Bilkent University

Department of Computer Engineering

Senior Design Project

Coda

Analysis Report

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Analysis Report
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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 impracticalities 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 Current System

There isn't a current system that the application will be built upon, but there are several similar products that tried to implement the same idea but with different fundamental objectives and therefore different implementation. For instance the major difference of Coda from the similar products will be the elimination of the need for controllers that are extra hardware which cause the product to be more expensive and less accesible.

- **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*. [5].

  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.* [6].

  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. [7].

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

3 Proposed System

3.1 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/

3.2 Functional Requirements

3.2.1 Instrument

The main functionality of *Coda* depends on the rendering of an instrument in Augmented 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.

3.2.2 Free Mode

In the Free Mode, the user will be able to play 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.

3.2.3 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. 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.

3.2.4 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.

3.2.5 Data Storage

The data saved by the user should be stored in the application and become available in the recording library. 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.

3.3 Non-Functional Requirements

3.3.1 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.

3.3.2 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,

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

3.3.3 Extendibility

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.

3.4 Pseudo-Requirements

3.4.1 Implementation Constraints

Since *Coda* only depends on a smartphone and a 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.
- 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.

3.4.2 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,.

- 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 [8].
- One-time-only fee for publishing the app on Google Play is 25 USD.

Total cost of the application will come to approximately 40 USD.

3.4.3 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 [9],

- *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.

3.4.4 Time Constraints

Development of *Coda* and it's documentation will be in line with the following schedule [10],

- - 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**

3.4.5 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 in order not to lose the notion of spatial awareness which may cause headaches and dizziness [11].
- The rendered virtual instrument should approximately be the same size as the original instrument for playing intuitively and enhancing the learning process.
- Visual directives given to the user should be easily understandable by the user.
- For better auditory immersion, headphones may be utilised by the user by plugging them in the phone.
- An internet connection must be established in order to use the application. Otherwise features will not be activated.
- The app will be launched in English since it is more universal. Other language implementations will be disregarded.

3.5 System Models

3.5.1 Scenarios

Use case Name:	Free Mode
Participating actors:	User
Entry Condition:	User should be in the main menu
Exit conditions:	User ends the playing instruments session
Success Scenario Event Flows:	1. User chooses an instrument to play. 2. User calibrates the his/her surroundings. 3. User calibrates his/her hands. 4. User plays the instrument by making hand gestures.
Alternative Event Flows:	1. If the user chooses to record the music session a. User chooses the option to record. b. In exit condition, recording is saved to memory. 2. If the user pauses the session a. User can recalibrate. b. User can exit the session. c. User can adjust the sound. d. User can resume the session.

Use case Name:	Practice Mode
Participating actors:	User
Entry Condition:	User should be in the main menu
Exit Condition:	1. User ends the practice session. 2. Music sample selected finishes.
Pre-conditions:	User has to choose a music sample to play.
Success Scenario Event Flows:	1. User chooses a music sample to play from the list. 2. User chooses a music instrument to play. 3. User calibrates the his/her surroundings. 4. User calibrates his/her hands. 5. User plays the instrument by making hand gestures. 6. Music session is recorded and saved to memory.
Alternative Event Flows:	1. If the user pauses the session a. User can recalibrate. b. User can exit the session. c. User can adjust the sound.

d. User can resume the session.

Use case Name:	How to Use
Participating actors:	User
Entry Condition:	User should be in the main menu.
Exit Condition:	The system returns to the main menu.
Success Scenario Event Flows:	1. The system displays the instructions. 2. User reviews the the instructions. 3. User chooses to return to main menu. 4. The system returns to the main menu.

Use case Name:	Settings
Participating actors:	User
Entry Condition:	User should be in the main menu.
Exit Condition:	The application applies new setting changes.
Success Scenario Event Flows:	1. The system displays settings. 2. User changes the level of sound. 3. User changes the playback settings. 4. User chooses to return to main menu. 5. The system saves the changes and returns to the main menu.

Use case Name:	Play Records
Participating actors:	User
Entry Condition:	User should be in the main menu.
Exit Condition:	User chooses to return to the main menu.
Success Scenario Event Flows:	1. User chooses one of the recording to be played. 2. Recording plays until it is stopped or finished.
Alternative Event Flows:	1. User decides to listen to another recording a. User pauses the current recording. b. User chooses another recording to be played. 2. When recording is finished a. User can choose another recording to be played b. User can go back to the main menu.

