



Saray: Solfege Learning Computer Game Based on Voice Analysis

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Original Article

Abstract

Introduction: The methods and tools used for learning are rapidly changing. One of the most interesting fields in educational tools are computer games. "Saray" is a solfege training video game, through which the players take solfege rehearsals in form of challenges while tracing a folklore story. The game receives the player's voice through the microphone.

Materials and Methods: Based on the algorithm and the written code, the player's voice was analyzed, and its fundamental frequency was extracted. The obtained frequency was entered into comparative calculations with pre-written patterns. If the user's voice frequency was within the defined range, the user would be successful and would earn the score.

Results: Solfege exercises took the form of intra-game challenges from basic to advance levels. Behind the scenes, all input sounds were processed. The frequency of the input sounds was analyzed to implement this process. The result of the analysis was compared to pre-designed didactic patterns that were confirmed by the music master. The result of this comparison revealed the correct or incorrect user feedback in the game.

Conclusion: Exercising in the form of games motivates players to spend more time for training, and has high impact because of the attractiveness of video games.

Keywords: Serious games; Training; Sight reading; Gamification; E-learning

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Introduction

Solfege is the ability to play musical notes based on intervals in a variety of musical scales by the human larynx without a music instrument (1). Based on years of experience in teaching solfege worldwide, it is clear that in the traditional way of teaching solfege, the presence of a teacher to express feedback and training points, as well as the existence of a single place for teaching is inevitable. In addition, the presence of different professors with different levels of ability and educational tastes and in some areas, the lack of a teacher is problematic.

There are several definitions of computer games, one of the most important being the one proposed by Prensky. According to him, computer games are

structured games consisting of six key elements "rules, goals, feedback or outcome, competition or challenge, interaction, and story" (2).

In order to establish a balance between the entertainment and educational goals, it is necessary to consider educational considerations to provide a valuable learning experience for the learner (3). One of the most important factors in the educational dimension, design, and evaluation of the game-oriented approach is transparency about educational goals; because if the goals are not clearly defined, it will not be possible to accurately assess learning (3). It is necessary for learners to be informed of the educational goals before starting the game in order to move them purposefully in the learning path. In the

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formal education process, it is necessary that the game design is fulfilled in order to achieve the goals set in the curriculum; in such a way that the activities and structure of the game are all related to the learning objectives (4). Given that technology has now a prominent presence in the lives of people in the community, it is natural to take the advantage of the use of web and mobile technologies to help the education process with the aim of improving knowledge and acquiring or regaining skills.

Fowler and Cusack conducted a study to provide a way to measure learning in computer games, and concluded that questions such as what, where, and how can be answered by identifying learning and measuring skills. This data can provide an understanding of the challenges that a player solves and the learning experience through computer games. Data on interactive variables describe learning and what is expected of video games (5).

In a study carried out with the aim of examining students' attitudes toward developing game-based skills, Barr found that commercial video games could be used to develop communication skills, ability, and adaptability in graduate students. These aspects included the need to communicate with teammates to succeed and the unpredictable nature of the challenges in the game. This study showed that while games play an important role in developing skills, facilitating interaction between students through games is also an important factor (6).

Washington and Zhong conducted a study to teach music in an adaptive learning style, during which the simple computer game Music Trainer was designed and produced. In this game, the player had to identify the wrong melody written on the note sheet music. In this game, adaptive learning was used to adjust the game problem based on user performance (7).

In a study on e-learning music, while examining how to calculate the duration of the notes performed by the user, Faghih also provided an algorithm for comparing the durations and the predefined pattern. Finally, he also examined the details of implementation of the "Music Dictation E-learning" software in an interactive form. Based on the results, the best way to perform the note duration was larynx, keyboard, and mouse, respectively. The proposed algorithm, which was tested on 1500 different durations, expressed the same opinion with that of the music experts in 97.87% of cases (8).

Among the serious games that have been produced internationally so far, there is no computer game to train solfège. In the present study, Saray game was designed and introduced as the first solfège training

game. This game was innovative compared to other existing games in terms of user input by trying to receive some of the information in audio form from the player, which will strengthen the player's solfège skill.

