
REALITY


VIRTUAL
WORLD

PROJECT
GAME DESIGN
Medical Open Platform

GAME DEMO:lynn-wonderland.com

A medical and surgical resource sharing and learning platform through VR technology. This immersive experience offers a comprehensive resource sharing hub, allowing medical professionals and students to practice and hone their surgical skills in a safe, virtual environment.

Genre: Medical/VR/First person

Platform: VR

Develop Engine: Unreal Engine 5.2.1

Control: VR device

Age Restriction:16+

1 Overview

This is a virtual surgical environment and medical resource sharing platform constructed through VR technology, which provides an opportunity for medical practitioners to learn and practice by sharing surgical cases and processing them appropriately, and at the same time provides immersive surgical processes and medical science for non-medical practitioners.

2 Background

2.1 Investigation
Breast cancer surgery

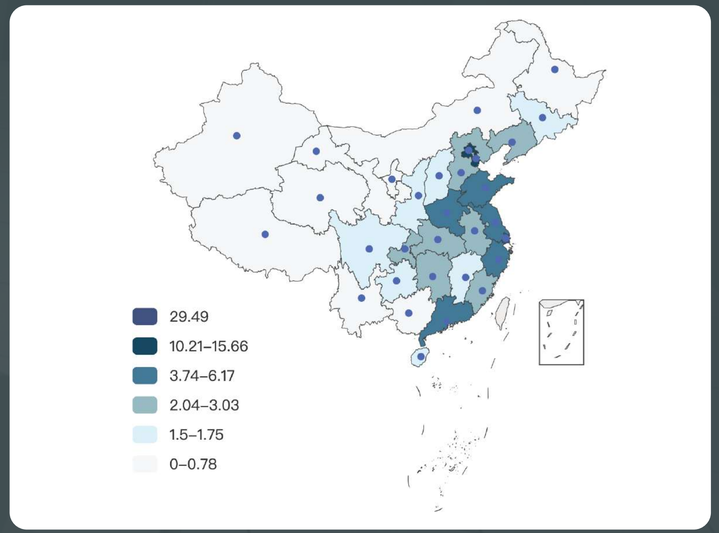
In China, the proportion of mastectomies in breast cancer surgery varies but is notably high. As per the data available:
About 61.3% of women with breast cancer underwent mastectomy without breast reconstruction, 26.4% underwent mastectomy with breast reconstruction, and 12.2% chose breast-conserving surgery.[1]
The rate of mastectomy was highest among women aged 50–65 years, at 82.1%, and in non-first-tier cities, where it was 88.4%. Additionally, in Northeast China, the rate went up to 93.2%.[2]
Over a 15-year period, mastectomy was the primary surgical strategy for breast cancer, accounting for 84.8% of cases, while breast-conserving surgery (BCS) was only 15.2%.[3]
The proportion of patients with early-stage breast cancer undergoing mastectomy exceeds 70% in China, and a particular surgical technique known as the Auchincloss operation is predominantly used for patients with axillary lymph node-positive breast cancer.[4]
Comapring with U.S.(In the United States, a study reported that 35.5% of the women in the study cohort underwent mastectomy for early-stage breast cancer. There was a 34% increase in the adjusted odds of mastectomy in women eligible for breast-conserving surgery (BCS) over the most recent eight years of the study period since 2011) the statics for China is staggering.[5]
Also, in China, the proportion of mastectomy in breast cancer surgery is notably higher in non-first-tier cities, with 88.4% of cases undergoing mastectomy, compared to first-tier cities, where the rate is not specified in the provided data. The overall mastectomy rate in the study was 77.2%, with the highest rates observed in Northeast China at 93.2%. Conversely, the rate of breast-conserving surgery was less than 10% in non-first-tier cities (9.8%).[6]
The data above leads to several serious questions.

What will the high propoertion of mastectomies bring about, especially for patients?

According to researches in psychological field[7], a breast cancer diagnosis and treatment can lead to considerable distress, comparable to post-traumatic stress disorder symptoms, affecting self-concept, lifestyle, and leading to anxiety and depression. The pretreatment phase is marked by critical changes, indicating increased vulnerability and the need for psychosocial support. Due to the ambiguous boundaries in determining psychological disorders, privacy concerns, and the lack of attention in the broader context, it is difficult to find specific data to illustrate the mental health status of Chinese women after mastectomy for breast cancer. However, based on thorough psychological surveys, it can be reasonably inferred that given such a high rate of mastectomy and the relatively late and underdeveloped state of postoperative rehabilitation, female breast cancer patients face challenging circumstances.

Is such uneven distribution of medical resources a problem prevalent in all medical treatment in China?

Based on the Gini coefficient, Theil index, and concentration index, China's medical resources are concentrated in economically developed areas such as Shanghai, Beijing, Tianjin, Jiangsu, and Zhejiang.[8]
Moreover, a greater proportion of financial support is also concentrated in these areas, including the attraction of talent, which exacerbates the phenomenon of uneven distribution. Hospitals in these regions have more medical resources and more humane and scientific medical technologies. At the same time, due to such concentration, medical cases are also gravitating towards these areas, which have a greater number of routine cases as well as cutting-edge and rare cases.

