Team 4

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Project SoundAround

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Synopsis

AR headset music synthesis application, allowing users to create music by 'wiring up' nearby objects, which produce sounds and effects based on their physical properties.

Description

This project is being undertaken to explore the rapidly-developing augmented reality space and its potential intersection with music production and real-word/tech interface interaction. Once AR technology is widely adopted, tools like SoundAround could allow consumers who own AR devices to experiment with making music with very little barrier to entry. Tools like SoundAround could also serve as an example of interfacing the real-world environment with applications in general.

AR can provide musicians with a highly-intuitive user interface which is easier to learn and interact with than existing PC-based music production software. AR music production tools would remove the cost and physical space overhead of purchasing dedicated equipment -synthesizers, MIDI keyboards, instruments -enabling users to make music using full-featured tools through a device they already own. The incorporation of physical objects into the application -as 'modules' which will have sometimes-unexpected effects on a user's creation -adds elements of fun and exploration to music creation.

Additionally, it is an embodiment of one of the most fascinating aspects of AR -the way in which, unlike video games or VR, AR encourages its users to interact with the real-world environment around them. Rather than obscuring or replacing reality, it enhances reality and allows users to see it and interact with it in new ways.

SoundAround will use the AR device's inbuilt object recognition (and supplemental SDKs if necessary) to discern between different objects, and will then determine what appropriate sound is created or played based on that object's properties. The application will apply diegetic user interface principles in order to create a 3D user interface that blends in with the environment and real space, as opposed to a standard user interface that would be imposed onto a flat plane on the screen.

Ultimately, our goal is for this project to result in a robust, fascinating, and accessible music creation tool. With intriguing visuals, an intuitive interface, and an immersive concept this instrument will allow our customers to transform the world around them into music.

Milestones	Target Completion Date
Fall Semester	
1. Produce Formal Proposal and Demonstration Video 2. Train With Software and AR Headset (Microsoft HoloLens) 3. Integrate MIDI with HoloLens and Unity	1. 10/29/2018 2. 11/11/2018 3. 11/12/2018
Spring Semester	
1. Build Algorithm For Sound Effects with Texture 2. AR 3D Module Design (Recognize Object Properties) 3. Incorporate Flexible User Interface 4. Create Unity project, recognize limited set of objects 5. Audio Module Design (Sequencer and Synthesis) 6. Build Algorithms For Object and Sound Association 7. Successfully "Play" Test Room, Able to Demonstrate 8. Expand Catalogue of Assets, Incorporate Assets 9. Final Report and Promotion	1. 2/19/2019 2. 2/22/2019 3. 2/22/2019 4. 3/01/2018 5. 3/04/2019 6. 3/12/2019 7. 3/20/2019 8. 4/05/2019 9. 4/15/2019

Budget/Materials

- Microsoft HoloLens Development Kit (MHDK) - Loaned From Dr. Brian McClendon
  - Head-mounted AR device with head movement and gestural control
  - Supports application development with Unity, Vuforia, Visual Studio
- Windows Development Machines meeting the following specifications for HoloLens emulator (Machines meeting these specs are likely available in the capstone lab.):
  - 64-bit Windows 10 Pro, Enterprise, or Education w/10 April 2018 update
  - 64-bit, 4+ core CPU
  - 8 GB+ RAM
  - BIOS/motherboard supporting:
    - Hardware-assisted virtualization
    - Second Level Address Translation (SLAT)
    - Hardware-based Data Execution Prevention (DEP)
  - GPU supporting:
    - DirectX 11.0 or later
    - WDDM 1.2 driver or later
  - Necessary software
    - Visual Studio 2017
    - Unity 3D LTS (Long-Term Support) release
    - HoloLens Emulator
- Korg MicroKey Air 25 MIDI Keyboard (Bluetooth) - **$115**
  - Entry-level 25-key MIDI keyboard for synthesizer control
  - Bluetooth support necessary to interface with HoloLens, but uncommon - a previous AR music research project used this keyboard
- Project Management
  - Trello - issue tracking
  - Slack - team communication
  - Git/GitHub - version control
- Training
  - Tutorials available for free
    - Unity 3D documentation
    - HoloLens API documentation
- Useful APIs
  - Object Recognition
    - Vuforia Engine - AR computer vision library supported by HoloLens/Unity

