Singing-Blocks: Considerations for a Virtual Reality Game to create chords and progressions

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Abstract. Harmony and Chord progressions are the foundational architecture of a number of genres of Western music, from Classical, to Jazz, to popular music. For any musician, mastering the rules can be an important step in learning the skills of composition. The rules are difficult to learn, however. There have been efforts to create innovative educational software displays but to date Virtual Reality (VR) systems have not been investigated. The innately physical nature of VR creates an immersive experience that is impossible with other approaches. This work explains our concept of a VR educational game for young adult learners upwards of certain Western music genres. It draws subtle analogies to the architecture of harmony by presenting a number of levels in which the user builds chords and progressions. The aim is that they journey towards interacting creatively with the harmonics representation. Suggestions are also given as to how an effective evaluation procedure may be carried out in the future.

Keywords: Music Education, Virtual Reality, Gamification, Harmony, Chord progression.

1 Introduction

The process of acquiring musical skills can be very enjoyable and it is widely acknowledged that the most fluent musicians spend many hours practicing. In all music genres there is much to learn and time must be divided between the technical skills required to play an instrument against that of studying the underlying theory of any musical genre. In several of these, Classical and Jazz in particular, but also including other popular styles, knowledge of theory is important to understand the structure of the music being played. This is very useful when it comes to activities such as interpretation, memorization, and particularly composition, as by properly understanding the patterns through which the music is structured all of these become easier. In western music, it is a significant task to learn about the various keys and their relationships in the ubiquitous equal temperament system [1]. In this system the frequency interval between every pair of adjacent notes is the same which facilitates three important features of certain Western musical styles [1]: transposition, modulation, and harmony.

Of the three, harmony is expressed through chords, which are vertical combinations of pitches, and the movement of the chords underneath the melody line is known as a progression. It could be said that the progression forms the structure or architecture on which the melody is supported. The organization of a progression sets the musical style. To illustrate, Jazz music exhibits many incidences of ii-V-I progressions, and the chords are mostly played in their seventh versions, for example, Dm7-G7-Cmaj7 [2]. On the other hand, in pop and rock music a popular progression is the modal sounding I-V-vi-IV [3]. For players of polyphonic instruments such as the piano or the guitar they would be expected to be familiar with chords and progressions as they are necessary for accompaniment. For players of monophonic instruments, including the voice, if they are called upon to create or improvise a melodic line it is extremely useful to understand the chords over which this occurs.

Although of fundamental importance, some students can find that the rule-oriented, technical, and almost-mathematical nature of chords and progressions make lessons difficult [4]. This is compounded for monophonic instrument players by the fact that they are physically unable to play the chords on their instrument, adding another frustration. For self-driven, non-child players that are outside a classroom situation technology can help to overcome this [5], primarily by making instruction more involved than traditional paper-based learning, allowing the learner to be more active and providing them with feedback throughout the process [6]. The use of technological tools for music education has been around for a while and their growing success is evident in the uptake of a commercial platform like Yousician [7] which reportedly has over 25 million users. This is not to say that technology always supplants tradition, and instead can be used as a new dimension to the educational experience that introduces new ways of learning.

Using technology facilitates Gamification of the learning process, making it more fun and interactive than traditional methods. It uses game-like elements to motivate and encourage the user. It offers continual rewards for achievement within sequences of small objectives and provides regular feedback to steer understanding. The Gamification approach is reaching VR platforms [8]. A Virtual Environment (VE) presented in VR is generally accepted as one in which the user[1] is completely immersed [9]. By providing real-time sensory stimulation across multiple modalities, VR immerses the user in a simulated reality, leading to a natural user-interface (NUI) that integrates interaction and imagination. This synthetic world may be used to mimic the real-world precisely or it can be used to exceed accepted boundaries by creating a sphere in which the physicality of space and time, mechanics and materials, and other scientific constants can be manipulated. VR technology is currently experiencing a wider consumer adoption as the quality of the interfaces have improved, along with standard computer processors and graphics cards becoming more powerful, and also the costs of equipment have fallen to within typical consumer price ranges. For a learning task that involves interacting with representations of chords and progressions, VR could be an interesting perfect platform. The three-dimensional VR immersive visual simulation can be used to engage with the features of music theory in a context that is impossible with traditional teaching methodologies and could, therefore, enhance the learning process.

