacked chords (e.g., stacked fifths which are easy to play and that sound sophisticated). Several videos also explain "standard" voicings that sound good, including So what chords, Kenny Barron voicings, Herbie Hancock voicings and Thelonious Monk voicings. Several videos encourage the practice of these chords in the 12 keys with suggested practice drills. For example, playing the chords across the 12 keys in increasing or decreasing order, or around the circle of fourths clockwise or anticlockwise.

Another much-addressed topic is chord progressions. The tutorials illustrate chord progressions such as the popular ii-V-I progressions. Another topic is the circle of fifths. Moreover, minimizing the number of finger movements between chords in the progression is another key concept. Another frequent topic is the use of chords to play melody lines by the means of four-way close, locked-hands and drop-2. All these techniques are based on having the melody lines as the top note in the chord and alternating with I and V chords across the scale.

In terms of melodic improvisation, several tutorials are addressing mode, which is musical scales of "valid notes" in each musical context (Ionian, Dorian, Phrygian, Lydian, Mixolydian, Aeolian, Locrian). Note that the topic of jazz piano is vast and that the topics mentioned only represent the most noticeable topics uncovered.

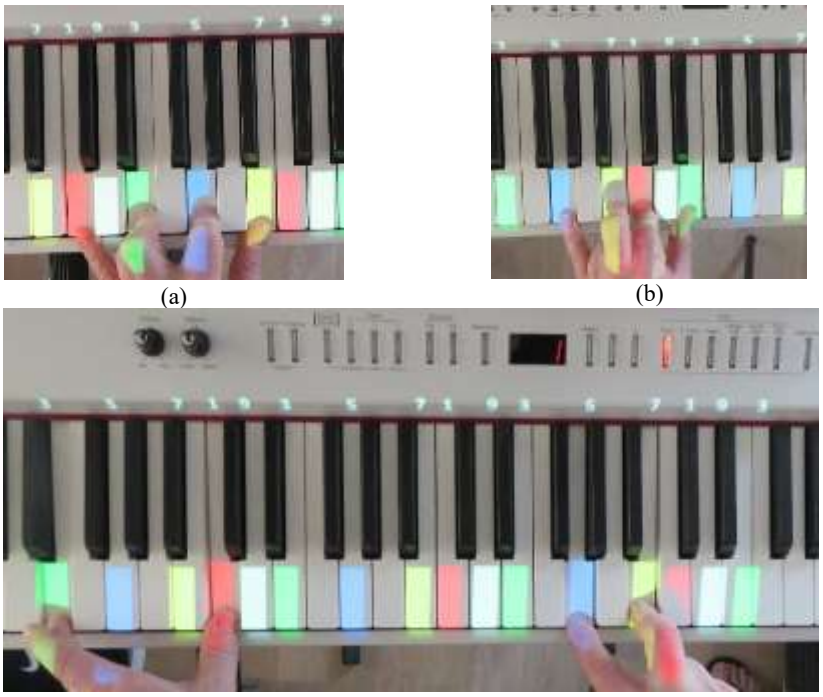
Fig. 1. A D11 minor Kenny Barron voicing. Note that two colors are used to differentiate the hands (green left and blue right).

Fig. 2. Controlling the tuition with keys. A Locked-hands drop-2 in the key of E.

4.2 Design cases

The simplest visualizations show specific chords. Fig. 1 shows an example of a Kenny Barron voicing which comprises two fifths in the left and the right hands. Students with large hands can practice the entire chord directly, while students with small hands can use the highlighted areas as targets for arpeggiating the chord (playing the six notes in sequence). Fig. 2 shows locked-hands with a drop-2 for playing a melody note. These visualizations are indeed not novel as they make use of similar ideas as what is demonstrated in other projection based piano tutors [12, 13, 14].

Although jazz piano, especially cocktail style jazz piano makes use of the entire keyboard, most jazz chords make use of the middle part and lower part of the piano for the best sounding chords. We therefore explored to use the upper part of the piano for controlling the tuition where a set of control keys is augmented with labels to indicate function and state. Fig. 2 also shows how the user can alter the key of the chord tuition, if it is a major, minor, dominant or diminished, and voicing to include in the visualizations. In this example the locked hand chord with drop 2 is moved from the key of C to the key of Eb minor. Obviously, these controls can be changed dynamically to match the given mode of instruction. This means that even a simple MIDI keyboard without control buttons can be used to control the tuition directly without having to use the computer interface. Hence, the focus remains on the piano keyboard.



(a) (b)

(c)

Fig. 3. (a) A C major 7 in first inversion played in the space of valid notes in a C9 major chord, (b) a C major 7 in the 3rd inversion, (c) A C major 7 played with the root and the third in the left hand and the fifth and seventh in the right hand.

Fig. 4. Chord progression from C major 9 to F major 9.

