ECE 445

SENIOR DESIGN LABORATORY

FINAL DEMO MATERIALS

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# Augmenting Virtual Reality (VR) with Smell

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**Team #15**

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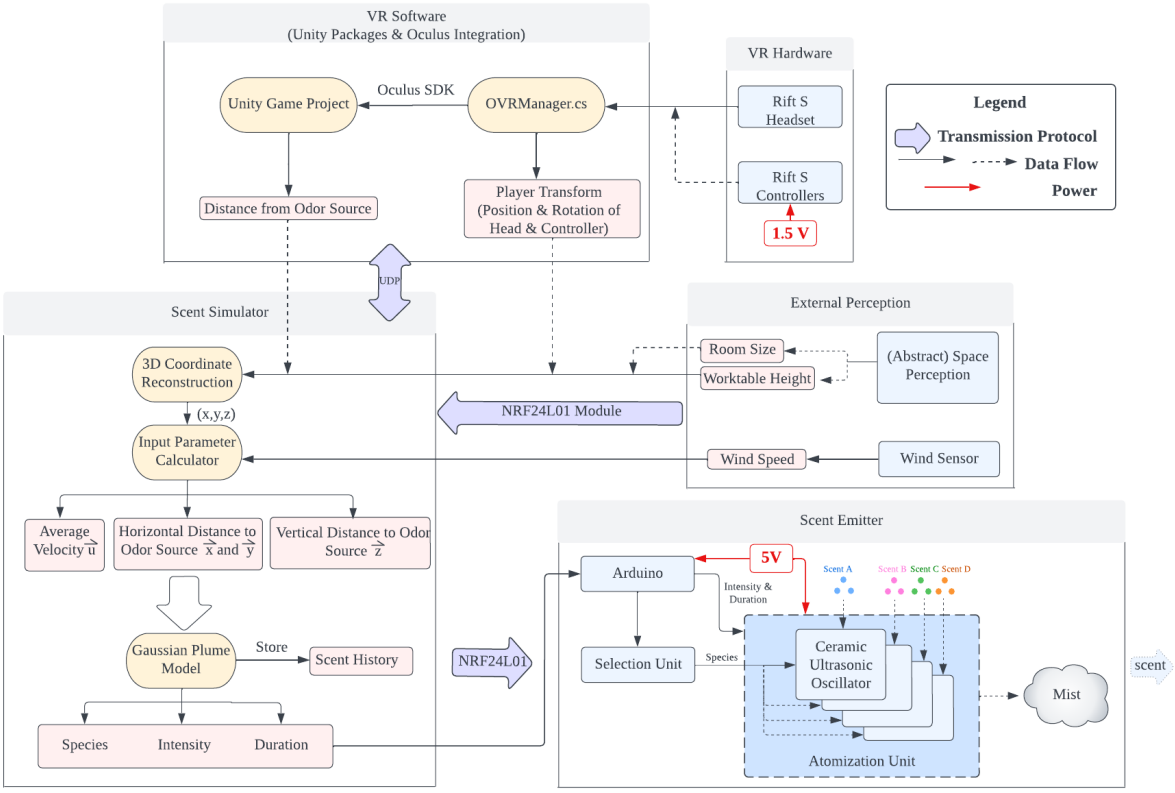
# 1 Introduction

Virtual reality (VR) technologies are rapidly growing and becoming more prevalent in our daily lives. However, these technologies have not yet fully addressed the sense of smell, which is a critical aspect of human experience. The absence of scent in virtual reality (VR) experiences limits the immersive potential of these technologies, preventing users from experiencing a full sensory experience. According to the problem we mentioned above, we propose a device that augment virtual reality (VR) experiences with smell. We incorporate hardware and software components that can simulate various scents in real-time, in response to events in the virtual reality (VR) environment. Our whole device consists of five subsystems, including two software subsystems: a virtual reality (VR) software to generate virtual scenes and a scent simulator to generate correct scents information corresponds to the given virtual scenes. To be more specific, the scents information will include scent species, scent intensity and scent duration. The remaining three subsystems incorporate hardware components: the virtual reality (VR) hardware for users' motion capture and model rendering, a scent emitter to emit scents based on information got from scent simulator, and an external perception module to collect environment information such as room size and wind speed.