[1] For VR usage medical professionals recommended that user are at least 12 years of age

The following sections will explain our idea for an application called, "Singing-Blocks". This was designed specifically to introduce learning and creativity with chords and progressions through VR. The next section will review some of the previous work on illustrations of harmony and harmonic movement using novel computer-based visualizations. Then, VR systems in music technology will be discussed. This will be followed by a section on how the Singing-Blocks system should appear: from concept to implementation and evaluation. The last section then will present some conclusions and lay out the tasks for future work.

2 Learning Chords and related Software Systems

The standard Western harmonic structure is based on chords (i.e., three or more simultaneous tones), which can be constructed on each note of the scale. The two most important chords are based on the tonic and dominant notes, designated the tonic chord (C E G in the key of C major) and dominant chord (G B D in the key of C major), respectively. A variant of the dominant chord is the dominant seventh chord (G B D F in the key of C major) [10]. It is worth noting that in the case of notes whose fundamental frequencies stand in small integer ratios (e.g. the octave is 2:1; the perfect fifth is, 3:2) they form consonant intervals. These are known to elicit more positive affective responses than notes whose fundamental frequencies stand in more complex, dissonant-sounding, ratios (e.g. the tritone is 45:32) [11]. Therefore, the intervals in the chords can create dissonances and consonances in a piece of music that lead to the perception of tensions and resolutions by the listener, thus imparting a momentum to the music.

To find appropriate methods for teaching chords during the past five decades, several efforts have been proposed such as [12, 13, 14, 15, 16, 17]. With the increasing availability of technology efforts have moved away from the traditional paper-based approaches to ones that are facilitated through software. The clear benefits of using the software in this context is that elaborate visualization can be created easily and musical exercises packages can be devised that can guide a learner though them when working on their own, and at their own pace. An associated academic concept is experiential learning [6]. Here, students use technology to combine concrete experiences, abstract conceptualization and reflective observation in active experimentation, and thus they reinforce what they are trying to learn. This makes the information much easier to understand and retain.

A few recent systems for displaying the harmonic content of music are worth mentioning. The first is not based inside a computer but is, in fact, held within a large physical space that is computer monitored. In this study [18] the researchers were looking at whether participants' understanding of harmonic relationships could be effectively mapped to their knowledge of their own bodies and situated sense of space. Essentially, their system employed a projector, placed on the top floor of an atrium, to display alphabet note names on the floor below. In addition, a camera was used to track the players' movements. The player's task was, therefore, to navigate through the space in time to a recording of a song to generate a bass line (or chord sequence). It was described to be analogous to the party game of "Twister". Feedback from the participants expressed that the whole-body interface and the associated tasks were captivating, attractive, demanding, and fun. However, the most important drawbacks of their system were that it demanded several pieces of equipment, such as a projector, camera, and tracker, but more importantly it needed a large, empty atrium. Thus, this system availability was limited. In addition, another disadvantage of their system was that the players' shadow occluded the labelling of nearby features.

Other computer-oriented approaches for displaying music, not specifically for teaching chords, have been documented. Gatzsche et al presented a pitch-space based musical interface approach [19], the theory of which was established by Lerdhal [20]. They employed a touch-sensitive surface, over which the player could move through the pitch-space and create music by tone selection. The emphasis of the paper was on the intuitive nature of the interface and how it elaborates on musical relationships. A different tool created for visualization of tonal space is MuSA.RT [21]. In essence, a MIDI stream of musical notes is visualized as a spiral array. The aim was to generate an environment by which expert musicians could see the tonal structures of what they were playing; where experienced listeners could then visually follow the structures that they were hearing and novices could learn to hear the structures that they were seeing. As it currently stands this representation appears to be too complicated for teaching chords and their progressions. The next section will explain more about VR systems, their application to education, and the use of Gamification for education. It closes by suggesting why both technologies might be brought together.