- ■ OpenCV - More general computer vision library
  - ○ Music Synthesis
    - ■ MIDI Player Toolkit - Unity MIDI player plugin
      - ● Basic version enables playing of arbitrary MIDI in predefined soundfont
      - ● Pro version (**$50**) allows for user-specified soundfont
    - ■ MIDIJack - Unity MIDI input plugin
      - ● Allows keyboard input to Unity
    - ■ Pure Data - Visual synthesizer programming language w/Unity plugin available
    - ■ Blunt - Unity procedural audio library
  - ○ AR
    - ■ Microsoft Mixed Reality Toolkit - Utility library adding additional components/scripts to Unity for AR development
- ● **Total Estimated Cost -- $115-$155**

General Work Plan

Jakob: Image Recognition Development, Audio Synth Design
Alex: Unity User Interface Development, Image Recognition Development
Austin: Graphics/Modeling, Audio Synth and Sequencer Design
Kari: Unity User Interface Design, Audio, Documentation/Deliverables
Dylan: Image Recognition Development, Audio Algorithm Design
Note: All members will contribute to production of project deliverables, design decisions, and feature testing.

See Gantt Chart Further Down For A Detailed Outline of Work

Final Design

SoundAround's primary goal is to provide a unique experience that allows the user to interact with their environment in an unfamiliar way, interfacing music creation with real-life objects. This starts with first recognizing real-life objects in order for the software to create/assign sounds to the environment.

In regards to this requirement, the Hololens has the ability to recognize and map the surfaces and textures of objects within the room. We plan to use this to create an object class that is defined by the properties of the objects that the user selects. Once the user selects the item, SoundAround will then assign an effect or unique instrument sound to this specific object. Each unique physical object will be attached to a 3D-rendered "wire" which will connect all objects in the room to the location of the keyboard itself. This can show the user the wide array of objects that are mapped to the keyboard, in which they can combine those items to create a melody or song unique to their location. We will implement a baseline color/texture-recognition functionality, and then use this to assign sounds and effects. The Hololens itself has a speaker that will be sufficient in regards to playing sounds for our application.

In addition to the HoloLens' gestural and voice interface, the Korg MicroKEY Air MIDI keyboard will be used to provide a standard synthesizer instrument interface for the user. This device was chosen for its portability and Bluetooth compatibility and will be connected to the Unity application on the HoloLens wirelessly using Bluetooth. The MidiJack Unity plugin has been implemented to read MIDI messages from the keyboard (or any other connected MIDI device). A script will convert these messages into the MPTKNote audio format used by the Midi Player Toolkit plugin, which allows for the playing of arbitrary MIDI notes and files through a Unity audio source. MPTK's pro version supports the use of imported soundfonts, allowing the keyboard to potentially produce a huge variety of instrument sounds. This audio source is run through an audio mixer, through which a wide range of customizable effects can then be applied to the output.

The instrument to be played and effects to be applied will, as mentioned, be determined by the user's selection of objects in their environment. The mixed reality functionality enabled by the Unity HoloToolkit and Vuforia computer vision will be used to allow for the user to select objects and apply different characteristics to the audio output based on the physical features of those objects. Some of the object characteristics we intend to use for the generation of effect parameters include the color, shape and size of the recognized object. With these parameters we will be able to create different tones based on whether the object is large in size or small in size. Another example would be the creation of a lighter and warmer tone when an object is added that is brighter in color, whereas a darker color will create a much darker and deeper tone. These are just sample ideas whereas the user will also have the ability to set predefined tones of their choice. These items in view of the HoloLens will generally need to be stationary as any movement will be hard for the HoloLens to recognize.

Based on these parameters, the connection of objects to the 'effects chain' will produce modifications to the final audio output. These modifications can potentially take the form of:

- Effect filters added to the audio output through Unity's audio mixer
- Modification of the delay, duration, and pitch of the MIDI notes to be played by MPTK
- Modification of the patch (instrument within a soundfont) used by MPTK
- Replacement of the soundfont by another soundfont, modifying the instrument sounds represented by the various patches or replacing them with other instruments altogether
   - Requires 'pro' version of MPTK plugin

Some effects may also present parameters outside of those generated from object properties in the form of a holographic user interface element, through which these effects can be customized by the user to an even greater extent. Effects will be applied in the order in which they are added to the 'chain' of connected objects, and different orderings may produce different overall results.

