A video game for ear training on chord recognition using smartphone-motion gestures and based on Tic-Tac-Toe

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ABSTRACT

Musical skills such as identifying chord progressions or scale degrees are ear training skills that can be hard to teach and learn.

We implement an interface for the chord progression recognition task that, instead of using common approaches based on dictation or listening and transcription, uses the motion sensors of a smartphone to acquire the learner's gestures and game mechanics based on Tic-Tac-Toe. Harmonic functions were incorporated to the state transitions of the game mechanics and two game modes were implemented: (i) two player cadence battle and (ii) free chord progression exploration.

We believe that the gamification of a user interface for ear training in general, and chord progression identification in particular, will allow music practitioners to embody and incorporate these tasks by heart, by means of the constant exposure that a gamified and engaging interface can provide.

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

Author Keywords

Music learning interfaces; Gamification in music interfaces; Gestural interfaces for music creation and listening.

INTRODUCTION

Since the first continuous background soundtrack was introduced in Taito/Midway's Space Invaders (1978), music has been part of videogame design, typically, in a subsidiary role [5]. It has been at some point the interest of music technologists and musicians to explore the combination of game design and new digital musical instruments [12]. There are some parallels in videogames and digital musical instruments, for example, both require a certain degree of *immersion*, *skill*, and *commitment* from the player. Austin even argues that a videogame *can be* a musical instrument [2]. Whether these claims are accepted or not, it is difficult to deny that there are similarities between videogames and digital musical instruments beyond the idea that both can be *played* [2].

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Videogames can also be valuable tools for education. In the context of music education, Gower and McDowall studied the relevance of rhythm and melody-based videogames to music learning in young children, stating that videogames may help to develop some music skills and there could be a place for them in music education [8].

In the core of game design lies the game mechanic. Sicart defines the game mechanic as the *"methods invoked by agents for interacting with the game world"* [10]. A definition rather inspired by the object-oriented paradigm and applied to his comparison of the games *Rez*, *Every Extend Extra*, and *Shadow of the Colossus*. Sicart also implies that a game mechanic is designed for regulating the transitions between game states. According to Collins [6], since the times of *Super Mario Bros*, it is not only possible but common to design music that reacts to the game states of a videogame. Such *adaptive audio* responds to in-game parameters and is characterized, among other things, by the ability to add musical elements as gameplay features. Therefore, if one pretends to blend the videogame and its musical interaction, special attention has to be placed to the transitions of the game states, as these should comprehend both the rules of gameplay and the adaptive audio synthesis.

Furthermore, if the resulting videogame pretends to be useful also as a tool for musical education, one should make one additional consideration during the design of its game states and mechanics, as they should gradually reward the player with increasing musical skill.

There are already applications focused in providing these gamified environments for ear training tasks [7, 1, 11]. One limitation of these applications is that they are typically designed to be played by a single player. We want to differentiate ourselves by designing a gameplay that can also allow players to compete with others in real-time. We believe that the simultaneous interaction of players through the interface of smartphone-motion gestures can be more engaging than single-player individual use, and at the same time, reward them with chord progression recognition skills. In order to simplify the design of a new gamified interface, we decide to mimic the game mechanics of the well-known game, Tic-Tac-Toe.

GAME MECHANIC

There are many variations for the game mechanic of Tic-Tac-Toe, some of them incorporate multi-dimensional approaches with a very large number of states and state transitions [3]. However, in its 3x3 version, Tic-Tac-Toe is a very simple game that users of all ages easily understand.

Tic-Tac-Toe Game Mechanic

In a typical match of Tic-Tac-Toe, two players take turns selecting cells of a grid. The objective of the game is to place three successive symbols from the same player in a horizontal, vertical or diagonal line, in which case the player wins the game.

Here we list some of the characteristics of the original game mechanic:

- The state transitions can be visually seen as symbols drawn in the grid. The symbols *X* and *O* represent cells chosen by the first or the second player, respectively.
- In a Tic-Tac-Toe match, it would take one player at least three turns (with two faulty decisions from the other player) to win the game.
- There is a limitation of a match to nine turns, if there is no winner after the ninth turn, the game ends with a draw.
- In Tic-Tac-Toe, the first player always has a bigger chance to win than the second player [4].

Proposed Game Mechanic

In our game mechanics, we modify some of these original characteristics in order to deal better with musical state transitions. A general overview of the game mechanic can be seen in Table 1:

- Instead of drawing visual symbols in a grid, we synthesize chord sequences over time, one chord for each turn.
- We propose an intermediate division of the match in *rounds*. Each round is fixed to three turns.
- Determining the winner of a round depends on the combination of the chords played during the round, plus the first chord of the next round.
- A match could continue for as many rounds as it takes for one of the players to lose his or her *"health"* points.
- The number of combinations for winning or losing are the same for both players, attempting to correct the *unfairness* of the original Tic-Tac-Toe.

GAME STATES

The proposed game mechanic contains a total of 21 states. The game states and their corresponding chord progressions can be seen in Figure 1. The game states are divided in five different groups.