Materials and Methods

This study, which was carried out with the aim of designing and producing the Saray computer game, started in October 2017 at Tabriz Islamic Art University, Tabriz, Iran. The solfège training and hearing boosting game is basically a game based on the user's voice. The game challenges include the solfège training exercises that were comprehensively selected from the most prestigious global educational sources; So that if the player of this game goes to the music school to learn solfège, the same exercises will be taught to him in the same order arranged in the game.

Results

Saray: It is a kind of solfège training game in which the user experiences solfège training exercises in the form of in-game challenges in a story context. The exercises are purposefully included in the game as a prerequisite. The goal of the game was to teach solfège and strengthen hearing for music learners in a way that they can acquire skills while playing the game as a hobby, in the form of a computer game with new methods. In designing the educational principles of this game, prominent music teachers were employed, whose teachings can be a very good basis for music beginners' learning.

The solfège exercises were performed in the form of in-game challenges from beginner to advanced levels. All input sounds were processed behind the scenes. In order to implement this process, an element of sound was required with a unique pitch and characteristics of each particular note. This element was frequency (9). The frequency of the input sounds was analyzed and the result was compared with pre-designed educational models the principles of which were approved by the music teacher. The result of this comparison would determine the correct or incorrect user feedback on the challenge as well as the in-game exercises.

Game mechanics: The process of designing an e-learning program is very different from the process of designing a serious game. Learning content in serious games plays a dominant role in the game, but the game mechanics and interactions should not be merely a funny layer added to the game's digital tools, but should be in line with the learning goals and facilitate the ground for the player to achieve these goals (10). One of the important factors in computer

games and the design of these games is the issue of game mechanics. The latest definition of game mechanics is the Sicart's definition, which is a method designed to interact with the game environment (11). According to Sweigart's theory, which introduced 31 well-known computer game mechanics (2), the mechanics of the steps designed in the Saray game are as follows.

Step 1: Jumping mechanic, which was designed as a platform and the player loses if he falls off. At this point, ambient light was removed and light sources were added in the form of lanterns. The lights would turn on by the player's voice.

Step 2: Strong bouncing object in which a luminous ball moves from the opposite side to the player. This luminous ball turns off the light sources in the environment by hitting them and increases the intensity of its own light. If the luminous ball hits the character, the player loses. To destroy the ball, the player must follow the exercises included in the game.

Step 3: Teleports, in which the character must leave a dead end. The only way is to move upwards. To do this, the player must play the note correctly by reaching a certain point and playing the guide sound. If he succeeds, he will be thrown to the next platform.

The gameplay was such that the progress of the game was based on the player's voice. The sounds heard by the player were notes with a certain frequency, and the player had to read that note at the same frequency (of course, taking into account and applying a tolerance). In this game challenge, the solfège exercises were implemented. The player was actually practicing solfège during the game.

The game process was designed in such a way that practice and continuous repetition strengthened the player's listening skills in note recognition and its correct expression. Definitely, a beginner is not able to read the notes at exactly the same right frequency. For this reason, the game's developers considered a frequency range and tolerance that, if the frequency received from the player's voice was in that range, the player would gain the points needed to pass that challenge. This tolerance was determined based on the opinion of the music teacher and on the theory that already existed. The allowable tolerance for the frequency range was (-15, +15) Cent (the distance in each semitone is divided into 100 equal units, with each unit called a Cent). The beginner users should observe a minimum of stability in the frequency range of 0.5 seconds (9) while playing the note. This rate increased to 2 seconds for more skilled users (9).

The general process of analyzing the user's voice was such that the audio signal was received from the

user by a microphone and was transferred to the frequency range using Fast Fourier transform (FFT). Then the frequency spectrum was extracted. Each note consists of several frequency ranges (12) and the fundamental frequency was extracted from these spectra. The rest of the frequency spectra were a coefficient of the fundamental frequency (12). Finally, the fundamental frequency was the desired pitch. Pitch was the main element in the design of the game; because all comparisons and analyzes were based on Pitch (Figure 1).