3 Virtual Reality and Gamification

In VR a computer and headset respectively simulates and displays a 3-D VE through which the user can walk and interact with objects and simulated avatars. VR systems for Music Technology have been developed since early 2000. Although progress has not been especially rapid it is a definite strand within the community for New Interfaces for Musical Expression (NIME). Typically, the main components of a VR system can be classified as:

- The Output devices: as visual, auditory [22], or haptic displays [23]; the quality of which very much relies on the processing power available.
- The Input devices: such as handheld controllers with triggers and buttons; with more recent VR platforms including motion tracking to sense the position of the user.
- The Software: running on a high-specification PC or integrated hardware of the output device.

When applying VR to music technology the researchers [24] recommended nine design principles that should be observed. This work emphasizes the importance of the interaction between the user and the system to give the best possible experience. They acknowledge that the evaluation of these systems is difficult. To discover the performer's viewpoint, post-task questionnaires are suggested along with the measurement of physiological features. They believe though that a lot of work remains to be done as regards the evaluation of VR systems in this context.

VR can have a significant role to play in educational activities according to [25]. It is VRs experiential and interactive nature that makes it different and so it can enhance and extend conventional learning paradigms [26] where abstract concepts can be presented in terms of an observable reality. The Gamification of learning has also drawn the attention of academics, practitioners and business professionals in domains as diverse as education, information studies, human–computer interaction, and health [27]. Likeability has been identified as a key component when merging VR and Gamification and has been deemed to be proportional to the sophistication of the resulting environment. [28]. The next section will explain the idea for the proposed game itself.

4 Our System

The name of our system is “Singing-Blocks” because the intention was to reflect the structural and architectural nature of building chords and progressions. Fig. 1 shows a screenshot of the environment made in the Unreal engine (UE4) [29].

Fig. 1. Screenshot of the Singing-Blocks game in the Unreal engine.

The idea is to have a game with several different levels, each delivering progressively more difficult concepts through iterative in terms of play. The first eight levels are outlined as follows:

1. Learn to arrange 8 notes of the C major scale in ascending order, starting from C and ending on the C one octave above.
2. Learn the triads in the key of C Major
3. Arrange the chords to make a progression in the key of C Major
4. Create 4 note chords using the C Major scale with additional notes such as 7ths / 9ths
5. Arrange new chords to make a progression in the key of C Major
6. Aural test challenge – Distinguish between major, minor and diminished chords

7. Creative chord progression “jamming” with chords from the C major scale to a metronomic beat and an ostinato drone bass note.
8. Using a variety of templates for basic musical forms, for example, ternary form, to compose a chord progression with modulation starting with chords from the C major scale over a metronomic beat and creating a modulation to a closely related key using the cycle of fifths.

In the first level of the game, the user is faced with 8 blocks and each block has a different colour. The lowest note C, is a dark colour, such as purple, and as the notes increase in frequency the colours become brighter. For example, the B above this C is pink. These singing-blocks are initially lying on a virtual floor desk as shown in Fig. 2.