3.5.2 Use Case Model

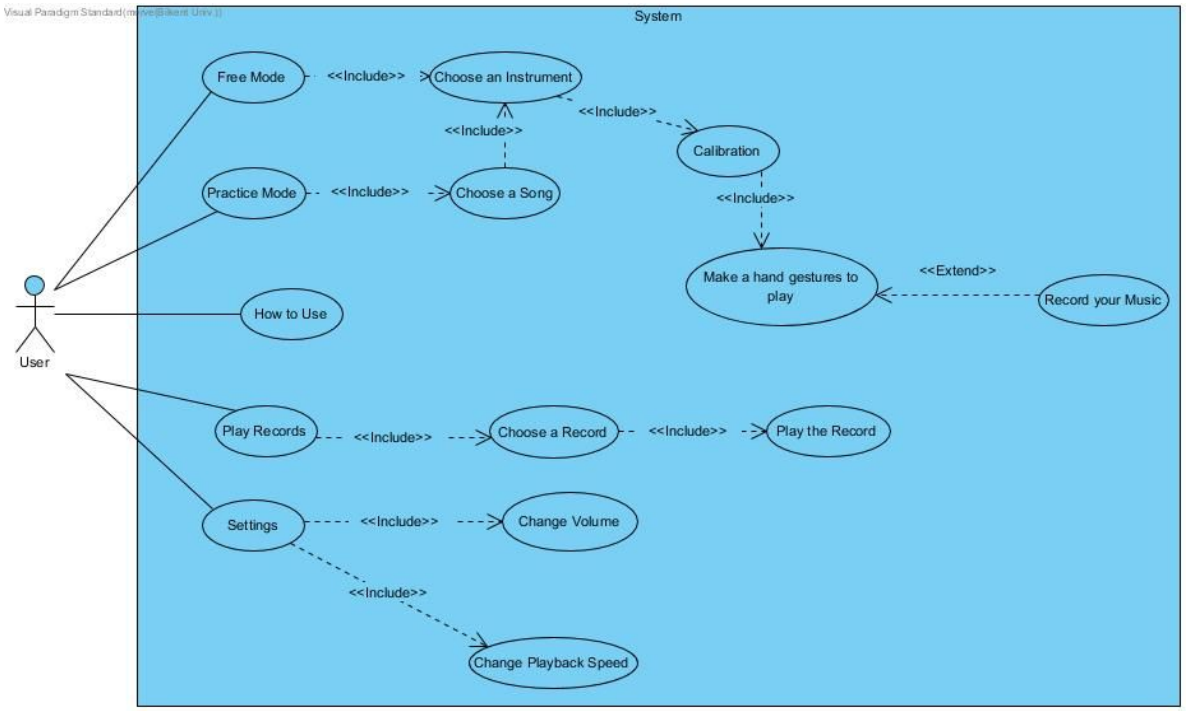


Figure 2: Use Case Diagram

3.5.3 Object - Class Model

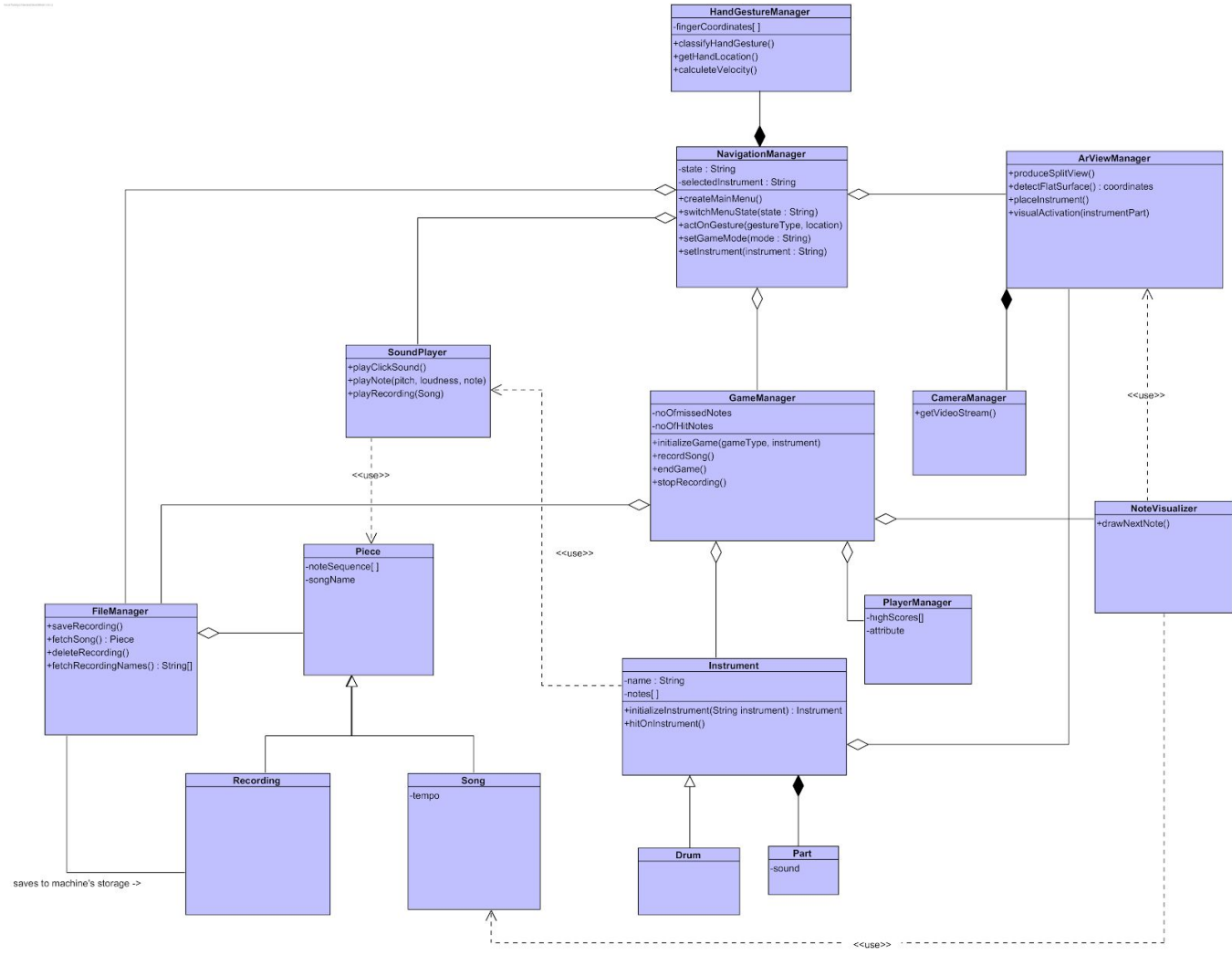


Figure 3: Object Class Diagram

3.5.4 Dynamic Models

3.5.4.1 Sequence Diagram

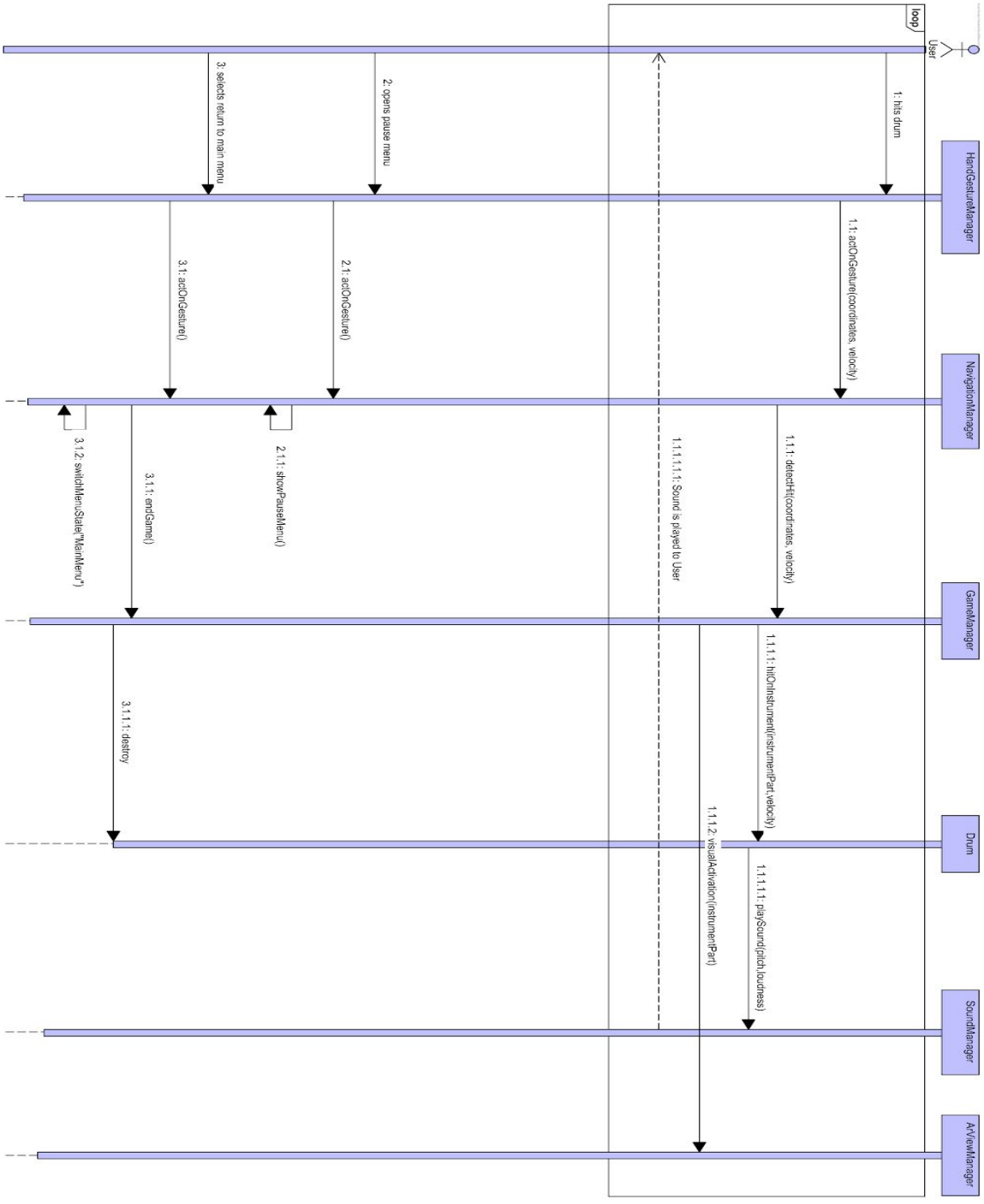


Figure 4: General Sequence Diagram

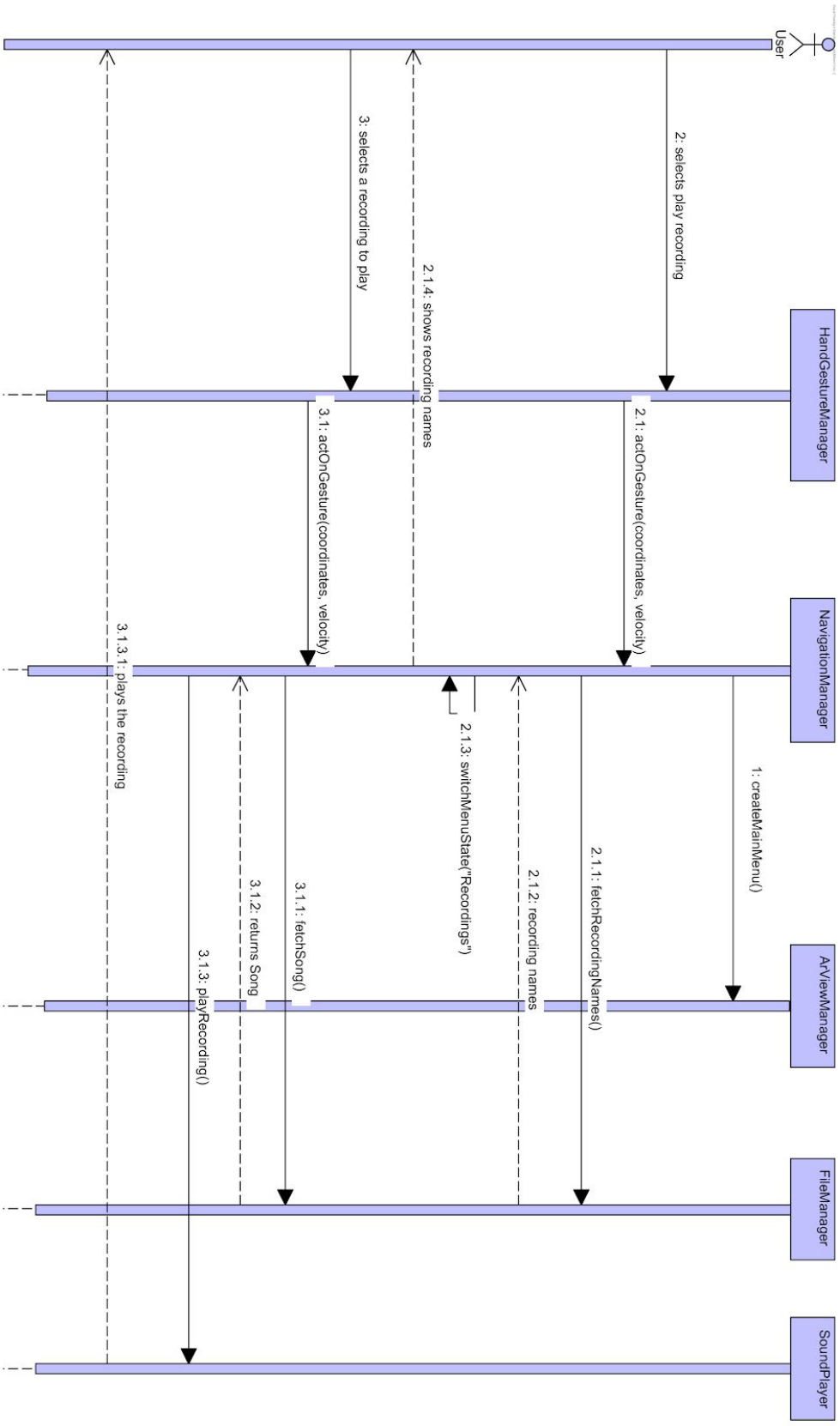


Figure 5: Play a Record Sequence Diagram

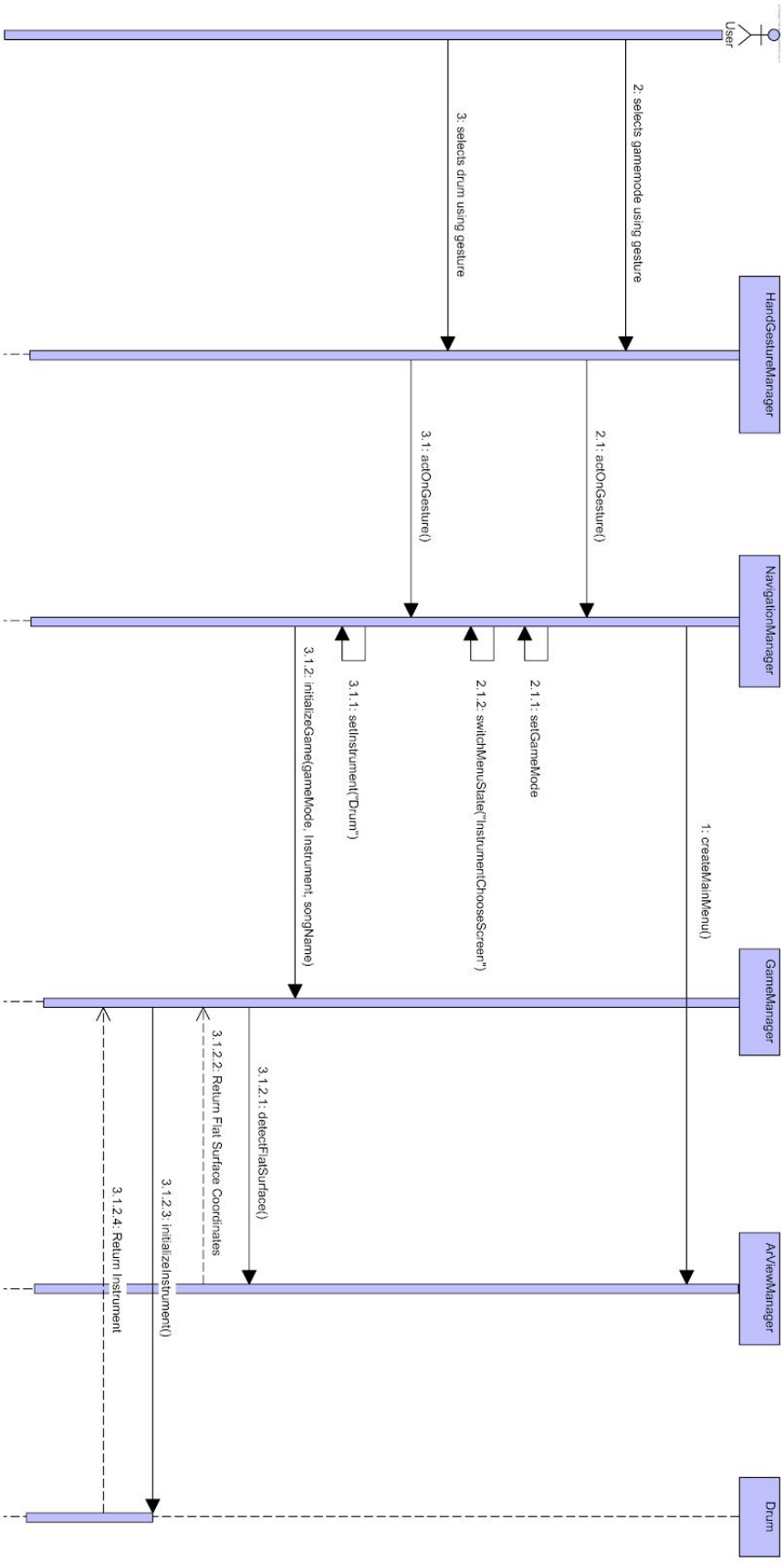


Figure 6: Mode Selection and Initialization Sequence Diagram

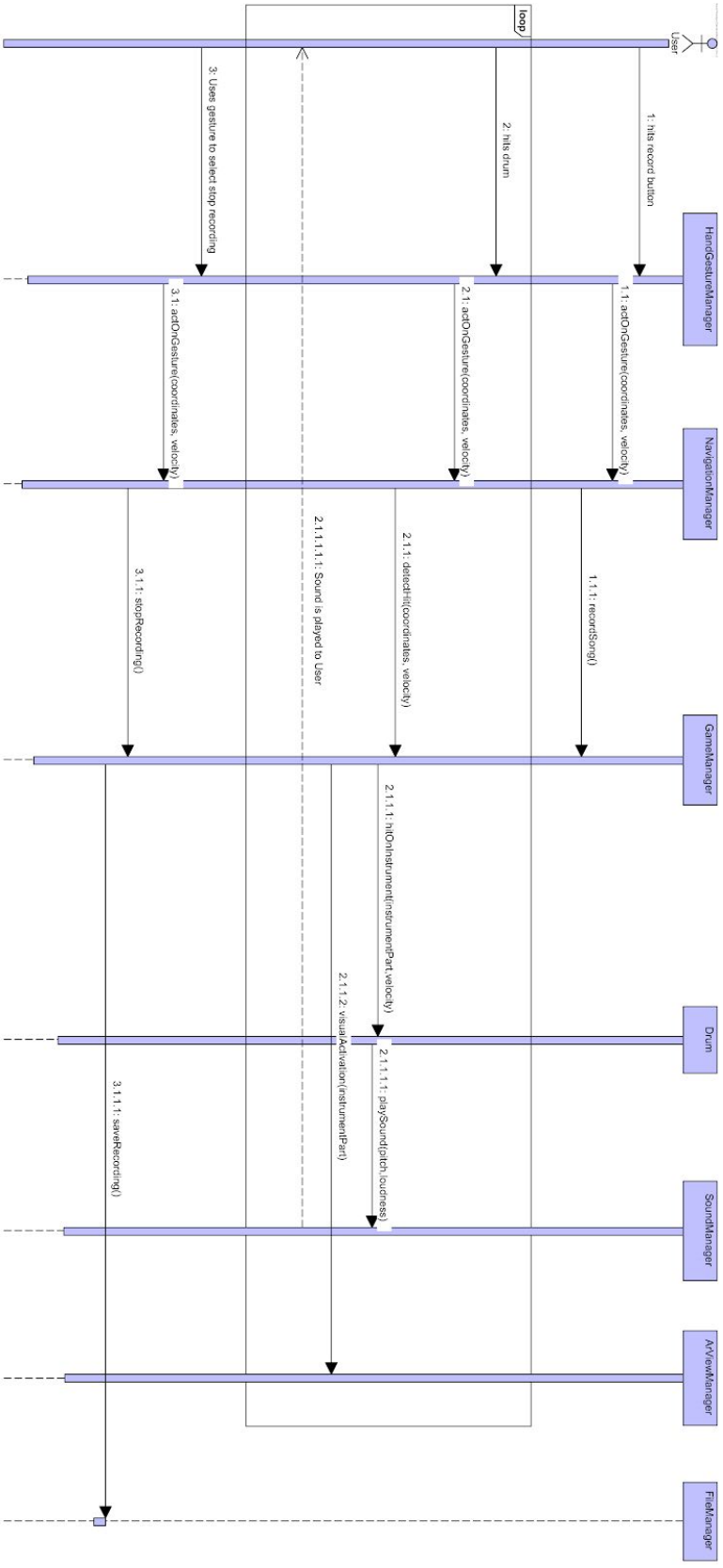


Figure 7: Free Mode Sequence Diagram

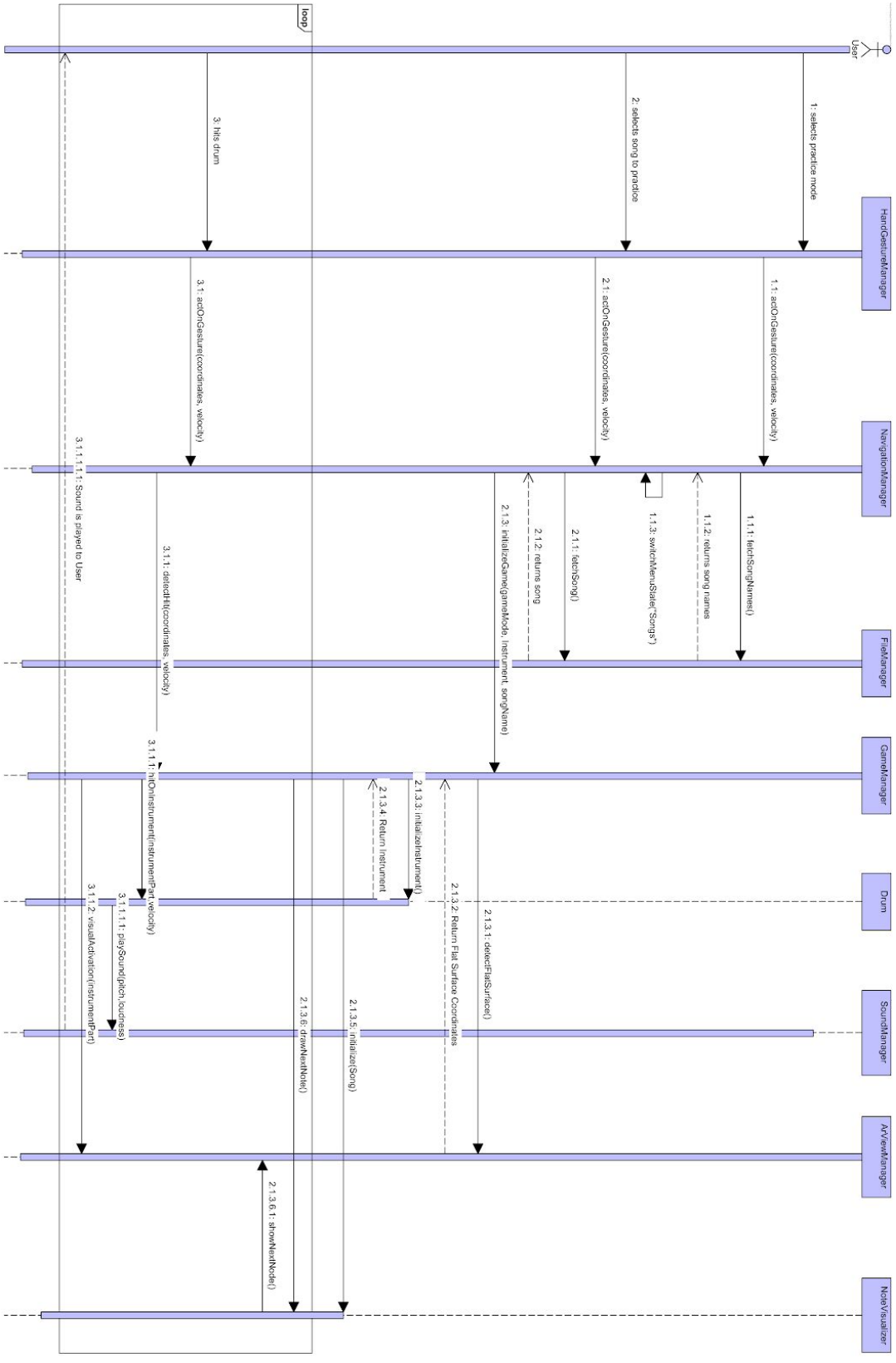


Figure 8: Practice Mode Sequence Diagram

3.5.4.2 Activity Diagram

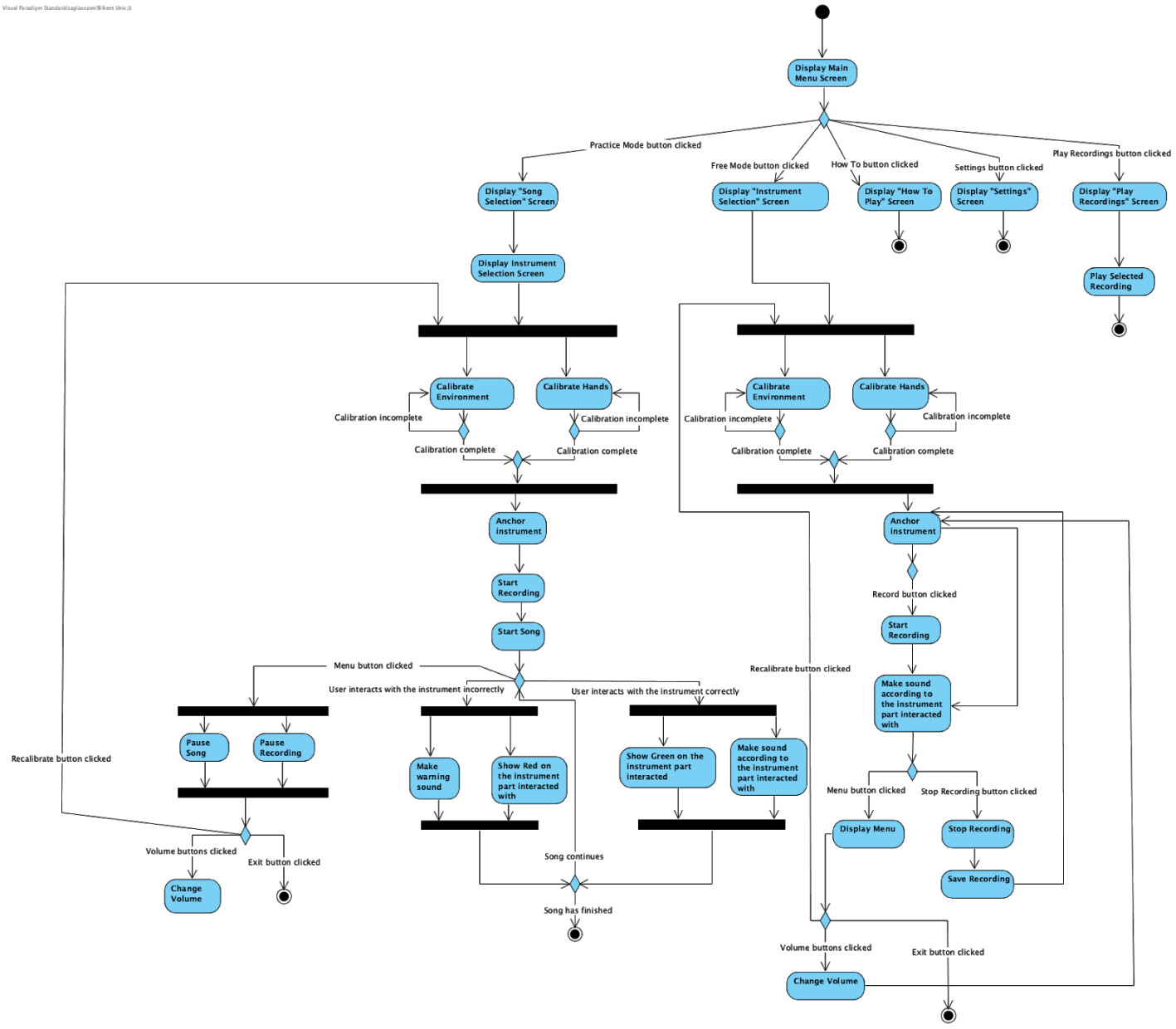


Figure 9: Activity Diagram

Main activities of the game are shown in *Figure 9*. In this diagram, the final nodes represent the ending of a particular activity, which results with the