



Bilkent University

Department of Computer Engineering

Senior Design Project

Coda

Project Specifications

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Project Specifications

Coda

1 Introduction

Music as a form of art has been the common interest of people used to express feelings and identity through a composition of rhythm, timbre and melody. In different forms and sounds by making use of the variety of instruments, music is present in almost every context for numerous purposes. Besides the pleasure of listening, it's been proven that playing instruments have positive effects on brain development, especially for spotting statistical patterns enabling the learner to better predict what would happen next in a pattern, so every child has the right to better themselves with the help of instruments insomuch as discovering their musical talents [1].

Over the last 20 years, the number of children learning to play an instrument or playing an instrument has increased significantly [2]. However 26% of children and 49% of adults in the UK stated that they've given up playing instruments although they've learned to play or started to [2]. Most common reasons for this are loss of interest, instrument cost, lesson costs and competing pressures from school [2]. Furthermore, the fact that some instruments are highly immobile by nature makes practicing very challenging for both individuals and for groups of people who practice together. In most cases, instruments become idle and forgotten because of the impracticabilities mentioned. As a result, buying instruments may be seen as an unnecessary expense. When the cost of learning instruments and the instruments itself is taken into consideration in addition to immobility, it can be stated that instruments can be made further accessible.

Thus, there is need for solutions to make playing and learning instruments more sustainable by making them more accessible in several aspects like cost and mobility. In this context, the idea of taking advantage of technological advancements is very prevalent and dates back to 1940's [3].

Considering that the number of smartphone users have surpassed 3.3 billion in 2019, using technological advancements of smartphones for improving accessibility is a popular idea in almost all domains [4]. Starting from this point of view, we propose a smartphone application that will use Virtual Reality and Computer Vision to simulate the experience of playing an instrument for a user, enabling them to practice without workstation, cost and even sound limitations. By using novel Computer Vision techniques, we will eliminate the need for any hardware or tools and make the whole experience only depending on the smartphone, an AR cardboard and the gestures of the user. Different from the current products in the same context, we will provide a more realistic and immersive experience using Augmented Reality both visually and aurally.

This report explains the details of the proposed system in terms of System Overview, Requirements, Constraints and Similar Products to further explain the purpose of the project in addition to innovativeness.

2 Proposed System

2.1 Overview



Figure 1: Example virtual reality view from the proposed system [5], [6], [7].

Project *Coda* will be a mobile application designed to make instruments more accessible in terms of cost and mobility. *Coda* will depend on a system that renders an instrument in an augmented environment on the smartphone's screen and creates a Augmented Reality environment with the use of only a Google Cardboard like headset. Also, *Coda* will track the hand gestures of the user using the smartphone's camera by Computer Vision as shown in *Figure 1*.

As the main feature, the system will give visual and auditory feedback to the user according to the user interaction by gestures for simulating the experience of playing an instrument only keeping out the tactile experience. Additionally, the user will be able to choose between several modes: Free Playing Mode and Practice Mode. These features will enable the user to either practice freely or practice on a particular piece of their choice from the library. In the practice mode, the system will provide visual directives for the user to play the piece correctly, further enhancing the experience and providing ease for learning pieces. These will be able to be recorded and saved for enabling composing a new piece. For initializing the system, the user will have to align their hands and environment. The instrument will be placed according to this alignment and it's location will not be changed after initialization.

The functionalities of *Coda* are extensible but not all of them will be implemented in the first iteration. For safety, we will only propose to implement the core functionalities and implement additional features like music sharing through a network and implementing the system for multiple instruments if time permits.

Further information and all documentation on *Coda* will be published on,

<https://ege0zcan.github.io/coda/>

2.2 Functional Requirements

2.2.1 Instrument

The main functionality of *Coda* depends on the rendering of a document in Virtual Reality. Thus, the first requirement is modeling the instrument in 3D that will enable the user to interact with it visually, and get both auditory and visual feedback. For feasibility reasons, our first instrument of choice is **Drums**. If time permits other instruments can be implemented.

2.2.2 Free Mode

In the Free Mode, the user will be able to play the instruments however they like without any constraints or directives. This mode can be used for making new compositions or trying an instrument to learn how the instrument is used and so forth.

2.2.3 Practice Mode

In Practice mode, the user will choose a piece from the library provided with the app. Library will also contain pieces saved using Free Mode as well. According to the piece chosen, the user will be given visual directives and will be expected to interact correctly with the instrument. This mode can be used to practice a particular piece.

2.2.4 Recording Sessions

User will be able to start recording a session and stop the recording whenever they want. These recordings will be saved in the library of the app and will be offered among the pieces in the library for playing in the Practice Mode.

2.2.5 Data Storage

The data saved by the user should be saved in the application for being available in the library for recording. For this either the cloud or the file system of the smartphone will be used. For memory efficiency, data will be saved in a compact form.

2.3 Non-Functional Requirements

2.3.1 Usability

Since one of the main objectives of *Coda* is providing accessibility, the following requirements should be matched

- Gestures to play an instrument should be intuitive. The player should be able to successfully complete the desired action in a single gesture.
- Controls in the system should be straightforward and the interface should be user-friendly. The user should be able to choose a piece from the library and start playing in no longer than 1 minute.
- The application should have clear instructions for initialization. The initialization stage and initial hand recognition should not take longer than 2 minutes when application performance is neglected.