Users will be able to import soundfonts and audio samples from the HoloLens filesystem. Soundfonts can be used to replace the default MPTK soundfont, changing the instrument voices which will be produced by different objects. Users will be able to attach samples to objects in the environment, enable or disable them, and set them to play repetitively at a user-specified tempo. As with the main MIDI keyboard input, a variety of effects can be added to samples using environmental objects. Certain objects, when selected, may, instead of an effect which can be added to the effects chain, produce a unique predefined sample based on their physical properties.

SoundAround will primarily make use of the HoloLens' gestural controls, allowing for an intuitive and unintrusive user interface and control experience. The standard HoloLens pointing/tapping gesture will be used to select objects in succession for 'wiring' into the effects chain. Additionally, holographic panels similar to the HoloLens' home menu will accompany each recognized object to allow for identification and further customization of each effect or

sample. These will be implemented using HoloToolkit's mixed reality UI features. A holographic main menu will be available as the primary method of invoking more complex features such as recording audio and importing samples. As a demonstration of the HoloLens' capabilities, voice commands will also be implemented to navigate some basic operations, such as minimizing or maximizing this main menu and resetting the holographic environment.

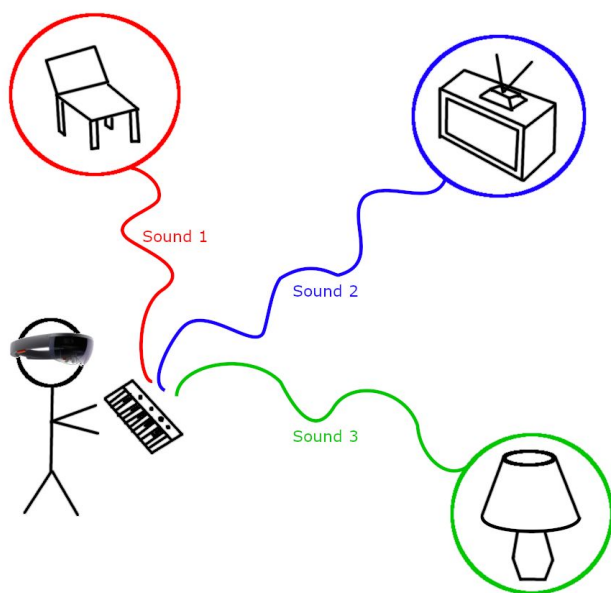Once users are satisfied with the custom 'instrument' they have created through the selection of environmental objects, they will be able to record the audio produced by SoundAround for a specified time period, including effects and samples, and save the result to the HoloLens filesystem in a standard audio format. This will allow for the recording and exporting of basic songs created entirely in SoundAround.
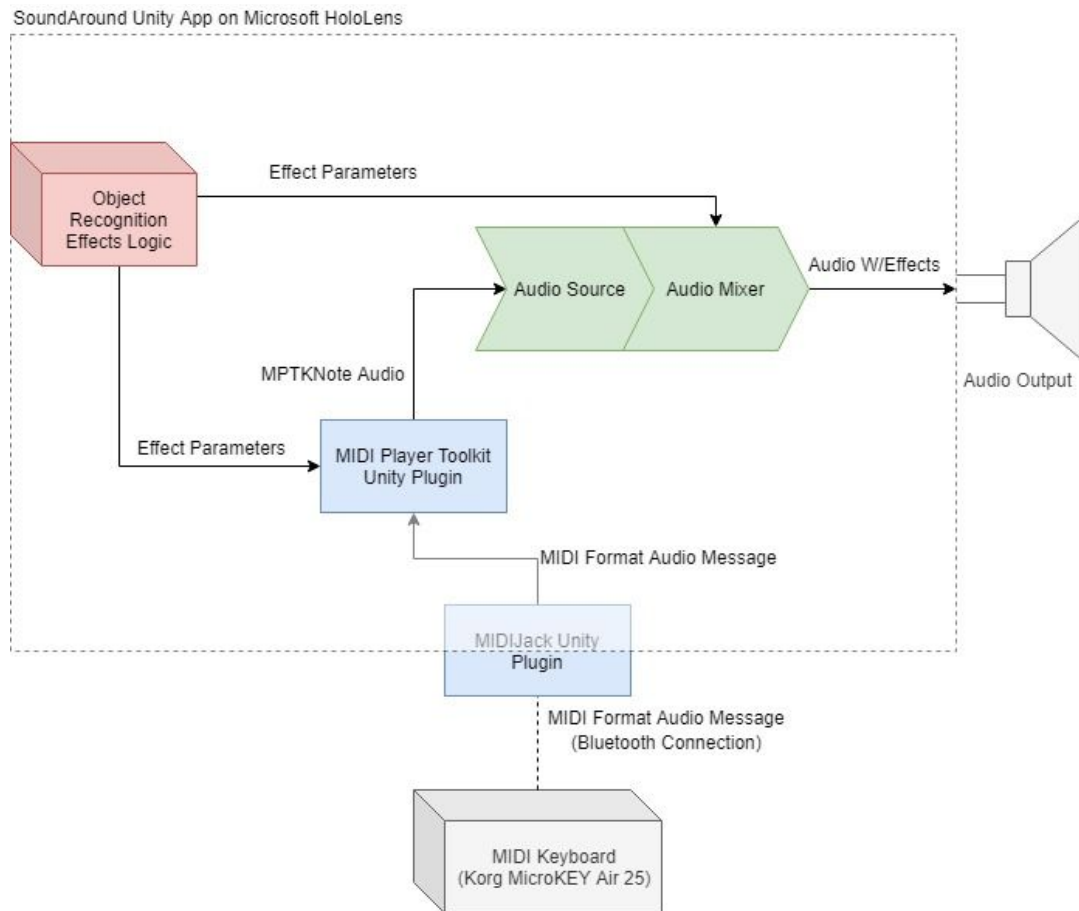
Design Constraints