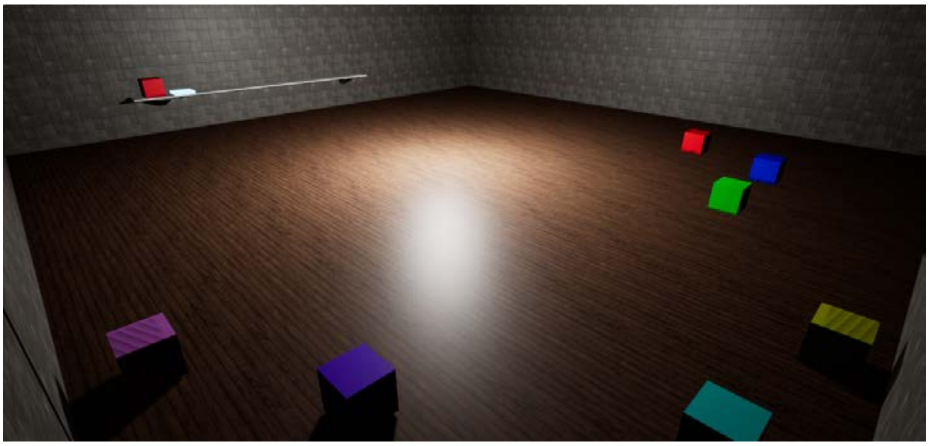


Fig. 2. Screenshot of the opening of the Singing-Blocks game.

When these blocks are touched, shaken or picked up, the note of the block being handled will sound a note at the appropriate pitch. The user is required to place the blocks on a shelf in ascending order as suggested in Fig. 1. When the correct block is placed on the shelf, it will sound again to indicate that the user is correct, it will "stick" to the shelf, and the next area will light up for a new block. If the placed block is incorrect, it will "bounce away" producing a sound indicating that it was an incorrect choice. When the next correct block is placed in the sequence, the previous blocks will sound in order, for example, if the E block is placed as the 3rd block, then the note sequence C, then D, then E will sound. If the new block is not the correct block, then the sequence will not sound.

The second level commences with a quick demonstration and furthermore if at any stage if the user needs to be reminded of the rules, they can use the controller to get the initial demonstration replayed. This demonstration is given with voice instructions and is as follows:

1. Show 2 octaves of Singing-Blocks in the key of C major.
2. If the C is selected and placed on the shelf (display “ROOT”) then this note will sound.
3. Demonstrate how the D note is skipped.

4. If the E is selected and placed on the shelf (display “THIRD”) then both notes will sound.
5. Demonstrate how the F note is skipped.
6. If the G is selected and placed on the shelf (display “FIFTH”) then all three notes will sound.
7. A new shelf above the C major triad then appears for the D minor triad.
8. Steps 2 – 7 are then repeated to demonstrate the construction of the D minor triad.
9. The user is then told to repeat this procedure to create triads for all the notes in C major.

The notes will sound together when the correct singing-blocks are placed in the correct order. The final and correct result should be that the notes are placed in the correct order in a fashion similar to Fig. 3.

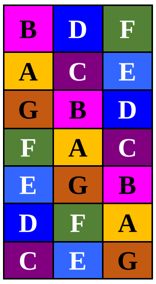
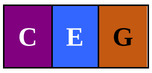


Fig. 3. Illustration of the block arrangement for learning triads in the second level.

In the third level, a demonstration is given to show that when the triads are stacked in a harmonically pleasing way, there is typically a common note from adjacent triads present. The color of the Singing-Blocks will help visualize this. The program will ask the user if they would like to create their own 4 chord progression or build a predesignated progression. If they decide to create their own progression, an algorithm will determine how harmonically satisfying a progression is judging the percentages of similar notes in adjacent triads and whether there are common notes or notes that are less than 1 interval away. If they decide to use a predesignated progression, then the computer will supply one of 10 predetermined progressions as mentioned in [30] or the common progressions given in [3]. The user will then be able to visually and audibly understand why such a progression works.

For example, if we use the progression: I – V – VI – IV in the scale of C major (C – G – Am – F). The user would stack the Singing-Blocks (as in previous levels) and should end up with something like:



In this case, note G is common to both the C major and G major triads. It should also be noted that the E in C major only increases by one step to D in the G major chords and that the C in the C major chord also only moves one step, down to B as shown

G	**B**	**D**

All the notes then increase by the same step upwards to the Am chord

A	**C**	**E**

Lastly, the notes A and C are common to both the A minor and F major triad. Furthermore, it should be noted that the note E in the A minor triad has increased by only one step.