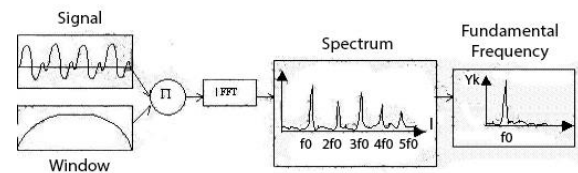


Figure 1. Algorithm for finding the frequency spectrum with a maximum error of 0.0092% (12)
Signal-Window-Frequency spectra-Fundamental frequency

Game Scenario: Saray is a game in the adventurous-educational genre with the goal to teach solfège in an attractive and entertaining environment. Solfège in this game takes place in the narrative context of the game. The player accompanies Saray and learns solfège with her on this journey. Saray is a warrior girl who goes to war against the devil and frees the light (sun) from captivity in the war against darkness. All stages of the game take place in the narrative context of the story of Saray. How Saray begins her journey, her struggles along the way, and what happens to her are all portrayed. The story of Saray is inspired by a story from Azerbaijani folklore (13).

Myths use art to express themselves in the best possible way to the audience, and one of the most important arts that is directly related to myth is literature. Literature is also one of the main arts that plays a role in the field of video games in the form of the game scenario (14). Perhaps no one had realized the power of mythology in the gaming world before the God of War game series entered the video game industry. Other arts, such as painting, theater, animation, and cinema, reached the power of these fascinating stories much earlier (14). With the advent of the God of War game, the true power of myth was revealed to the world; The God of War series quickly became the only major Sony and PlayStation brands and was named one of the best games in history (14).

The Saray game was designed in such a way that in the first stage, Saray, the main character of the game, enters a dark world. She hears voices there. By repeating and imitating that sound, a lantern is lit, the light of which illuminates part of the character's path. She hears a sound as she passes the light range of the first lantern. This process is repeated during this stage, and the way to play in this stage is to listen well to those sounds and repeat them to light the lanterns. The game at this stage is in the form of a platform. So if the player cannot light the lantern and go ahead in the dark, she falls off the platform and loses the game (Figure 2).



Figure 2. A view of the first stage

In the second stage, the player must acquire the second desired ability, which is "Solfège of the major second and third intervals". Therefore, an exercise was designed with this approach. Saray is moving when a luminous ball approaches her from the front. The moving luminous ball, when strikes the light sources illuminating the path, extinguishes them, and increases the intensity of its own light. If this luminous ball reaches the character, the player loses. The running character hears sounds that she must imitate them correctly, as in the previous step. If he repeats three of them correctly, the luminous ball disappears and another ball appears and this process continues. The challenges of this stage of the game are the same exercises of solfège of the major second and third intervals that are taught as standard in the solfège training (Figure 3).

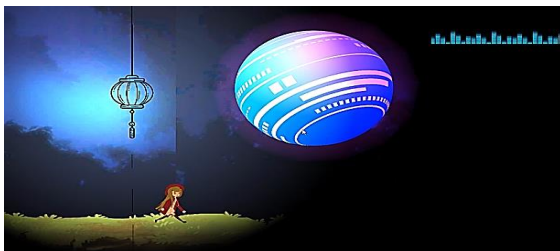


Figure 3. A view of the second stage

The third step is to learn the "solfège of the perfect fourth and fifth intervals" exercises. At this stage, the character reaches a dead end and the only way out is an upward path. Here, the character also hears the reference voice and repeats it. By singing the notes correctly, the character ascends and reaches a platform by repeating each note. The next note is played again and ascends again by repeating it. Finally, at the end of the exercise, the character is released from that place and reaches the sky and light (Figure 4).



Figure 4. A view of the third stage

User interface: In e-learning, the user interface plays a pivotal role in achieving educational goals (15). Among the important points of creating a suitable user interface, the following can be mentioned (16);

Top-down approach: In this case, the user interface of a successful game can be taken and made unique according to the features of the game.

Adding theme to user interface: The whole game should have a unique integration. You have to smooth out every inch of the game and find a way to tie the user interface to the whole game.

The user interface in e-learning software is the interaction point between the user and the computer software, and the success and failure of the software program depends on its design (15). It should be noted that the user interface design can affect the user experience. The user experience in video games is how players perceive and understand a game, their interaction with the game, and the emotions and conflicts evoked by this interaction, and include usability and the ability to engage (17). The user interface should not only be seen as an artistic phenomenon, but the artistic tools such as graphics, music, animation, etc. should also be compatible with educational psychological issues (15).