returning of the program in the main menu. The application is divided into main activities starting from the main menu. Each button in the main menu represent a distinct activity. As observed in *Figure 9*, most dynamic activities in the application are Practice Mode and Free Mode. Sub-activities in these two activities constitute the main flow of the program. For brevity, buttons for returning to main menu and to the previous page are excluded from the Activity Diagram.

3.5.4.3 State Diagram

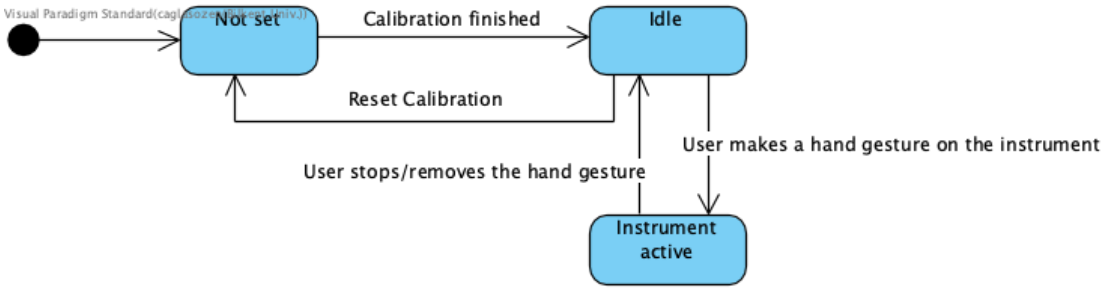


Figure 10: State Diagram

The only dynamic structures in the program are the instruments, as a result of this dynamicness, an instrument can get in a number different states. The states and related transitions in between them are demonstrated in *Figure 10*. State explanations can be found below.
Not Set: The instrument is not visible on the screen yet. The environment and the hands are being calibrated.
Transition (Calibration finished): Both the environment and the hand calibrations are complete.
Idle: The instrument is anchored in the room idly and is ready to be interacted with by the user.
Transition (User makes a hand gesture): The user makes a valid hand gesture to interact with the instrument.
Transition (Reset Calibration): The user chooses, from the menu, to recalibrate the application.
Instrument Active: The user interacted with the instrument and now the instrument is active, meaning that it gives visual and auditory feedback.
Transition (User stops/removes the hand gesture): The user stops performing the hand gesture or removes the gesture.

- It should be noted that the interactions are going to be constrained, hence the hand gestures used for interaction should be coherent with the future design choices for the constraints for the instrument to change state according to the interactions.