F	**A**	**C**

In Level 4 the goal is like that of Level 2, but it also includes an additional note. For example, if the program asks the user to create the chord of Cmajor7 and when the Singing-Blocks are placed in this order, the chord will sound to indicate the correct sequence. Some predetermined chords for testing are: Dm9, Em7, Am 7, and Bdim7. Level 5 is also similar to Level 3, where these new chords can be arranged into progressions. This exercise emphasises the perceptual qualities of the extended chords as they have played a defining role in the music of impressionist composers like Debussy [31] and Jazz [2]. Level 6 is a game element to get the user to practice their skills at chord recognition. Levels 7 and 8 are intended to be creative where the user explores the making of chord progressions by themselves. In Level 7 the use of an ostinato, a repeating motif that is in many musical genres, allows the user to hear the relationship sound of the individual chords and their movement through the progression in relation to the bass note drone. It can produce an effect reminiscent of Keith Jarrett's approach to improvised piano [32]. Level 8 raises expectation for the user by requiring them to follow a music form and compose a modulating chord progression that follows the circle of fifths. This is an advanced task, extending the aural skills to deal with an essential technique for providing musical movement and interest to a composition [33].

4.2 Implementation

The game is implemented using the Unreal (UE4) game engine [29], released in the 1990s by Epic Games. The version used for the project is Unreal Engine 4.18 (UE4). The engine is currently free to use. It uses C++ and also implements visual scripting in its own *Blueprint System*. Its graphics capabilities are very powerful and its audio capabilities facilitate multiple spatial sound effects and realistic sound simulation. Some additional plugins are also currently being used to help maximize audio programming potential. Specifically for the Singing-Blocks project the individual FMOD Studio and *Epic Games*' official beta version Synthesizer plugins are used.
The VR equipment system is a HTC Vive [34]. It consists of three main components:

- A VR headset with two 1080x1200 resolution displays (one per eye). It works at a refresh rate of 90Hz and a total field of view (FOV) of 110 degrees.

- Two hand controllers with 9 different buttons and a track-pad for the user's thumb and XY positioning for advanced control.
- Two tracking stations (lighthouses) that spatially track the headset and the two hand controllers with position and rotation in real time.

The software is running on a Dell Alienware Arura R6 which has an Intel i7-7700K Processor, dual NVIDIA GeForce GTX 1080 with 8GB GDDR5X each, and 64GB DDR4 memory.

4.3 Evaluation Approach

As mentioned in Section 3 evaluation of VR music technology games is still a developing area. For the Singing-Blocks game three groups of ten students will be selected to evaluate the system. The first group will be self-taught musicians that are not attending formal or informal classes and are therefore motivated to learn chords through this system. The second group of participants will be amateur musicians that are attending some formal classes and would be the type that could appreciate the system as supporting educational tool. Finally, the third group will be experienced students of music that would evaluate the relationship of the system to any previous instruction in harmony they had received.

To determine the effectiveness of the system, all groups will be allowed to use the system at the university campus for 30 minutes a day over a 3-week period (excluding weekends). They will be tested on their knowledge regarding triads and chords after each session using a browser-based survey. In addition to this feedback will be obtained from the users on how they perceived the interface in terms of metrics such as usability, learnability, and user experience [35]. The results will be compiled and then assessed.

5 Conclusions and Future Work

This paper has proposed a system called Singing-Blocks that connects VR and Gamification. The different levels of the game were explained, its implementation using the HTC Vive and Unreal engine (UE4) was discussed, and a procedure for evaluation was outlined. The next step is to evaluate the game with the user groups. Feedback will be used to improve the game. In particular, it would be interesting to add exercises associated with more standard chord progressions such as Ragtime [36] and explore techniques such as Chord substitution [2]. Other pedagogical exercises could be included [37]. Lastly, future experiments could be conducted to understand how to apply the Tonal Pitch Space (TPS) concept [38, 39] to bring a perceptual approach to the relationships within chord progressions.

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