One constraint will be the speaker on the device, which is only played out of one portion of the headset, which will result in us not being able to create a surround sound based setting. This will limit the amount of immersive sounds in which the user can experience, as well as the quality of the sounds.

Another major constraint of the project is the limited field of view within the Microsoft Hololens itself. When wearing the headset there is a noticeable difference in what can be seen in the real-world environment and what the Hololens itself will display through the glasses. While the Hololens does render objects in the real-world space, which appear fully 3D to the user, the user still must view these objects through a small "window" in front of them. Our initial proposal came with the idea that the user can use a 3D-rendered keyboard the user would be able to play through gesture recognition. After our first experience with the Hololens, the group has decided to instead use a bluetooth keyboard for the implementation. Constantly having to move the user's head to play the sound would ruin a major amount of immersion that Augmented reality would present for our project. With the keyboard the user just has to press a certain button and the sound tied to that object will be played. Another constraint that also led to this decision was the sensitivity of the gesture recognition. While the Hololens has a robust (albeit small) ability to display 3D "holograms", its gesture recognition is known to have problems. After sufficient testing, we have decided the device would not be able to recognize the fine details of the users' movement, which would be necessary for playing a digitally-rendered keyboard.

Another initial design constraint comes with how we ultimately decide to visually display the object mapping to the user. Among other things, we are considering a solid floating wire that runs from our keyboard to the object itself, a floating "aura" around selected objects, or even a pulsing wave that originates from objects as they are played. An issue with this is not obscuring the users vision too much, and not creating too much visual clutter.