3.5.5 User Interface

Figure 11: Home Screen

Figure 12: How To Play? - Controls

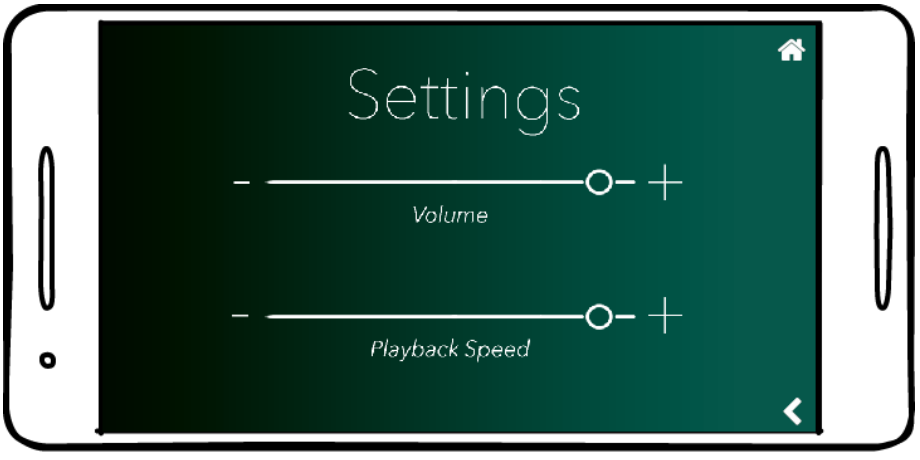


Figure 13: Settings

Figure 14: Play Recordings

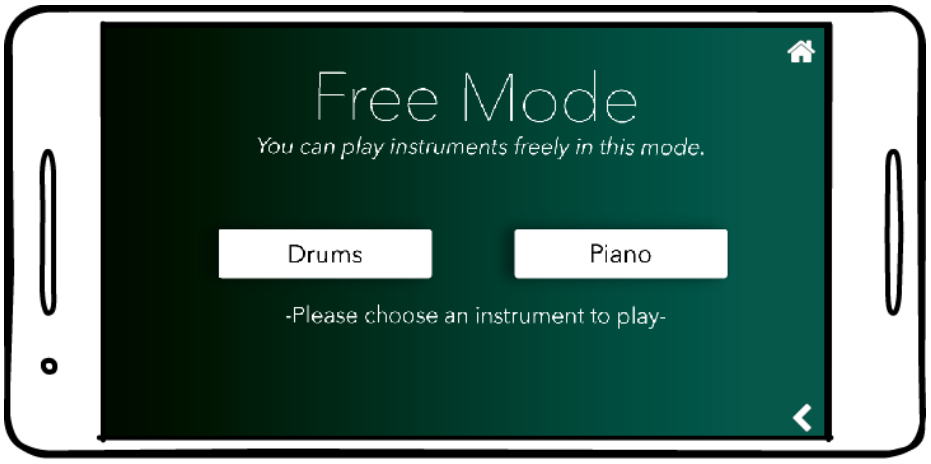


Figure 15: Free Mode Instrument Selection

Figure 16: Calibration

Figure 17: Free Mode Calibrated

Figure 18: Free Mode Play

Figure 19: Free Mode Play and Record

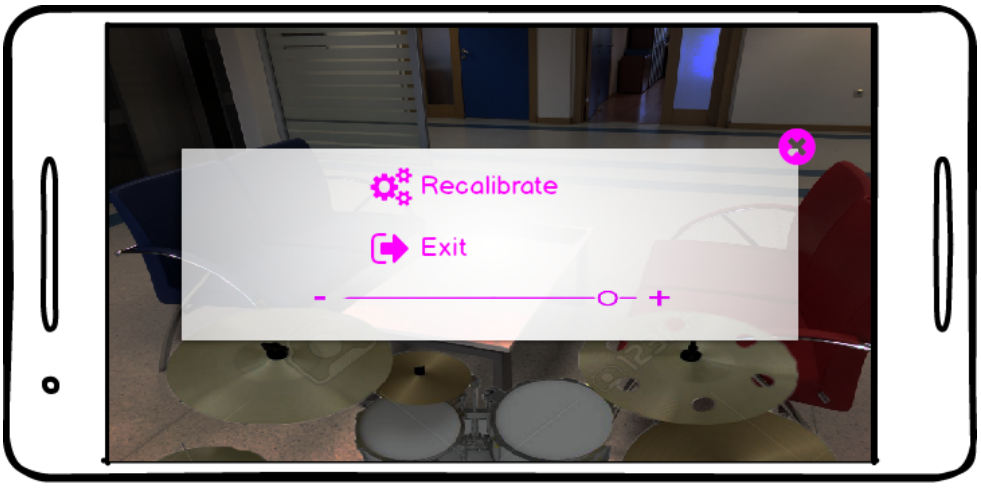


Figure 20: In-Session Menu

Figure 21: Free Mode Stop Recording

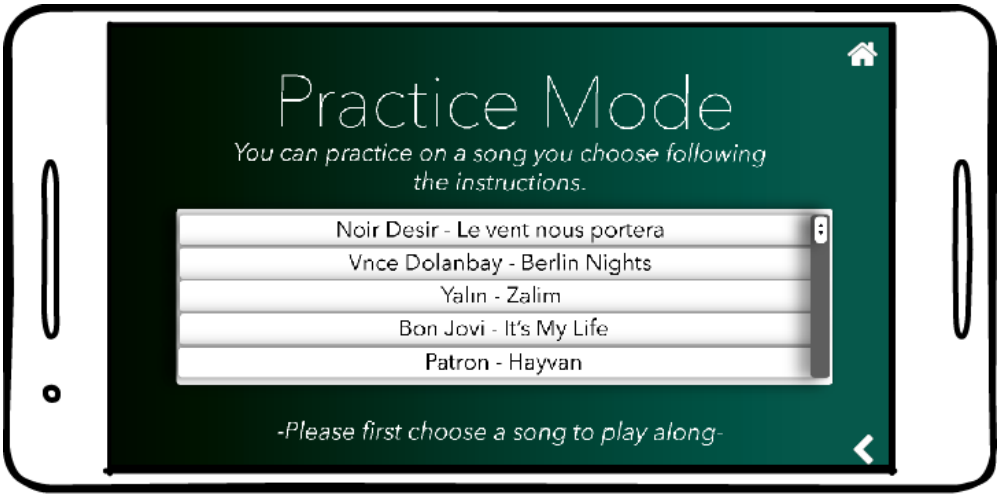


Figure 22: Practice Mode Song Selection

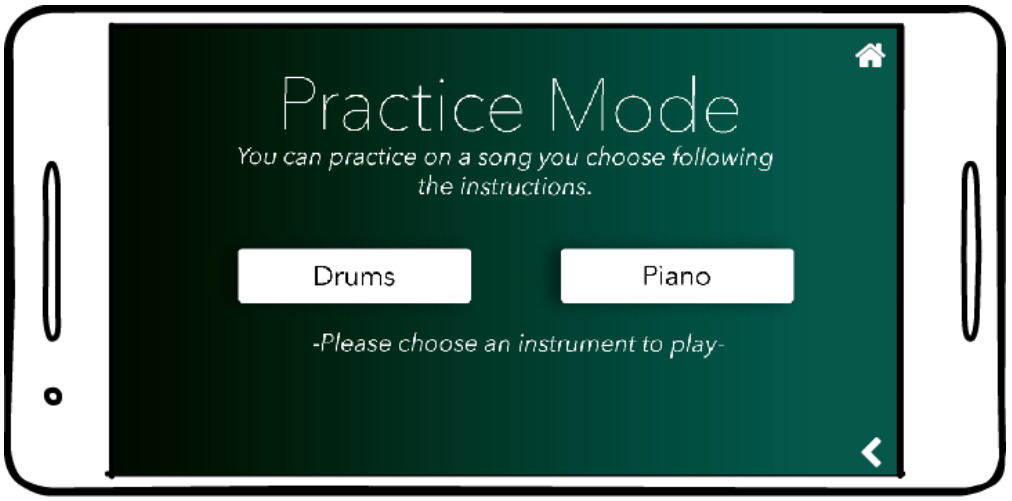


Figure 23: Practice Mode Instrument Selection

Figure 24: Practice Mode Calibrated

Figure 25: Practice Mode Play and Record

4 Other Analysis Elements

4.1 Consideration of Various Factors

A table explaining the effects of various factors on the design phase can be found below.