Player	X	O	X	O	X	O	X
Chord	T1 T2	S1 S2	D1 D2	T1 T2	S1 S2	D1 D2	D1 D2
Round	1			2			3
Turn	1	2	3	4	5	6	7

Table 1. A musical Tic-Tac-Toe. Each round comprehends three turns, the outcome of a round depends on the combination of the three chords presented in the round plus the first chord of the next round. The first turn of each round is alternated by the players, meaning both players get the opportunity to decide the outcome of a round. *T* stands for tonic, *S* for subdominant, and *D* for dominant.

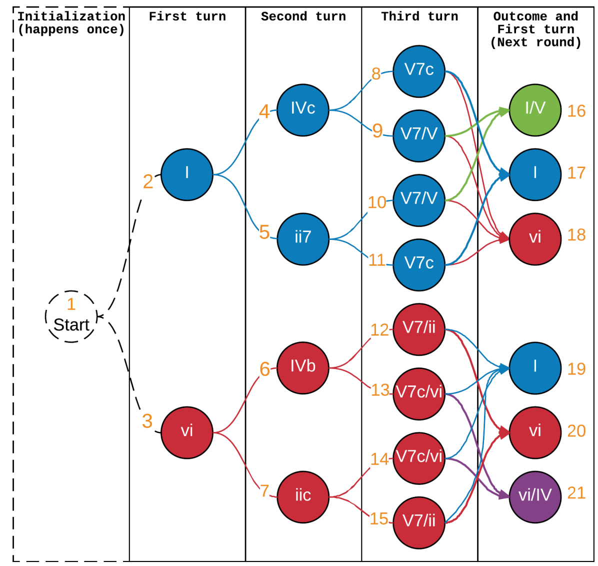

Figure 1. All 21 game states and transitions. The states in the upper branch (blue) transition through chords in the context of a major key. In the other hand. the states in the lower (red) branch through chords in the context of the relative minor key. All game states of the first turn play tonic chords, the ones in the second turn play subdominant chords, and the ones in the third turn play dominant chords. Game states 16 (green) and 21 (purple) represent modulations to the dominant and subdominant, respectively.

Game State 1: Initialization

This state is the *initialization* state, it is the state in which the game starts, it is also the only state which does not play any sound. Starting from this state, it is only possible to transition to game states 2 or 3.

Game States 2-3: First Turn

Game state 2 plays the tonic chord of a major key, game state 2 plays the tonic chord of a minor key.

Game States 4-7: Second Turn

Game states 4 and 5 play a subdominant chord in the context of a major key. Game states 6 and 7 play a subdominant chord in the context of a minor key.

Game States 8-15: Third Turn

Game states 8 to 11 play a dominant chord in the context of a major key. Game states 12 to 15 play a dominant chord in the context of a minor key. The chord played during these states could be the dominant chord to the tonic played in the first turn or it could also be the dominant to a different tonic of another key.

Game States 16-21: Outcome and New Round

These states also correspond to the *first turn* of a round. They are analogous to the game states 2 and 3, however, states 16 to 21 determine the outcome of the previous round. There are three possible outcomes for a round, these can be observed in the last column of Figure 1 and also in their harmonic context in Figure 2:

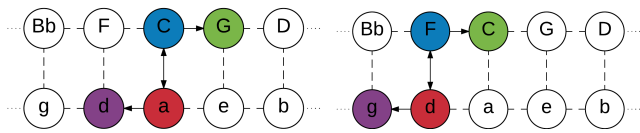

Figure 2. Harmonic context at initialization (left) and after a modulation driven by game state 21 (right). The modulations performed by this game state are always in the direction of the subdominant.

- Cadence: Game states 17 (blue) and 20 (red) complete the cadence proposed in the first turn of the round
- Modulation: Game states 16 (green) and 21 (purple) modulate to a different key, playing the tonic chord of the new key
- Relative key: Game states 18 (red) and 19 (blue) transition to the tonic chord of the relative minor or major key, respectively. Even though this transition is considered a change of key, it is not considered a modulation. These states also have the additional effect of increasing the speed (tempo) of the game.

TWO PLAYER CADENCE BATTLE MODE

As we mention during the introduction, one of our main motivations is to design a chord progression identification interface that allows players to compete with each other in real-time. Therefore, this game mode has been the main focus of this work. In its current format, the game mode is designed to be played by two players, each one with a smartphone. In the following lines, we summarize the rules, objective and gameplay of the game mode.

Objective of the Game

- The general objective of the game is to clear the other player from its *"health"* points.
- The players clear some of the *"health"* points of the other player by completing cadences or modulations.

Rules of the Game

- Players are not allowed to get information about the chord chosen by the other player, except for the audio feedback that will be synthesized when the other player completes the turn.
- When it is their turn, players will have a choice between two chords to play to the other player. The available chord choices are determined by the current game state.
- Since the first turn of the round determines any cadences or modulations, the players will always alternate the first turn for each round, guaranteeing that both have the opportunity to complete a cadence or modulation.