2.3.2 Responsiveness

Responsiveness of *Coda* is critical since the application will work in real-time and should provide instant visual and auditory feedback as a real instrument would. The following responsiveness requirements should be met,

- Frame Per Second (FPS) should not drop below 25.

2.3.3 Extensibility

For the main purpose of *Coda*, the application should be extendible by the following,

- Design of the application code should be written in such a way that new instruments that will enable addition of new instruments.
- Storage in the system should be designed in such a way that it can be extended to be shared over a network or by utilising the cloud.
- Design of the network usage should be in a way that it supports a potential implementation of **band mode** which allows people from different devices to collaborate and play different instruments at the same time.

2.4 Constraints

2.4.1 Implementation Constraints

Since *Coda* only depends on the smartphone and the Google Cardboard headset, it is important that the smartphone used provides the following requirements,

- Phone used has at least one camera.
- Phone used should have Android 7.0 or higher installed.
- *Coda* will rely on real-time gesture detection and recognition. Thus, we will use novel Computer Vision techniques like Neural Networks for detecting and classifying hand gestures.
- Due to limited processing capacity of phones, mentioned computations required for gesture detection will be done on a Cloud Server like AWS for performance and feasibility requirements. Request will be initialized by phone and the processing job will be sent to the cloud server through wireless connection hence user experience will be enhanced [8].
- Open source libraries and frameworks such as Tensorflow will be used for development.
- GitHub will be used for Version-Control.
- Trello will be used for Issue Tracking.
- Implemented instruments, must not be played while attached to the body. Since we will be using a headset, camera is not going to be able to detect the hand gestures while playing instruments like violin. Instead instruments like piano or drums which are played within camera's line of sight will be implemented.

2.4.2 Economic Constraints

During the implementation of *Coda*, the following economical constraints will be taken into account since the project is not funded by any means,

- Cost of renting a cloud server will be taken into account. Cost of renting a cloud server (Amazon AWS) with one year standard period will be approximately 131 USD if paid in advance [9].
- Frameworks and libraries used will be open-source, so free to use.
- The website will be powered by GitHub thus, there will not be a domain rental cost.
- GitHub is a free Version Control tool so there will be no expense for Version Control.
- For development and demo, Google Cardboard or a similar headset will be used which is expected to cost between 20-60 TL [10].
- One-time-only fee for publishing the app on Google Play is 25 USD.

Total cost of the application will come to approximately 161 USD and further payment for cloud server will continue yearly or according to the usage.

2.4.3 Professional and Ethical Constraints

All the practices during the implementation and during deployment of *Coda* will comply with the following in accordance with the Code of Ethics proposed by National Society of Professional Engineers [11],

- *Coda* will be an application that depends on music. *Coda* will either own the rights of all the pieces and songs provided in the library or will pay for including them in the library to the right owner.
- User data will not be shared with any third parties under any circumstances.
- No user data will be saved without the consent of the user.
- No ads will be displayed for financial means.
- Any external software or library used in the development of the project will be properly referenced if it is protected by copyright.

2.4.4 Time Constraints

Development of *Coda* and it's documentation will be in line with the following schedule [12],

- - Project Specifications: **Monday, October 14, 2019**
- - Analysis Report: **Monday, November 11, 2019**
- - High-Level Design Report: **Friday, December 31, 2018**
- - Low-Level Design Report: **Monday, February 17, 2020**
- - Final Report: **Thursday, May 8, 2020**
- - Presentations & Demonstrations: **May 11 - 14, 2020**

2.4.5 User Experience Constraints

For providing a comfortable user experience the following should be taken into account,

- The app should not be used for more than 30 minutes at once for not losing the notion of spatial awareness which may cause headaches and dizziness [13].
- The virtual instrument rendered should be approximately in the same size with the original instrument for playing intuitively and for enhancing the learning process.
- Visual directives given to the user should be easily understandable by the user.
- For better auditory and immersive experience, headphones may be utilised by the user by only plugging them in the phone.

- In order to use the application internet connection must be established otherwise features will not be activated.
- The app will be launched in English since it is more universal. Other language implementations will be disregarded.

3 Similar Products

- **The Music Room:** The Music Room simulates a studio with various instruments in which the user can interact to practice or make new compositions. Although The Music Room provides a very good functionality for a similar purpose with *Coda* it could not eliminate the controller from the system and the application is not free which doesn't comply with the accessibility mission of *Coda*. [14].

Further information can be found on : <http://www.musicroomvr.com>

- **EXA The Infinite Instrument:** EXA provides a virtual environment in which bands can be formed and many instruments can be played with. In EXA you can also see the other users with their instruments in the environment. Although EXA provides a variety of functionalities, it could not eliminate manual controllers from the design, which will be the main purpose of *Coda*. [15].

Further information can be found on:

https://store.steampowered.com/app/606920/EXA_The_Infinite_Instrument/

- **Playthings VR:** Enables the user to interact with a Virtual Reality of choice using drumsticks in hands. Although the fundamentals of the project is similar with *Coda* the purpose and functionalities are completely different. Playthings VR gives arbitrary musical feedback when interacted with an arbitrary object whereas *Coda* will simulate the experience of playing a real instrument. [16].

Further information can be found on : <http://playthingsvr.com>

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