However, the strength of the approach is the ability to visualize the musicians' freedom. Fig. 3 shows how all the keys of a keyboard that make up valid C9 chords are highlighted and how the learner can intuitively experiment with various inversions and moving of notes around. Fig. 3 shows how colors can be used to highlight the

various degrees of a 9th chord. Annotations are augmented on the keyboard frame of the keyboard to help the learner, that is, chord name, note names and scale degrees.

Fig. 5. Investigating ambiguous chords. The user enters a chord with three consecutive tones (C, D, E), which can be interpreted as Cadd9, C9, C9b5, D9, Dm9, Cmaj9, E7#5, D13, C69, dm11, am11, c11, D9#11, C/D, d9sus4, d9b5, a#9b5, c9#5, d11, cmaj13, fmaj13 and Bb9b5.

Augmented visualizations can also be used to help learners understand smooth chord transitions. One rule-of-thumb is to select chord voicings in chord progressions that result in the minimum number of finger movements. Fig. 4 illustrates one possible chord progression from C9 to F9 (one step on the circle of fifths) with the common keys in white, the unique C notes in green and the unique F notes in red.

Fig. 5 shows a chord explanation mode where the student plays a set of tones and the possible chords these tones can be interpreted as displayed. The various physical keys are used to show the keys this chord can be used for, while the list of types of chords functions as a histogram. By selecting a specific chord using the control keys, the additional notes needed to make a full chord are displayed. Note that the information projected onto the black key does not show very well.

5 Conclusions

The learning of spatial jazz piano chord structures was addressed. A projector was used to augment the physical keyboard with chord voicing information. In addition to fixed chord voicings, we explored visualizing the space of valid chords to train on-the-fly chord voicings. Future work involves improving the interactivity by connecting the physical keyboard (if it has a MIDI or USB interface) to the music tutorial system allowing the system to respond to the student's actual keypresses with feedback in real-time. Moreover, usability assessments of the system as well as measuring potential learning effects should be conducted.

References

1. Serafin, S., Adjorlu, A., Nilsson, N., Thomsen, L., Nordahl, R.: Considerations on the use of virtual and augmented reality technologies in music education. In: 2017 IEEE Virtual

Reality Workshop on K-12 Embodied Learning through Virtual & Augmented Reality (KELVAR). IEEE (2017).
2. Sandnes, F. E., Jian, H. L.: Sketching with Chinese calligraphy. Interactions 19(6), 62-66 (2012).
3. Sandnes, F. E., Jian, H. L.: Pair-wise variability index: Evaluating the cognitive difficulty of using mobile text entry systems. In: International Conference on Mobile Human-Computer Interaction, pp. 347-350. Springer, Berlin, Heidelberg (2004).
4. Zhang, Y., Liu, S., Tao, L., Yu, C., Shi, Y., Xu, Y.: ChinAR: facilitating Chinese Guqin learning through interactive projected augmentation. In: Proc. Third International Symposium of Chinese CHI, pp. 23-31. ACM (2015).
5. McCarthy, K. M., McVey, J. M., Ericson, J. M., Eveland, Z. E., Taylor, M., Ruscher, T. H.: *U.S. Patent No. 9,092,994*. Washington, DC: U.S. Patent and Trademark Office. (2015).
6. Sandnes, F. E., Eika, E.: Head-mounted augmented reality displays on the cheap: a DIY approach to sketching and prototyping low-vision assistive technologies. In: International Conference on Universal Access in Human-Computer Interaction, pp. 167-186. Springer, Cham. (2017).
7. Trujano, F., Khan, M., Maes, P.: ARPiano Efficient Music Learning Using Augmented Reality. In International Conference on Innovative Technologies and Learning, pp. 3-17. Springer, Cham. (2018).
8. Hackl, D., Anthes, C.: HoloKeys-An Augmented Reality Application for Learning the Piano. In: Forum Media Technology, pp. 140-144. (2017).
9. Zeng, H., He, X., Pan, H.: FunPianoAR: A Novel AR Application for Piano Learning Considering Paired Play Based on Multi-Marker Tracking. In: Journal of Physics: Conference Series 1229 (1), p. 012072. IOP Publishing (2019).
10. Birhanu, A., Rank, S.: KeynVision: Exploring Piano Pedagogy in Mixed Reality. In: Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play, pp. 299-304. ACM. (2017).
11. Liang, H., Wang, J., Sun, Q., Liu, Y. J., Yuan, J., Luo, J., He, Y.: Barehanded music: real-time hand interaction for virtual piano. In: Proc. 20th ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games, pp. 87-94. ACM (2016).
12. Rogers, K., Röhlig, A., Weing, M., Gugenheimer, J., Könings, B., Klepsch, M., Schaub, F., Rukzio, E., Seufert, T., Weber, M.: Piano: Faster piano learning with interactive projection. In: Proc. Ninth ACM International Conference on Interactive Tabletops and Surfaces, pp. 149-158. ACM (2014).
13. Weing, M., Röhlig, A., Rogers, K., Gugenheimer, J., Schaub, F., Könings, B., Rukzio, E., Weber, M.: PIANO: enhancing instrument learning via interactive projected augmentation. In: Proc. ACM conference on Pervasive and ubiquitous computing adjunct publication, pp. 75-78. ACM (2013).
14. Raymaekers, L., Vermeulen, J., Luyten, K., Coninx, K.: Game of tones: Learning to play songs on a piano using projected instructions and games. In: CHI'14 Extended Abstracts on Human Factors in Computing Systems, pp. 411-414. ACM (2014).
15. Chiang, P. Y., Sun, C. H.: Oncall piano sensei: Portable ar piano training system. In: Proc. 3rd ACM Symposium on Spatial User Interaction, pp. 134-134. ACM (2015).
16. Sun, C. H., Chiang, P. Y.: Mr. Piano: A Portable Piano Tutoring System. In: 2018 IEEE XXV International Conference on Electronics, Electrical Engineering and Computing (INTERCON). IEEE (2018).