# 2 High-level Requirements

- The scent-emitting device will need to be able to emit various scents for normal operation, that is, walk or adjust view with normal speed in our constructed virtual world for a period of at least 1 hour without adding new materials.
- The scent-emitting device should emit proper scents in 300 milliseconds after the sensor capturing the user's location and orientation. This also includes time a scent simulation software needs to calculate the intensity and duration of scent emissions. To be more specific, as the major delay may happen in data transmission stage, the time for scent simulation software to calculate scent species, intensity and duration should be under 100 milliseconds.
- As a wearable electronic device, we want our device to be portable and lightweight. We expect the weight of the headset not exceed 0.5 kilograms, and the weight of the neck scent-emitter will not exceed 0.3 kilograms, making it easy for users to carry around during virtual reality (VR) experiences, and have less stress on users' neck.

# 3 Block Diagram




# 4 Points Summary Table

| Module Name | High-level Requirements | Points |
|---|---|---|
| VR Software | • Deliver a smooth and immersive demo at a minimum of 90 FPS.<br>• Incorporate diverse scenarios to showcase the integration of olfactory elements in VR scenes. There should be 0 latency when switching into different scenarios. | 10 |

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| Scent Simulator Software | • Employ suitable physical models for scent simulation, incorporating valid modifications and assumptions.<br>• Accurately map the relationship between distance and scent intensity for a seamless and natural user experience. 1 object should be match to exactly 1 scent without mistakes. | 10 |
| Scent Emitter | • Ensure stable emission of various scents. The frequency of oscillator is between 108 and 110 Hz. The overall frequency should between 0.12 and 0.13 Hz for low-level, between 0.24 and 0.26 Hz for medium-level and no-gap oscillating for high-level.<br>• Select distinct and appealing scents for differentiation. Combinations of different scents should be available.<br>• Design the scent emission device to be lightweight, comfortable, and aesthetically pleasing. The weight of the neck scent-emitter will not exceed 0.3 kilograms, making it easy for users to carry around during virtual reality (VR) experiences, and have less stress on users' neck. | 10 |
| External Perception Module | • The wind sensor should transmit wind speed to the computer smoothly with a speed of at least 100Kbps.<br>• The wind speed should affect the virtual scenarios. The wind sensor must be able to detect wind speed in the range of 1m/s to 60m/s for the resolution ratio to be lower than 0.2m/s to fit our requirements. | 10 |

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| Communication between Components | • Maintain sufficient bandwidth no less than 2Mbps for real-time inter-component communication.<br>• Ensure communication doesn't obstruct user movement or interaction with VR scenes.The overall reaction time should be no more than 300 milliseconds. This includes the scent simulator's calculation time and data transmission time between different protocols. | 10 |

# 5 Requirement and Verification Tables

## 5.1 Virtual Reality (VR) Software

| **Requirements** | **Verifications** |
|---|---|
| 1. The demo should run smoothly and consistently with at least 90 Hz frames per second(FPS) to provide visually comfortable and immersive experiences to users. | 1. Use bench-marking tools, such as *Oculus Tray Tool* or *SteamVR Performance Test*, to measure the frame rate of the VR demo while it is running.<br><br>2. Conduct user testing: Invite potential users to test the VR demo and provide feedback based on their experience. |
| 2. The software must be designed to work seamlessly with the latest lineups of Oculus virtual reality (VR) devices. | 1. Ensure that the design is compatible with Oculus' software development kits(SDKs) and tools to guarantee that the software is optimized for Oculus devices and takes advantage of their features and capabilities.<br><br>2. Create and validate our demo software using an Oculus Rift S, and if feasible, test it on other Oculus device models. |
| 3. The demo needs to include adequate examples to be considered a comprehensive and general implementation of incorporating scent into virtual reality (VR) systems. | The demo should offer at least 3 different scenes/objects, such as a bakery or a bouquet of roses, to incorporate different scents for the users to interact with and experience. |

## 5.2 Scent Simulation Software

| Requirements | Verifications |
|---|---|
| 1. The simulator should be able to calculate the appropriate intensity and duration of the scents emitting based on the diffusion equation. | 1. Through careful experiment and referring to the Odor Detection Threshold (ODT) which is the minimum concentration of an odorant that can be detected by humans, and Oder Intensity Standard Curves, we can make sure that the scents can be emitted within an acceptable and comfortable range.<br>2. Use specialized equipment: Use specialized equipment, such as gas chromatography-mass spectrometry (GC-MS), to verify that the simulator accurately calculates scent intensity and duration. |
| 2. The real-time result should be delivered correctly to the emitter. | Use Arduino's Universal Serial Asynchronous Receiver Transmitter(USART) protocol to transmit real-time signals to the PC for debugging. |