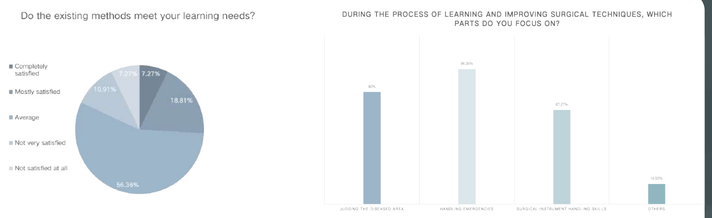


Medical Resourse Distribution calculaed in concentration Index

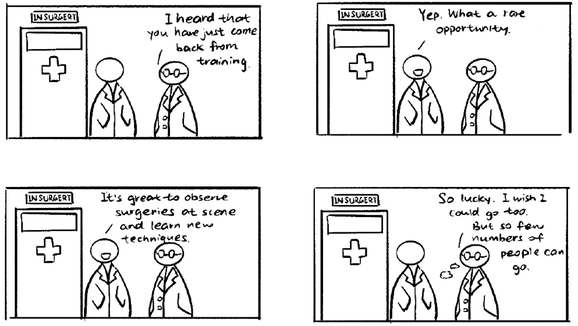
Current Surgery Learning Method

In order to investigate the current situation of how surgeons in China learn surgical skills and accumulate case experience today, I have created a questionnaire, which was distributed to surgeons from different cities and hospitals.

https://lynn-wonderland.com/Sites/Survey%20on%20the%20Current%20State%20of%20Resources%20for%20Learning%20Surgical%20Operations.html



Also, statics show that 90.91% of survey respondents seek help from surgery video materials and up to 85.45% of them have to go to other hospitals for surgical study.



2.2 Conclusion

Based on the above, I have come up with the following ideas

1.Build a shared medical resource platform through VR. On this platform, share cutting-edge cases through VR technology and 3D reconstruction techniques of MRI and CT images, allowing surgeons to observe and learn surgical procedures within their own hospitals. Through VR, they can immerse themselves in the experience and accumulate experience, enhancing surgical skills so that they can provide more accurate and suitable surgical planning for different cases tailored to the patient's needs. Furthermore, since many doctors in the survey focus on identifying the lesion location and dealing with emergencies when learning about surgical cases, I believe that VR technology can emphasize and train doctors in determining the lesion area when reconstructing the surgical scene and process. It could also include simulations of unexpected emergencies to help doctors better adapt to the real surgical flow.

2.Design a VR controller that approximates the feel of a surgical scalpel to complement this medical resource platform. Since most VR controllers on the market today differ significantly from the feel and size of a surgical scalpel, I propose using Arduino to integrate the necessary modules and attempt to design a VR controller suitable for surgical training.

3.The VR platform can also be aimed at non-professionals, incorporating a filter mode that reduces realism as a means of popular science education, helping people to better understand various diseases and enhance their basic medical knowledge.

2.3 Market Research

Considering that there are some surgical simulator games available on the market, I will conduct some research to study their characteristics and contemplate how this medical resource sharing platform can be compatible, inclusive, and improved upon.

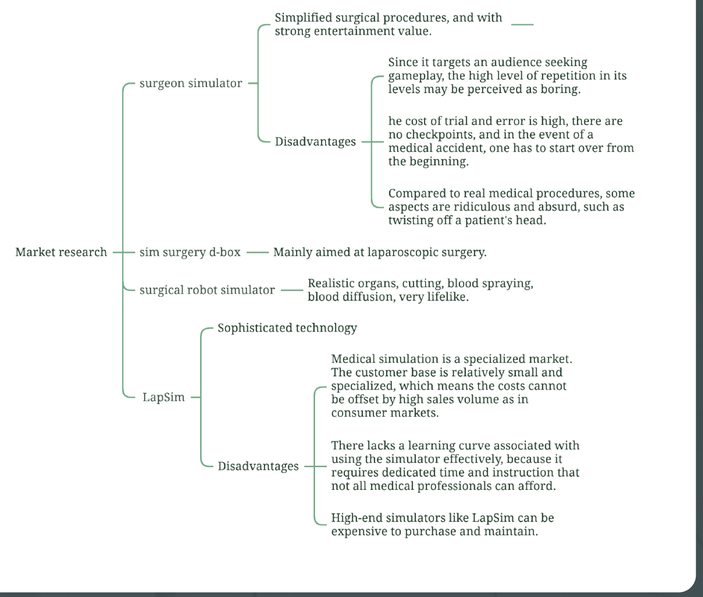
Surgeon Simulator

Surgical Robot Simulator

1.Offering a basic version of the simulator with optional modules can reduce the initial cost. As is mentioned above, I would like to make it also aimed at non-professionals, incorporating a filter mode that reduces realism as a means of popular science education.

2.Make medical surgery materials an open source platform where plenty hospitals can upload resources and programmers can help to edit.