In addition, there are a significant amount of technical constraints involved in designing and implementing our project. To develop for the Hololens, we will be using the Unity game engine. Unity will be the easiest in terms of creating an application in which we can download to our Hololens. We will be implementing using C# as our primary language for this application. Unity is a new platform, and C# is a new language, for many of us. In addition, developing in an AR space is brand new to the team. There are several APIs that we are looking at that will allow for easier implementation of features for application, an example being a tool for better object recognition. Using pre-existing APIs will allow for us to spend more time implementing things for sound creation and mapping and not spending time in creating the mapping for objects. Some of these API's include Vuforia Engine and OpenCV for object recognition, and Pure Data and Blunt for music synthesis. All of these APIs are open source, so there are no prior costs for us to use them in our implementation of our application.
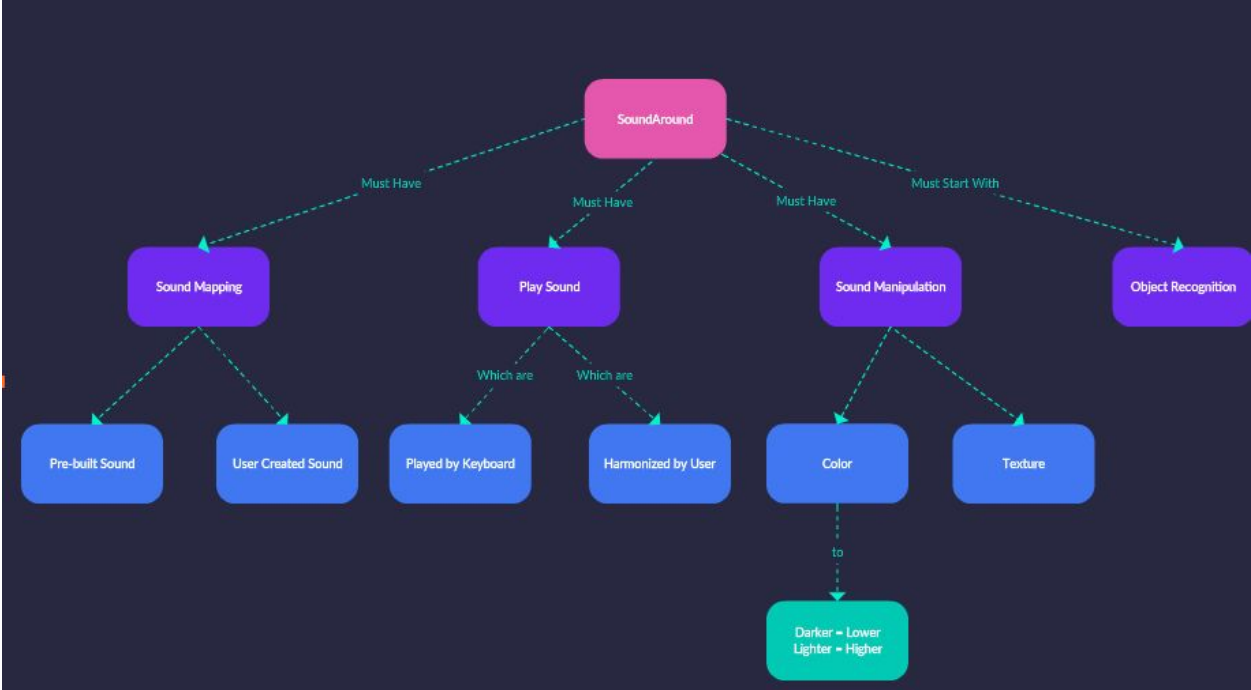
Ethical and Intellectual Property Issues

Ethical:

> People may use SoundAround in places that they ought not to. People may trespass on private property in order to find some new and unique sounds. This is an issue because it violates the property rights of those who own or reside on the land our users may trespass on. It also violates the privacy of said landowners or proprietors. There is also a concern that people may bring their headsets to sacred places such as churches or graveyards. This is disrespectful towards people who hold reverence for those places. Another place that would generate interesting and exciting sounds is a museum. It may ruin the experience of other museum goers if there are people using SoundAround. It could take away from people being able to admire the artwork or historic artifacts. If our users are standing in front of the people trying to admire the museum's items, they may not be able to see and their experiences would therefore be diminished.

Intellectual:

> We need to be careful about using other people's creations. We will be using Unity to help us generate graphics. Our group will most likely not be doing our own graphics from scratch so we need to make sure we use only open source graphics or get the appropriate permissions before using content created by other programmers. In addition to graphics, we also need to be careful about where we get our sound samples from. One way we may deal with this issue is by creating our own sounds. We were planning on getting together to record our own sound samples. Users would then be able to modify those sounds using filters based on objects in their environments. There is a possibility that users may use SoundAround to recreate their favorite songs, but that is outside the realm of our control and they would then be the ones to violate copyright, not us. If we are unable to make our own sounds, we will be sure to use open source audio, or otherwise license the use of the needed sounds.