## 5.3 Virtual Reality (VR) Hardware

| Requirements | Verifications |
|---|---|
| 1. The virtual reality (VR) hardware should be equipped with wireless or wired connection with a personal computer (PC) to enable model rendering. | Check whether the personal computer (PC) is equipped with a DisplayPort adaptor. Note that if the connection only supports HDMI personal computers (PCS), Oculus does not guarantee compatibility. So make sure they have a DisplayPort or Mini DisplayPort and a USB 3.0 port. |
| 2. Use at least an Nvidia GTX 1060 or AMD Radeon RX 480 graphics card, an Intel i5-4590 or AMD Ryzen 5 1500X or later CPU, and at least 8GB of RAM for the personal computer (PC). | First, right-click on Computer – Properties and go to the Computer Properties Tab. We can see the basic CPU and memory configurations in the Properties TAB. For more details, we can click Device Manager on the left of the selection. Check these configurations to ensure they satisfy the requirements. |

## 5.4 Scent Emitter

| Requirements | Verifications |
|---|---|
| 1. The emitter should be driven by an inexpensive, efficient, and user-friendly microcontroller (MCU), enabling easy setup and operation. | The emitter will be streamed by an Arduino Uno R3 as the microcontroller board based on the ATmega328P. |
| 2. Five ceramic ultrasonic oscillators should all function well when given an appropriate trigger signal. | The range switch of the multimeter should first shift to $2.5V$ DC voltage, and let the red pen connect to the metal sheet, let the black pen be placed horizontally on the ceramic surface, and slightly pressure the left hand, and then loosen so that two voltage signals of opposite polarity are generated on the piezoelectric ceramic sheet. Make the multimeter pointer first swing to the right, then back to zero, and then swing to the left. The swing amplitude is about 0.1-0.15V. The larger the swing, the higher the sensitivity. If the pointer of the multimeter is stationary, it indicates that this ceramic ultrasonic oscillator has some problems. |
| 3. The emitter consists of 5 small scent cartridges with scent cartridges installed. | 1. Design and conduct extensive unit test cases for every possible scenario.<br><br>2. To ensure accurate delivery of scents, we plan to use simulator software to capture the density. If possible, we would like to use specialized equipment, such as gas chromatography-mass spectrometry (GC-MS), to verify the precise chemicals being emitted at each time st. |
| 4. Real-time cues from the API through the OpenXR should be delivered to the Arduino using Web Serial to trigger scents. | Utilize Arduino's USART protocol to send real-time signals to the PC, allowing for comparison with signals received through the API. |

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| Requirements | Verifications |
|---|---|
| 5. The power supply must provide a voltage in the range of 4.5-5.5V. | Measure the output voltage using an oscilloscope, ensuring that the output voltage stays within the range of 4.5-5.5v. |

## 5.5 External Perception Subsystem

| Requirements | Verifications |
|---|---|
| 1. The wind sensor should transmit wind direction and speed to the computer smoothly with a speed of at least 100Kbps. | 1. Send write instructions to the Bluetooth device that has completed pairing, and record the current timestamp. Note that it contains a verification packet for the Bluetooth device to write.<br>2. After receiving feedback from the Bluetooth device, calculate the writing time based on the current system time and the first timestamp.<br>3. Send a read instruction to the Bluetooth device and record the current second timestamp. The Bluetooth device then reads the written verification packet and generates a reply signal.<br>4. After receiving the response signal fed back by the Bluetooth device, the sending time is calculated based on the current system time and the second timestamp.<br>5. Calculate the transmission speed based on two time stamps. |
| 2. The wind sensor must be able to detect wind speed in the range of $1m/s$ to $60m/s$ for the resolution ratio to be lower than $0.2m/s$ to fit our requirements. | 1. Design and conduct extensive tests of different wind speeds to make sure the sensor works in these wind conditions.<br>2. Conduct experiments especially on low wind speed and high wind speed to ensure the property. |

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| 3. The power supply must provide a voltage in the range of 4.5-5.5V for a current load up to 20mA. | Measure the output voltage using an oscilloscope, ensuring that the output voltage stays within the range of 4.5-5.5v. |