Gameplay

At the begining of each round, the outcome of the previous round is decided, together with the tonic chord for the current round. There are three possible outcomes distributed among the combinations of chords chosen by the players, the list of combinations can be seen in Table 2. The players decide the outcome by the following criteria:

Combination	Winner		
	P1	P2	Deferred
T1-S1-D1-T1	X		
T1-S1-D1-T2			X
T1-S1-D2-T1		X	
T1-S1-D2-T2			X
T1-S2-D1-T1		X	
T1-S2-D1-T2			X
T1-S2-D2-T1	X		
T1-S2-D2-T2			X
T2-S1-D1-T1			X
T2-S1-D1-T2	X		
T2-S1-D2-T1			X
T2-S1-D2-T2		X	
T2-S2-D1-T1			X
T2-S2-D1-T2		X	
T2-S2-D2-T1			X
T2-S2-D2-T2	X		

Table 2. All possible outcomes for a round depending on the combination of the chords presented. *P1* represents the player that selected the first and third chords of the combination. *P2* represents the player that selected the second and fourth chords of the combination.

- If a player starts a round, he/she will decide the outcome of the *previous* round.
- If a player does not start a round, he/she will have the opportunity to decide the outcome of the *current* round.
- When deciding the outcome of the previous round, the player also has the opportunity of *deferring* the winner of the previous round. This increases the tempo of the game and carries the damage of the previous round to the current round. The musical result of this action is presenting the relative major/minor key as the tonic for the current round.
- The player in charge of the turn will have two choices of chords to play. The proposed chord transitions for each game state can be seen in Figure 1.

FREE CHORD PROGRESSION EXPLORATION

An alternative proposal of the game for a single player is to remove the objectives of the combat mode and leave the game states and transitions unchanged. This allows a single player to *explore* freely through cadences and modulations. Among the possibilities of this game mode, we can list:

- The user can play any major, minor, and dominant seventh chord in its corresponding tonal context.
- The player can modulate, at will, through any major or minor key of the tonal system.
- The game abstracts the rules for voice leading and chord progressions from traditional harmony into a layer of smartphone-motion gestures. This means the user is able to play infinite sequences of tonal music, without any knowledge of music.

We believe this could be a good approach for players who want to learn about music theory but lack the skill of playing a musical instrument. The proposed game mechanics abstract

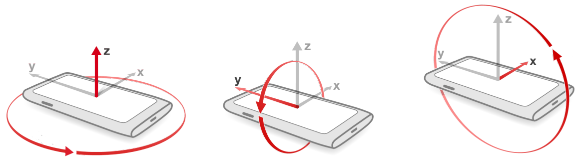

Figure 3. The six discrete gestures of the game controller, based on three different rotation axes. Gestures *T1* and *T2*, perfomed by rotating the smartphone in the positive or negative yaw axis, respectively (left). Gestures *S1* and *S2*, perfomed by rotating the smartphone in the positive or negative roll axis, respectively (middle). Gestures *D1* and *D2*, perfomed by rotating the smartphone in the positive or negative pitch axis, respectively (right).

the difficulties of the performance of an instrument and provide the player with an interface based on simple motion-gestures of a smartphone.

SMARTPHONE-MOTION GESTURES

In the past, music technologists such as Wang have designed musical interfaces in the boundaries of devices available to many users, such as smartphones and tablets [13]. We try to replicate that approach in the design of the gestural controller for the proposed game. The main input of the controller is based on six discrete gestures taken from a gyroscope-accelerometer sensor of the smartphone, as shown in Figure 3.

IMPLEMENTATION

The prototype of the interface has been implemented in the PureData programming language, empowered by the capabilities of MobMuPlat [9]. The implementation consists of five main modules:

1. Controller: A module that is in charge of processing the input of the gyroscope-accelerometer sensors of the smartphone, providing as an output the discrete gesture performed by the player.
2. Gesture parser: A module that parses the input gesture and performs the transition of the game state.
3. State parser: A module that parses the properties of the current game state for feeding the synthesis and gameplay modules.
4. Audio synthesizer: A module that synthesizes the audio for the chord of the current game state, using five physical string models based on the Karplus-Strong algorithm.
5. Gameplay parser: A module that determines if there is a winner of the match, calculates the damage received by the players, accumulates the damage for deferred rounds, among other gameplay tasks.

CONCLUSIONS

In this paper, we propose an interface for ear training in the task of chord progression recognition that uses the motion sensors of a smartphone to acquire the learner's gestures and game mechanics based on Tic-Tac-Toe. We differentiate the current approach from other gamified interfaces for ear training by designing a gameplay that can allow players to compete with each other in real-time. We believe that this mode of interaction can be more engaging for the players, and by means of their constant exposure to it, reward them with chord progression recognition skills. Future work could lead towards the design of more ear training interfaces or the fine-tuning of the one proposed here.

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