The Saray game interface is in the form of an Audio visualizer at the top of the game home screen. When the user plays a note, the user's voice frequency is displayed visually and in color, and the

user can play the notes accordingly. The game environment and character design is as fantasy. The most important element that attracts the most attention in the game scene is the presence of light and shadow. This is consistent with both the game scenario and the folklore story that forms the basis of the game's story. The Esc key displays a menu with two options that can either exit the entire game or return to the menu.

User-game interaction: How the player interacts with the game is in two ways:

a. Keyboard: Using the Arrow keys, the player can move forward and backward. In addition, the player has the ability to jump with the Space key. To select the keyboard control keys, it was tried to use the keys that create the least mental engagement for the user and minimize the user reaction time when using the keyboard.

b. Receiving player voice: First the player hears the guide voice. When the player plays that note, his voice is received by the microphone and analyzed according to the above methods and compared with the defined patterns. Therefore, after analysis, the user's voice will be used as the game driver. In fact, the game interacts with the user's voice to be completed. System feedback with the player will also be different at each stage; in this way, in the first step, the user's voice feedback is transmitted to the user when the lantern is lit and the ambient light is on. In the second stage, with the destruction of the luminous ball, the rest of the path is observed, and finally, in the third stage, it is depicted by moving upwards and being thrown to the high platforms and reaching the light and the sky.

By identifying the hardware and software factors of the audio receiver in the system in which the game was designed and produced, the problem with receiving the user's voice was solved. For the versions that will be provided for the user, the game access to the audio system of the user's device will be explained in the game settings.

Discussion

The present study was conducted with the aim of designing and developing a software for teaching solfège based on a game and led to the production of Saray. Given the investigations, this study was completely innovative and no report was obtained from other software designed in Iran or abroad with the aim of gamification of solfège training. Due to the novelty of the study and its output as a computer game and the lack of a similar case in teaching solfège using a computer game, it was not possible to

compare the results.

Music education in the country has always suffered from shortcomings and the main body of this education is in the traditional method. This makes the music training not available to everyone equally, and therefore some potential musical talents in individuals will never be realized. Ultimately, this problem causes the foundations of the country's music to not develop. Failure to train young and talented forces to flourish and be able to stand out on the world stage and educate the next generation, will gradually lead to the destruction of the music industry in the country. On the other hand, solfège education is of therapeutic value in subjects with speech and hearing impairments.

A review of studies on game-based learning in recent years shows the positive effect of computer games on learner performance at different levels of attitudes, cognition, and metacognition (18). One of the common approaches in integrating games in the teaching and learning process is the participation of educational experts with game designers in the process of designing and producing educational games to achieve specific learning goals. The first educational games (specifically for specific learning purposes) were produced in the United States in the 1970s, including the Oregon Trail for teaching history to the eighth-grade students (19).

In the field of music education, there is a Music trainer game. In this game, the user must take a music test before starting the game. By observing users' scores on this test, as well as recording other factors such as the game play time and the time the player reaches the difficult level, it is concluded that music theory using adaptive learning was a quick and effective way to learn musical concepts. Evaluating the effectiveness of any computer-based educational method includes epistemological value, goal inclusion, flexibility, and the basics of learning motivation (7). The Music trainer game met all these criteria and therefore is a good example of a game suitable for educational settings. The findings revealed that such educational games can be used as an effective educational tool for teaching music theory. There are several ways to develop this game in the future. Currently, this game is only used to teach very simple musical concepts including learning notes, recognizing intervals, and pitch. However, the game can be extended to learning chords and melodies (7). Production techniques are not limited to music education. Adaptive learning through games can easily be applied to a wide range of fields, including mathematics, history, grammar, art, computer science, and even rehabilitation. It is

predicted that play-based learning techniques will play an important role in the future of education (20) and rehabilitation interventions (21).

Learning along with entertainment can be a very good situation and due to the lack of access to music experts in different cities, it is possible to facilitate music education by designing a standard educational game under the supervision of experts, and provide knowledge to everyone regardless of geographical boundaries. On the other hand, the same tool can be useful in teaching the production of sounds and vowels in individuals with communicative disorders and provide them with access to rehabilitation at a lower cost, in addition to making this time-consuming process attractive.