GitHub:

We changed repositories to bring all of our work together.

Original Repo: https://github.com/austinirvine/soundaround

New Repo: https://github.com/austinirvine/sound-around-official

Original SoundAround Gantt Chart

Task	Risk		Assigned	%	Date	Days
Initial Planning	Milestone	▼	Entire Team			
Project Design Document	Med Risk	▼	Entire Team	80%	10/18/2018	4
Project Video	Med Risk	▼	Entire Team	10%	10/21/2018	6
Research	Low Risk	▼	Entire Team	50%	9/20/2018	30
Diagrams	Milestone	▼	Entire Team			
Gantt Chart	Low Risk	▼	Austin	100%	10/17/2018	5
UML	Low Risk	▼	Dylan	100%	10/17/2018	5
Illustration	Low Risk	▼	Alex	100%	10/18/2018	4
Use Case	Low Risk	▼	Dylan	100%	10/18/2018	4
Project Setup	Milestone	▼	Entire Team			
Install Unity	Low Risk	▼	Entire Team	0%	10/18/2018	7
Install DevKits & APIs	Low Risk	▼	Entire Team	0%	10/18/2018	7
Training on Platforms	Low Risk	▼	Entire Team	0%	10/27/2018	14
AR & Computer Vision	Milestone	▼	Entire Team	0%		
Integrate Unity and Hololens	High Risk	▼	Alex, Dylan	0%	10/30/2018	12
Object Recognition From Mesh	Med Risk	▼	Alex, Dylan, Jakob	0%	11/11/2018	20
Color Recognition	Med Risk	▼	Alex, Dylan	0%	11/11/2018	6
Texture Recognition	Med Risk	▼	Dylan and Jakob	0%	11/18/2018	20
Algorithm For Sound-Object Association	High Risk	▼	Jakob, Dylan	0%	1/27/2019	20
Audio	Milestone	▼	Entire Team			
Integrate Sound In & Out	High Risk	▼	Jakob, Austin, Kari	0%	10/27/2018	7
Record <100 Audio Samples For Testing	Low Risk	▼	Entire Team	0%	10/30/2018	3
Integrate Midi, External Keyboard, & Unity	High Risk	▼	Austin, Jakob, Kari	0%	11/2/2018	10
Build Sound Sequencer	High Risk	▼	Austin, Kari, Alex	0%	11/12/2018	20
Save Audio and Export	Med Risk	▼	Austin, Kari	0%	1/24/2019	7
Algorithm For Sound Effects on Objects	Med Risk	▼	Austin, Kari	0%	1/31/2019	20
Save Audio Setups in Locations	Low Risk	▼	Dylan, Jakob	0%	2/20/2019	14
GUI Implementation	Milestone	▼	Kari, Austin, Alex			
Setup 3D Placeholder Wires For Sound Connections	Med Risk	▼	Austin	0%	1/27/2019	14
Isolate Wire Meshes For Specific Objects	Med Risk	▼	Alex	0%	2/10/2019	14
Build User Interface & Map of Wired Connectivity	Low Risk	▼	Kari, Austin, Alex	0%	2/24/2019	7
Add Voice Controlled Selection	Low Risk	▼	Kari	0%	3/3/2019	7
Asset Creation/Acquisition	Milestone	▼	Entire Team			
3D Wire Asset	High Risk	▼	Austin, Jakob, Alex	0%	2/27/2019	14
Particle Effects (Optional)	Med Risk	▼	Dylan, Kari	0%	3/13/2019	7
Diegetic UI Assets	Low Risk	▼	Alex, Kari	0%	3/20/2019	5
Implement All Created Assets	Low Risk	▼	Entire Team	0%	3/25/2019	5