	Effect level	Effect
Public health	8/10	Considering the duration limitation of using AR applications, the amount of time a user can continuously spend using the application is limited to approximately 20 minutes to avoid possible occurrences of dizziness, headaches etc. This condition limits the amount of time a user can practice an instrument using the app.
Public safety	6/10	Coda is an AR application that partially limits the hearing and the vision of the user. Visual content will be rendered upon the real world view of the user to avoid isolating the user completely from the real world, but there might be delays in rendering that may result in accidents caused by limited sight or hearing. But this does not have any specific limitations on the design or the usability of the product.
Public information security	7/10	Coda is an application that requires neither a user profile nor getting any information from the user. Hence, there will be no possible security gaps or additional information claims that require getting the consent of the user. We fully respect the privacy of the user in our design.
Public welfare	5/10	Coda is a non-profit application which neither provides nor demands for any kind of fees. It is important for us to offer this application to users from all kinds of economical levels without any economical drawbacks. Hence, Coda will not impose and economical insecurities to it's users.
Global factors	3/10	Coda aims to access people from anywhere hence the application will be designed in such a way that any user will be able to use the application in any way they wish to. Nonetheless, the current design goals of Coda does not aim to connect users but rather aims to create a more individualistic experience. Hence, the design phase is not highly affected by global factors.
Cultural factors	8/10	The essential value of Coda is making music which is a fundamental structure of Culture. The design will be made such that the variety instruments offered in Coda will be extendible after the demo. Cultural factors will be considered in implementing instruments, and the team will place emphasis on ethnic instruments.
Social factors	10/10	Idea of Coda debouched from increasing accessibility of instruments, therefore social factors are critical for all kind of design phases. . For that reason, the idea design was made such that Coda will be in full service of the society and increase the mobility and the accessibility of instruments. Design in terms of

Figure 26: Consideration of Various Factors Table

4.2 Risks and Alternatives

Since the project requires the use of novel and advanced technologies that were not yet implemented in the same context as we do, implementation process will not be trivial. We accept the challenging nature of this project from several aspects and therefore we have designed several backup plans to overcome these challenges with minimum loss from our key objectives.

	Explanation	Likelihood	Effect on the project	B Plan Summary	Effect Explanation
Risk: Hand Gesture Recognition Limitations with a single Mobile Phone	Detecting and recognizing hand gestures on a dynamic background with a single moving camera attached to the Cardboard is not a simple task. Hence, we should recognize the risks that may stem from this challenge and provide several backup plans.	Low - Medium	High	In such case, we will convert the project into a desktop project that will use 2 exterior cameras to be able to measure depth in an easier and more accurate way.	This will decrease the mobility of the project which is among the fundamental objectives of the project idea.
				In such case, we will impose a device constraint and we will make it obligatory to use the app with a mobile device with a camera which has depth sensor for better and easier hand gesture recognition.	This will decrease the availability of the project which is among the fundamental objectives of the project idea since such mobile devices are highly unavailable and inaccessible to a large portion of our target audience.
				We may impose a constraint to use the app while the background of the hands is a solid and single color, to ease hand gesture recognition process.	This will decrease the mobility of the project because such a constraint will not be fulfillable in every environment that the user might want to use the app in.
Risk: Reconstruction of the environment in AR	Since the application is going to be an AR application, we need to first analyze the environment from the camera and reconstruct it in the AR to put an object. This is not a trivial task so this should be considered as a risk.	Low - Medium	Low - Medium	In such case, we will switch the project from AR to VR and render the instrument in an interactable way onto a virtual environment rather than the real one.	This will not effect the fundamental objectives of the project but only decrease user-experience as a result of constraints of using VR applications for long durations.

Figure 27: Risks and Solutions Table

4.3 Project Plan

List of the work packages and the responsibles can be found below.

WP#	Work package title	Leader	Members involved
WP1	App Structure	Merve Kılıçarslan	Yağız Efe Mertol
WP2	Hand Gesture Recognition	Çağla Sözen	Ege Özcan, Murat Tüver
WP3	AR Modeling	Yağız Efe Mertol	Çağla Sözen, Murat Tüver
WP4	Instruments Graphics Modeling	Ege Özcan	Yağız Efe Mertol, Çağla Sözen
WP5	Auditory Feedback	Murat Tüver	Yağız Efe Mertol, Çağla Sözen
WP6	Hand Gesture Recognition - Auditory Feedback Integration	Murat Tüver	Ege Özcan, Çağla Sözen
WP7	Hand Gesture Recognition - Instrument Graphics Integration	Çağla Sözen	Merve Kılıçarslan, Murat Tüver
WP8	*Instrument Graphics - AR Rendering Integration*	Yağız Efe Mertol	Merve Kılıçarslan, Ege Özcan
WP9	Demo for CS Fair	Çağla Sözen	Merve Kılıçarslan, Murat Tüver
WP10	Final Presentation	Yağız Efe Mertol	Ege Özcan, Çağla Sözen
WP11	Final Report	Çağla Sözen	Merve Kılıçarslan, Murat Tüver, Ege Özcan, Yağız Efe Mertol
WP12	High Level Design	Çağla Sözen	Merve Kılıçarslan, Murat Tüver, Ege Özcan, Yağız Efe Mertol
WP13	Low Level Design	Yağız Efe Mertol	Merve Kılıçarslan, Murat Tüver, Ege Özcan, Çağla Sözen

Figure 28: Work Packages

PACKAGE SET: DEVELOPMENT			
WP 1: *App Structure*			
Start date: *11.11.2019* **End date:** *15.02.2020*			
Leader:	*Merve Kılıçarslan*	**Members involved:**	*Yağız Efe Mertol*
Objectives: *This work package is for the development of the application in terms of User Interface and basic structure.*			
Tasks: *Task 1.1 <Basic App Structure >* **:** Deploying a simple application to test the features and other tasks on. *Start date: 10.11.2019* ***End date: 30.11.2019*** *Task 1.2 <App Structure Optimization>* **:** After integration of features, the app structure will be enhanced and optimized for better user experience and efficiency. **Start date:** *01.02.2020* **End date:** *15.02.2020*			
Deliverables *D1.1: Application itself V0* *D1.2: Application itself V1*			
WP 2: *Hand Gesture Recognition*			
Start date: *11.11.2019* **End date:** *22.12.2019*			
Leader:	*Çağla Sözen*	**Members involved:**	*Ege Özcan* *Murat Tüver*
Objectives: *This work package is for the development of providing hand gesture recognition feature.*			
Tasks: *Task 2.1 <Basic Hand Gesture Recognition>* **:** Development of a module that will enable the development of features that are dependent of Hand Gesture Recognition in an initial form. *Start date: 11.11.2019* ***End date: 22.12.2019*** *Task 2.2 <Hand Gesture Recognition Optimization>* **:** After integration of the initial forms of the features , hand gesture will be enhanced and optimized for better user experience, accuracy and possibly for a larger variety of instrument. *Start date: 15.02.2020* ***End date: 31.03.2020***			
Deliverables *D2.1: Hand Gesture Recognition Module Version 0* *D2.2: Hand Gesture Recognition Module Version 1*			
WP 3: *AR Modeling*			
Start date: *30.11.2019* **End date:** *31.03.2020*			
Leader:	*Yağız Efe Mertol*	**Members involved:**	*Murat Tüver* *Çağla Sözen*
Objectives: *This work package is for the development of the AR module for modeling the camera view into AR.*			

Tasks: *Task 3.1 <Basic AR Modeling>* : Development of a simple module that will render the camera view into AR. *Start date: 30.11.2019 End date: 23.12.2019* *Task 3.2 <AR modeling Optimization>* : After integration of the initial forms of the features, AR modeling will be enhanced and optimized for better user experience and rendering. *Start date: 15.02.2020 End date: 31.03.2020*			
Deliverables *D3.1: AR Modeling Module Version 0* *D3.2: AR Modeling Module Version 1*			
WP 4: *Instrument Graphics Modeling*			
Start date: *11.11.2019* **End date:** 31.*03.2020*			
Leader:	*Ege Özcan*	**Members involved:**	*Yağız Efe Mertol* *Çağla Sözen*
Objectives: *This work package is for the development of the graphics module for rendering instruments into AR.*			
Tasks: *Task 4.1 <Basic Instrument Graphics Modeling>* : Development of a simple module that will render the camera view into AR. *Start date: 11.11.2019 End date: 15.12.2019* *Task 4.2 <Instrument Graphics Modeling Optimization>* : After integration of the initial forms of the features, Instrument Graphics Modeling will be enhanced and optimized for better user experience and rendering. *Start date: 15.02.2020 End date: 31.03.2020*			
Deliverables *D4.1: Instrument Graphics Module Version 0* *D4.2: Instrument Graphics Module Version 1*			
WP 5: *Auditory Feedback*			
Start date: *22.12.2019* **End date:** 15.*03.2020*			
Leader:	*Murat Tüver*	**Members involved:**	*Yağız Efe Mertol* *Çağla Sözen*
Objectives: *This work package is for the development of a module that will provide auditory feedback to the user according to the gestures and instrument.*			
Tasks: *Task 5.1 <Basic Auditory Feedback>* : Development of a simple module that will provide auditory feedback according to the interaction received from the user on a specific instrument. *Start date: 22.12.2019 End date: 31.12.2019* *Task 5.2 <Auditory Optimization>* : After integration of the initial forms of the features, Auditory Feedback will be enhanced and optimized for better user experience and audio. *Start date: 15.02.2020 End date: 15.03.20*			
Deliverables *D5.1: Auditory Feedback Module Version 0* *D5.2: Auditory Feedback Module Version 1*			