There are some software applications in the field of music such as simulators of various musical instruments (Piano Music Tiles and Acoustic Guitar Simulator) or software for displaying the input sound frequency for tuning (Tuner & Menronome and Noteworthy Tuner) and displaying the frequency of singers (G Strings and String Tuner) (1). Despite the educational games of various instruments available to everyone, the lack of a computer game for teaching solfège, which is the basis for playing, composing and singing, is felt.

Given the above, it can be claimed that Saray is the first game-based solfège learning software that, while simple, provides the basics of teaching this skill in an interactive environment. Although this is the first version of this software and can be developed for various educational, therapeutic, and rehabilitation purposes, its simple and attractive design makes it easy for children and adults to enter the world of entertainment. The design and production of this computer game for teaching solfège will have achievements both in the field of music education and in the production of computer games based on the player's voice and in the field of rehabilitation of individuals with speech and hearing disorders. This computer game can be useful not only for those who want to learn solfège, but also for most age groups; because it has a new novel of getting input from the player. It also makes the time-consuming and complex treatment process attractive and understandable to individuals with congenital or acquired speech or hearing problems.

Limitations

Among the limitations of the present study were the microphone detection of the system on which the game is run, by the program to create an integrated software and hardware system, the high impact of

ambient sounds while receiving the user's voice frequency, and the negative impact on the comparison results, inability of players in the continuous expression of the note displayed that leads to the lack of starting of the process of measuring the user's voice frequency, the environment designing in such a way as not to impede the player's smooth movement and not to distract the player during play, and designing a suitable range to record the player's voice in the game environment which does not cause the character to return to the location capable of recording sound.

Due to the high importance of receiving the user's voice frequency and the need for proper in-game feedback, the software's sensitivity in receiving the user's voice did not decrease and now there is a problem with ambient sounds.

Given that the audience of this game is beginners, it is natural that in the early stages, they are not perfect in performing the note duration. To solve such a problem, as mentioned, the amount of stability in the expression of each note for users in the early stages was considered 0.5 seconds, and with the progress of the game, this amount will reach 2 seconds.

Recommendations

Solfège training has standard levels that must be passed step by step. In the Saray computer game, part of the beginner level was implemented. Regarding the design of the environment and the range of audio recording, considering that the version provided was the initial version to receive feedback and identify game defects, all the user suggestions and the above-mentioned items will be considered and resolved in the final version. Certainly, the broad issue of solfège training requires more practice to acquire the required skills. The future plan of the designers of this game is to design and develop the next levels to the advanced training level. Due to the high usability of Saray game, other goals such as teaching various instruments such as piano or rehabilitation in communication disorders can be considered for it.

Conclusion

The objective of this study was to teach solfège. To achieve this goal, first the relevant sources for teaching solfège were examined. According to the components of music, each note has a unique frequency, which was the basis of Saray game design. The audio signals of the player's voice are received and analyzed by the microphone, the fundamental frequency is extracted and compared with the designed patterns, and the appropriate and correct

feedback is given. The steps designed in the game are based on standard solfège exercises. These exercises are implemented on a story basis to be able to accompany the player and spend more time playing and, in fact, solfège exercises. It should be noted that a comprehensive evaluation is underway and the results will be presented in future articles.

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Authors' Contribution

Nazanin Ali Farshbaf Akbari: Study ideation and implementation, manuscript preparation, specialized evaluation of the manuscript in terms of scientific concepts, approval of the final manuscript to be submitted to the journal office, the responsibility of maintaining the integrity of the study process from the beginning to the publication, and responding to the referees' comments; Yoonas A. Sekhvat: Game design consultation, manuscript preparation, specialized evaluation of the manuscript in terms of scientific concepts, approval of the final manuscript to be submitted to the journal office, the responsibility of maintaining the integrity of the study

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Conflict of Interest

The authors declare no conflict of interest. Nazanin Ali Farshbaf Akbari has been an MSc degree student at the School of Multimedia, Tabriz Islamic Art University since 2018 and performed the studies and implementation of this project as her dissertation. Dr. Yoonas A. Sekhvat, Assistant Professor, School of Multimedia, Tabriz Islamic Art University and Dr. Mohammad Reza Azadehfar, Professor, School of Music, Tehran University of Art, Tehran, Iran, as the project supervisors, and Engineer Samad Roohi, Instructor, School of Multimedia, Tabriz Islamic Art University as the implementation consultant, collaborated on this project.

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