Revised SoundAround Gantt Chart

Task	Status		Assignee	%	Date	Days
Diagrams	Milestone	–	Entire Team			
Gantt Chart	On Track	–	Austin	100%	10/17/2018	5
UML	On Track	–	Dylan	100%	10/17/2018	5
Illustration	On Track	–	Alex	100%	10/18/2018	4
Use Case	On Track	–	Dylan	100%	10/18/2018	4
Project Setup	Milestone	–	Entire Team			
Install Unity	On Track	–	Entire Team	100%	10/18/2018	7
Install DevKits & APIs (HoloLens DevKit)	Low Risk	–	Entire Team	100%	10/18/2018	7
Training on Platforms	Low Risk	–	Entire Team	100%	10/27/2018	14
AR & Computer Vision	Milestone	–	Entire Team			
Integrate Unity and Hololens	Med Risk	–	Alex, Dylan	100%	10/30/2018	12
Object Recognition From Mesh	Med Risk	–	Alex, Dylan, Jakob	30%	2/2/2019	20
Color Recognition	Med Risk	–	Alex, Dylan	0%	2/7/2019	6
Texture Recognition	Med Risk	–	Dylan and Jakob	10%	2/12/2019	20
Algorithm For Sound-Object Association	High Risk	–	Jakob, Dylan	0%	2/20/2019	20
Audio	Milestone	–	Entire Team			
Integrate Sound In & Out	High Risk	–	Jakob, Austin, Kari	100%	1/20/2019	7
Record <100 Audio Samples For Testing	Low Risk	–	Entire Team	50%	1/30/2019	12
Integrate Midi, External Keyboard, & Unity	High Risk	–	Austin, Jakob, Kari	100%	2/2/2019	10
Build Sound Sequencer	High Risk	–	Austin, Kari, Alex	0%	2/12/2019	20
Save Audio and Export	Med Risk	–	Austin, Kari	30%	1/31/2019	13
Algorithm For Sound Effects on Objects	Med Risk	–	Austin, Kari	0%	2/13/2019	20
Save Audio Setups in Locations	Low Risk	–	Dylan, Jakob	0%	3/5/2019	8
GUI Implementation	Milestone	–	Kari, Austin, Alex			
Setup 3D Placeholder Wires For Sound Connections	Med Risk	–	Austin	0%	2/3/2019	14
Isolate Wire Meshes For Specific Objects	Med Risk	–	Alex	0%	2/17/2019	14
Build User Interface & Map of Wired Connectivity	Low Risk	–	Kari, Austin, Alex	0%	3/3/2019	7
Add Voice Controlled Selection	Low Risk	–	Kari	0%	3/10/2019	7
Asset Creation/Acquisition	Milestone	–	Entire Team			
3D Wire Asset	High Risk	–	Austin, Jakob, Alex	0%	2/11/2019	14
Particle Effects (Optional)	Med Risk	–	Dylan, Kari	0%	3/20/2019	7
Diegetic UI Assets	Low Risk	–	Alex, Kari	0%	2/17/2019	5
Implement All Created Assets	Low Risk	–	Entire Team	0%	3/25/2019	23

Detailed Gantt Chart:

https://docs.google.com/spreadsheets/d/14ESgS9XI-9af41ORbzQtXL6KPoRWr8b4NazVAYNlrpE/edit?usp=sharing

Change Log

Section	Changed (Yes/No)
Project Description	No
Project Milestones/Gantt Chart	Yes
Project Budget	No
GitHub / Resources	Yes

Fall Semester

Project Description: Added paragraph on the user experience

Milestones: reordered and updated to reflect current progress with HoloLens obtained and AR experimentation underway. Reflects our decision to use a physical MIDI Keyboard. Added additional milestones and dates.

Budget: HoloLens emulator-capable PC specifications provided. Removed request for AR headset - we are using Dr. McClendon's HoloLens for now. Added request for a specific Bluetooth-enabled MIDI keyboard model. Added additional info on materials including information resources and potential libraries/technologies to be used.

Work Plan: Added more specific tasks based on task spreadsheet.

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Spring Semester

Project Description: No changes

Milestones: Reorganized milestones and dates to reflect work done and still required for the completion of the project. The first semester provided us with a lot of knowledge and learning experience about how to develop software for augmented reality.

Preliminary Design/Design Constraints: Updated to Final Design with more specific information about functionality and implementation.

Budget: Added MPTK Unity plugin pro version

Work Plan: Trello Board & Gantt Updated with Reasonable Dates & Deadlines. We re-assessed when we could finish the project and what we can do. The GitHub repository was changed to organize everyone's work into one place.