17. Gerry, L., Dahl, S., Serafin, S.: ADEPT: Exploring the Design, Pedagogy, and Analysis of a Mixed Reality Application for Piano Training. In: Proc. 16th Sound & Music Computing Conference. (2019).
18. Xiao, X., Aguilera, P., Williams, J., Ishii, H.: MirrorFugue iii: conjuring the recorded pianist. In: *CHI Extended Abstracts*, pp. 2891-2892. ACM (2013).
19. Xiao, X., Ishii, H.: MirrorFugue: communicating hand gesture in remote piano collaboration. In: Proc. fifth international conference on Tangible, embedded, and embodied interaction, pp. 13-20. ACM (2011).
20. Xiao, X., Ishii, H.: Inspect, embody, invent: a design framework for music learning and beyond. In: Proc. 2016 CHI Conference on Human Factors in Computing Systems, pp. 5397-5408. ACM (2016).
21. Suzuki, G., Murase, T., Fujii, Y.: Projecting recorded expert hands at real size, at real speed, and onto real objects for manual work. In: Companion Publication of the 21st International Conference on Intelligent User Interfaces, pp. 13-17. ACM (2016).
22. Nemoto, T., Umezu, N.: Support for Keyboard Performing Practice With Mirrored Video of Model Performances. In: 2018 IEEE 7th Global Conference on Consumer Electronics (GCCE), pp. 90-93. IEEE. (2018).
23. Xiao, X., Puentes, P., Ackermann, E., Ishii, H.: Andantino: Teaching children piano with projected animated characters. In: Proc. 15th international conference on interaction design and children, pp. 37-45. ACM (2016).
24. Hsiao, C. P., Li, R., Yan, X., Do, E. Y. L.: Tactile teacher: Sensing finger tapping in piano playing. In: Proc. Ninth International Conference on Tangible, Embedded, and Embodied Interaction, pp. 257-260. ACM (2015).
25. Fujii, K., Russo, S. S., Maes, P., Rekimoto, J.: MoveMe: 3D haptic support for a musical instrument. In: Proc. 12th International Conference on Advances in Computer Entertainment Technology. ACM (2015).
26. Kallionpää, M., Gasselseder, H. P.: Creating a Super Instrument: Composers and Pianists Reaching Beyond Their Technical and Expressive Capabilities. In: Proc. Audio Mostly 2015 on Interaction With Sound. ACM (2015).
27. Sandnes, F. E., Eika, E.: Visual Augmentation of Printed Materials with Intelligent See-Through Glass Displays: A Prototype Based on Smartphone and Pepper's Ghost. In: 2018 IEEE International Conference on Artificial Intelligence and Virtual Reality (AIVR), pp. 267-273. IEEE (2018).
28. Rusiñol, M., Chazalon, J., Diaz-Chito, K.: Augmented songbook: an augmented reality educational application for raising music awareness. Multimedia Tools and Applications 77(11), 13773-13798 (2018).
29. Donahue, C., Simon, I., Dieleman, S.: Piano genie. arXiv preprint arXiv:1810.05246. (2018).
30. Dias, R., Guedes, C.: GimmeDaBlues app for iOS: overview and ongoing developments. In: SIGGRAPH Asia 2012 Symposium on Apps. ACM (2012).
31. Snydal, J., Hearst, M.: ImproViz: visual explorations of jazz improvisations. In: CHI'05 extended abstracts on Human factors in computing systems, pp. 1805-1808. ACM (2005).
32. Ciuha, P., Klemenc, B., Solina, F.: Visualization of concurrent tones in music with colours. In: Proc. 18th ACM international conference on Multimedia, pp. 1677-1680. ACM (2010).
33. Bergstrom, T., Karahalios, K., Hart, J. C.: Isochords: visualizing structure in music. In: Proc. Graphics Interface 2007, pp. 297-304. ACM (2007).