Figure 29: Work Packages in Development Set

PACKAGE SET: INTEGRATION & TESTING			
WP 6: *Hand Gesture Recognition - Auditory Feedback Integration*			
Start date: 31.12.2019 **End date:** 31.01.2020			
Leader:	*Murat Tüver*	**Members involved:**	*Çağla Sözen* *Ege Özcan*
Objectives: *This work package is for the integration of the Hand Gesture Recognition Module and Auditory Feedback Module.*			
Tasks: *Task 6.1 <Integration >* : Integrating Hand Gesture Recognition Module with Auditory Feedback Module **Start date:** 31.12.2019 **End date:** 31.01.2020 *Task 6.2 <Testing >* : Testing the integrated Hand Gesture Recognition Module and Auditory Feedback Modules. **Start date:** 25.12.2019 **End date:** 25.01.2020			
Deliverables *D6.1:* Integrated Hand Gesture Recognition Module and Auditory Feedback Modules.			
WP 7: *Hand Gesture Recognition - Instrument Graphics Integration*			
Start date: 22.12.2019 **End date:** 29.02.2020			
Leader:	*Çağla Sözen*	**Members involved:**	*Murat Tüver* *Merve Kılıçarslan*
Objectives: *This work package is for the integration of the Hand Gesture Recognition Module and Instrument Graphics Modules.*			
Tasks: *Task 7.1 <Integration >* : Integrating Hand Gesture Recognition Module with Instrument Graphics Module **Start date:** 22.12.2019 **End date:** 31.01.2020 *Task 7.2 <Testing >* : Testing the integrated Hand Gesture Recognition Module and Instrument Graphics Modules. **Start date:** 31.01.2020 **End date:** 29.02.2020			
Deliverables *D7.1:* Integrated Hand Gesture Recognition Module and Instrument Graphics Module.			
WP 8: *Instrument Graphics - AR Rendering Integration*			
Start date: 23.12.2019 **End date:** 30.04.2020			
Leader:	*Yağız Efe Mertol*	**Members involved:**	*Ege Özcan* *Merve Kılıçarslan*
Objectives: *This work package is for the integration of the AR Rendering and Instrument Graphics Modules.*			

Tasks: *Task 8.1 <Integration >* : Integrating AR Rendering Module with Instrument Graphics Module **Start date:** *23.12.2019* **End date:** *23.01.2020* *Task 8.2 <Testing >* : Testing the integrated Hand Gesture Recognition Module and Instrument Graphics Modules. **Start date:** *31.03.2020* **End date:** 30.*04.2020*
Deliverables *D8.1:* Integrated AR Rendering Module and Instrument Graphics Module.

Figure 30: Work Packages in Integration and Testing Set

PACKAGE SET: DEMO			
WP 9: *Demo for CS Fair*			
Start date: *01.05.2020* **End date:** *11.05.2020*			
Leader:	*Çağla Sözen*	**Members involved:**	*Merve Kılıçarslan* *Murat Tüver*
Objectives: *This work package is for the arrangement of the Demo for the CSFair.*			
Tasks: *Task 9.1 <Demo Preparation >* : Preparation of the Demo and the Demo Plan.			
Deliverables *D9.1:* Complete Application Demo			
WP 10: *Final Presentation*			
Start date: *01.05.2020* **End date:** *11.05.2020*			
Leader:	*Yağız Efe Mertol*	**Members involved:**	*Ege Özcan* *Çağla Sözen*
Objectives: *This work package is for the preparation of the final presentation.*			
Tasks: *Task 10.1 <Presentation Preparation >* : Preparation of the Final Presentation.			
Deliverables *D10.1:* Final Presentation			
WP 11: *Final Report*			
Start date: *17.02.2020* **End date:** *08.05.2020*			
Leader:	*Çağla Sözen*	**Members involved:**	*Ege Özcan* *Murat Tüver* *Merve Kılıçarslan* *Yağız Efe Mertol*
Objectives: *This work package is for the preparation of the final report and documentation.*			
Tasks: *Task 11.1 <Report Preparation >* : Preparation of the Final Report.			
Deliverables *D11.1:* Final Report			

Figure 31: Work Packages in Demo Set

PACKAGE SET: DESIGN PHASES			
WP 12: *High Level Design*			
Start date: *11.11.2019* **End date:** *31.12.2019*			
Leader:	*Çağla Sözen*	**Members involved:**	*Yağız Efe Mertol* *Murat Tüver* *Ege Özcan* *Merve Kılıçarslan*
Objectives: *This work package is for the performing the High Level Design*			
Tasks: ***Task 12.1*** **<*Design Goals*>** : Design Goals will be determined. ***Task 12.2*** **<*Architecture*>** : Designing the Software Architecture. ***Task 12.3*** **<*Subsystem Decomposition*>** : Designing the Subsystem Decomposition.			
Deliverables ***D12.1:*** High Level Design Report			
WP 13: *Low Level Design*			
Start date: *25.12.2019* **End date:** *17.02.2020*			
Leader:	*Yağız Efe Mertol*	**Members involved:**	*Murat Tüver* *Ege Özcan* *Merve Kılıçarslan* *Çağla Sözen*
Objectives: *This work package is for the performing the Low Level Design*			
Tasks: ***Task 13.1*** **<*Design Tradeoffs*>** : Design Tradeoffs will be determined. ***Task 13.2*** **<*Engineering Standards*>** : Engineering Standards will be determined. ***Task 13.3*** **<*Packages*>** : Packages will be determined.			
Deliverables ***D13.1:*** Low Level Design Report			

Figure 32: Work Packages in Design Phases Set

4.4 Ensuring Proper Team-work

For ensuring proper teamwork, we have been using two platforms already, Trello and Slack. These two platforms were used to ensure the participation of all team members to the project selection and proposal stages. Additionally for the future stages of Coda, we will be using 2 more tools, Github and Monday Visual Management Tool.

The ways in which these tools and platforms were used and going to be used can be found below,

- **Trello:** Trello was used to track tasks and issues, especially during the project selection stage. Project ideas that were discussed and waiting to be discussed were kept in separate lists and were moved accordingly. Sources that could be used for projects and the related links were also kept in Lists in Trello. Meetings were documented and their agenda were followed through there as well. Although we've decided to use Monday for tracking tasks, we might still use trello for smaller task and issue trackings because of its ease of use.

- **Slack:** Slack was again used firstly during the project selection stage. Slack is the primary communication platform to set meetings and make decisions. Also, project related discussions are made there. The reason we are using Slack is to have a channel in which there is no noise that can distract us from the topic. Furthermore, Slack provides numerous tools like polling and setting reminders that are useful for tracking updates about the project and communicating from mobile devices anytime.

- **Github:** GitHub was used for setting up the project website. All members of the team has a GitHub account which can access and contribute to the repository regarding the project website. The same procedure will be followed for the development of the project. However, in the case of the development we will utilise different branches for different work packages and different versions to be able to backup the project and ensure proper integration of branches.

- **Monday:** Monday's use for the team will be similar to the use of Trello. We will track the status of the Work Packages and Tasks from Monday in a way that is better visualized in terms of schedule. Package and Task leaders are clearly defined in Monday as well as deliverables and deadlines for each Work Package and Task.

4.5 Ethics and Professional Responsibilities

As engineers, we believe that our first and foremost responsibility is to increase the availability of products and opportunities of every context for the benefit of the people while following proper ethical values.

Ethics: First of all, we acknowledged during our analysis phase that Coda is responsible from respecting the copyright laws for the musical content. We investigated the extent to which we can use different types of musical data and did our planning accordingly. In other words, Coda will protect the rights of the music owners and will not use any unauthorized music in the application.

Environmental Responsibilities: In the environmental context, Coda recommends using recyclable VR glasses like Google Cardboard which are mostly made out of paper. No additional waste will be created by using Coda and Coda is believed to decrease the amount of waste by eliminating the need for physical instruments and hence the material that the instruments they are made of, which is mostly plastic.

Economical Responsibilities: As explained in the former parts of this report, Coda stemmed from the idea of creating a mobile, accessible and cheap way of playing and learning instruments. For that reason, Coda acknowledges it's responsibilities to aid the society to enhance musical education without seeking any profit. Coda requires no more than a mobile phone with a camera in order to be functional. For increasing accessibility in terms of economical constraints, we require no extra hardware or no advanced hardware. With this approach, we also provide accessibility to instruments without the cost of purchasing real instruments and the increase the mobility of instruments by keeping them in virtual level only .

Societal Responsibilities: Coda aims to serve people from all kind of societal and economical levels. Coda is especially suitable for being used in schools for musical education. Schools in the countryside in which students do not have the privilege to purchase real musical instruments, can use our project to provide musical education. Moreover, everyone with the application will have access to music instruments even they do not own any. People will able try and choose between the music instruments to their liking and maybe get further education for it. Hence, playing a music instrument can be more mainstream and music education can be supported in the society. Social impacts of arts argued to improve the quality of life and welfare. We are hoping to shape our community and improve lives through the power of art and engineering.

4.6 New Knowledge and Learning Strategies

First and foremost, we plan to learn about Image Processing in order to understand hand and finger gestures for enabling the user to interact with the instruments in the augment reality we render without the need for any other external tools like controllers. Since Image Processing might come short for detecting gestures with a non-constant background, and we will need to employ the help of deep learning. Hence we will learn about Computer Vision implemented by advanced Deep Learning and Image Analysis techniques. We plan to go over different implementations of such applications and writing our own simple code snippets which will give us the chance to gain hands-on knowledge.

Another challenge for us will be programming an AR app that overlays 3D objects onto real world. Most of the current systems do not employ AR with VR Glasses/Cardboards, hence we will need to understand and learn how to reconstruct an environment to be able to put AR objects to a real environment. We plan to follow along with online video tutorials and read from other online materials in order to learn about this topic. At this point, we might also perform interviews with experts from SimSoft which is a company experienced with AR and VR systems, by the help of our Innovation Expert.

If time permits, we would like to add certain cloud computing functionalities to our project for improving performance. In that case online learning will most probably be our primary source for learning the basics whereas doing exercises will be necessary for grasping the implementation details.

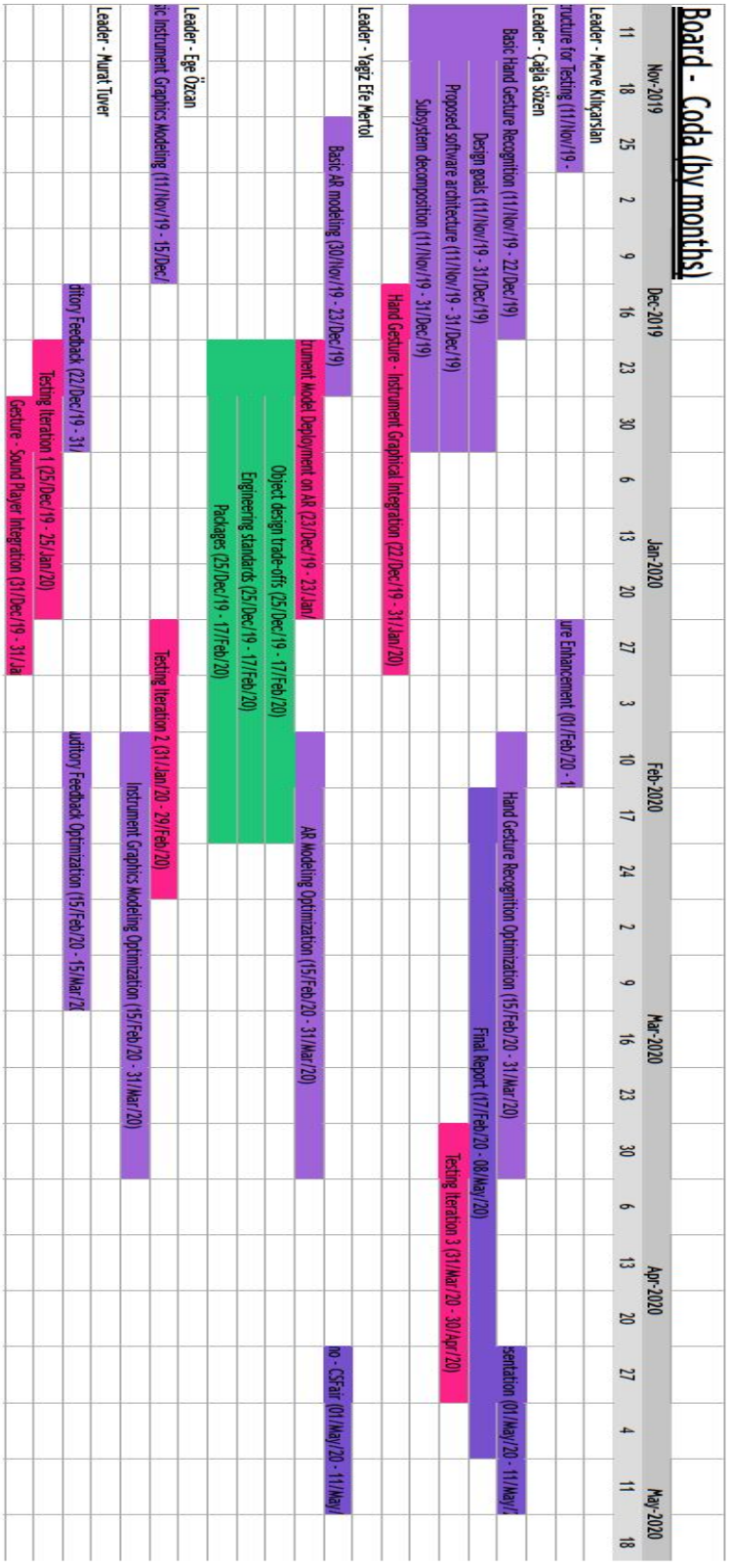
5 Glossary

AR : Augmented Reality. A computer enhanced version of the real-world where virtual objects can be put on real world objects in an interactive environment.

VR : Virtual Reality. A computer generated world that is completely virtual in terms of environment and the objects in it which provides a virtual interactive environment to the user.

Computer Vision: Combining/Using advanced Image Processing, Machine Learning and Deep Learning techniques to enable computers to see as a human does.

6 Appendix


Board - Coda (by months)
Nov-2019
Dec-2019
Jan-2020
Feb-2020
Mar-2020
Apr-2020
May-2020
11 18 25 2 9 16 23 30 6 13 20 27 3 10 17 24 2 9 16 23 30 6 13 20 27 4 11 18
Leader - Merve Kılıçarslan
ructure for Testing (11/Nov/19 -
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Leader - Çağla Sözen
Basic Hand Gesture Recognition (11/Nov/19 - 22/Dec/19)
Hand Gesture Recognition Optimization (15/Feb/20 - 31/Mar/20)
esentation (01/May/20 - 11/May/
Design goals (11/Nov/19 - 31/Dec/19)
Final Report (17/Feb/20 - 08/May/20)
Proposed software architecture (11/Nov/19 - 31/Dec/19)
Testing Iteration 3 (31/Mar/20 - 30/Apr/20)
Subsystem decomposition (11/Nov/19 - 31/Dec/19)
Hand Gesture - Instrument Graphical Integration (22/Dec/19 - 31/Jan/20)
Leader - Yağız Efe Mertol
Basic AR modeling (30/Nov/19 - 23/Dec/19)
trument Model Deployment on AR (23/Dec/19 - 23/Jan/
AR Modeling Optimization (15/Feb/20 - 31/Mar/20)
no - CSFair (01/May/20 - 11/May/
Object design trade-offs (25/Dec/19 - 17/Feb/20)
Engineering standards (25/Dec/19 - 17/Feb/20)
Packages (25/Dec/19 - 17/Feb/20)
Leader - Ege Özcan
ic Instrument Graphics Modeling (11/Nov/19 - 15/Dec/
Testing Iteration 2 (31/Jan/20 - 29/Feb/20)
Instrument Graphics Modeling Optimization (15/Feb/20 - 31/Mar/20)
Leader - Murat Tüver
ditory Feedback (22/Dec/19 - 31/
uditory Feedback Optimization (15/Feb/20 - 15/Mar/2
Testing Iteration 1 (25/Dec/19 - 25/Jan/20)
Gesture - Sound Player Integration (31/Dec/19 - 31/Ja

7 References

[1] Smith. B, "*New study demonstrates link between music and statistical learning*," The Sydney Morning Herald, 2019. [Online]. Available: https://www.smh.com.au/technology/new-study-demonstrates-link-between-music-and-statistical-learning-20170514-gw4eec.html. [Accessed: Oct. 10, 2019].

[2] ABRSM, *ABRSM:*. [Online]. Available: https://es.abrsm.org/en/making-music/4-the-statistics/. [Accessed: Oct. 10, 2019].

[3] Adlers. F, "*Fender Rhodes: The Piano That Changed the History of Music*," [Online]. Available: http://www.fenderrhodes.com/history/narrative.html. [Accessed: Oct. 10, 2019].

[4] Statista, "*Number of smartphone users worldwide 2014-2020* | *Statista*," statista.com, 2019. [Online]. Available: https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/. [Accessed: Oct. 10, 2019].

[5] The Music Room, "*The Music Room: Unique Instruments, Inspiring Spaces in VR*," 2019. [Online]. Available: http://www.musicroomvr.com. [Accessed: Oct. 10, 2019].

[6] EXA, "*EXA: The Infinite Instrument on Steam*," 2019. [Online]. Available: https://store.steampowered.com/app/606920/EXA_The_Infinite_Instrument/. [Accessed: Oct. 10, 2019].

[7] Playthings, "*Playthings: VR Music Vacation*," 2019. [Online]. Available: http://playthingsvr.com. [Accessed: Oct. 10, 2019].

[8] Hepsiburada.com. "*Vr Google Cardboard Vr 3D Sanal Gerçeklik Gözlüğü Fiyatı*," 2019. [Online]. Available: https://www.hepsiburada.com. [Accessed: Oct. 10, 2019].

[9] Nspe, "*Code of Ethics* | *National Society of Professional Engineers*", Nspe.org, 2018. [Online]. Available: https://www.nspe.org/resources/ethics/code-ethics.[Accessed: Oct. 11, 2019].

[10] Bilkent CS. Department, "CS491/2 - Senior Design Project I/II," *Bilkent CS. Department,* 2019. [Online]. Available: http://www.cs.bilkent.edu.tr/CS491-2/current/. [Accessed: Oct. 10, 2019].

[11] Business Insider, "*Here's what happens to your body when you've been in virtual reality for too long*," *Business Insider,* 2017. [Online]. Available: https://www.businessinsider.com/virtual-reality-vr-side-effects-2018-3. [Accessed: Oct. 10, 2019].