3.Instead of pursuing the ultimate simulation, the goal is to closely align with the users' needs, targeting their 'pain points' precisely. During the simulation process, the focus is on identifying the lesion area and simulating various emergency scenarios. By placing playable videos and patient-related data UIs, such as oxygen saturation levels, on the VR glasses, it helps players to better compare and observe the lesions during the process. At the same time, they can monitor the patient's various vital signs, preparing for any emergencies that may arise, which more closely matches the focus and slight tension of a real surgical scene.

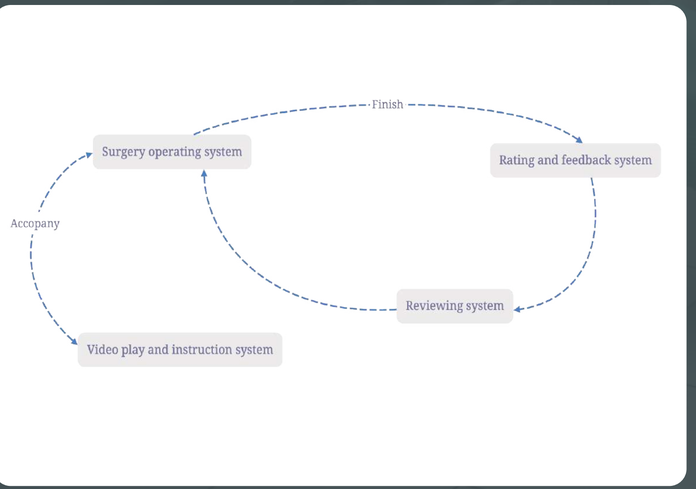


3 Mechanics

3.1 Game loop

Game systems

- Video play and instruction system
- Surgery operating system
- Rating and feedback system
- Reviewing system



3.2 Game Flow

One person mode						
select the type of disease	choose a case study (Here, take breast cancer surgery as an example)	choose a perspective	Assistant mainly observes and learns	process selection	the entire surgical process	Make incisions as directed by the attending surgeon.
						Delivering surgical instruments (e.g., a free knife) to the attending surgeon to help immobilize the tissue around the surgical site as requested by the attending surgeon to allow the surgeon better visibility and access to the area where the tumor resection is being performed.
						Removing excess fluid or fat from the surgical site using a suction device to keep the area clear and visible for the attending surgeon. Breast cancer tissue is removed for x-ray scanning to confirm margin integrity, to help the attending surgeon hold the tissue in place or to assist in suture closure of the wound.
					pertaining to the treatment of the lesion.	
				Whether to open the instrument operational trajectory diagram		
				Whether to turn on the lead surgeon's presentation options		
			Chief surgeon	process selection	Then entire process	The incision location is determined from the CT/MRI recovery map of the labeled lesion area on the monitor
						Regional disinfection
						Incision (cut through skin layer, subcutaneous fat layer)
						Determine the exact location of the breast cancer based on the real-time scan on the monitor (since breast cancer surgeries are usually performed with the area of the lesion labeled by radioactive elements prior to surgery, this can be done with more real-time images).
						Preserve a 1-2 mm margin of healthy breast tissue when excising the area of breast cancer. Need to ensure continuity of excision if there is a cluster of similar discontinuous breast cancers
						The assistant(by system) will confirm that the margins of the breast cancer area are intact based on x-rays
						Clean the incision and surrounding skin. Select the appropriate suture and suture needle and pass the suture under the skin through the skin and tissue.
						Precision discrimination based on the trajectory of instrument
						Evaluation and feedback at the end
					pertaining to the treatment of the lesion	
				Whether to open the instrument operational trajectory diagram		
				Whether or not to turn on accidental contingency selection		
		Comparing cases	Two cases can be selected at the same time for comparative observation			

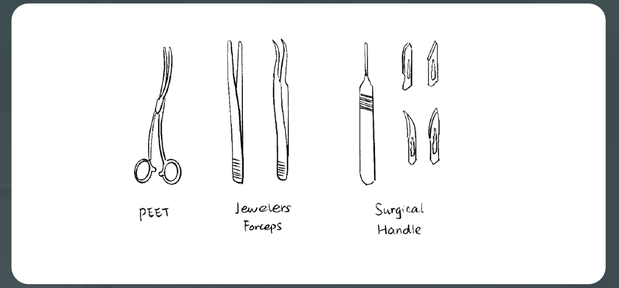
3.3 Game Play

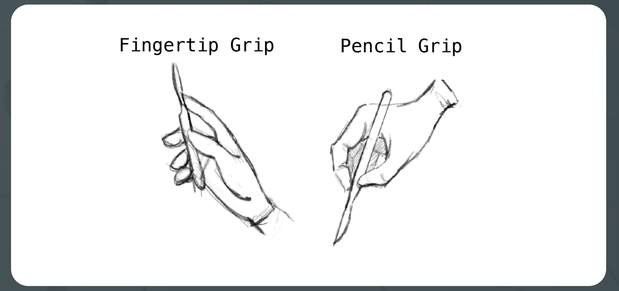
3.3.1 Game device Investigation

Surgical instruments are essential tools in any operation. Common types include scalpels for cutting, forceps for gripping, and retractors for exposing areas of the body.
Scalpels, scalpels, which is used very often in particular, have two main grips:

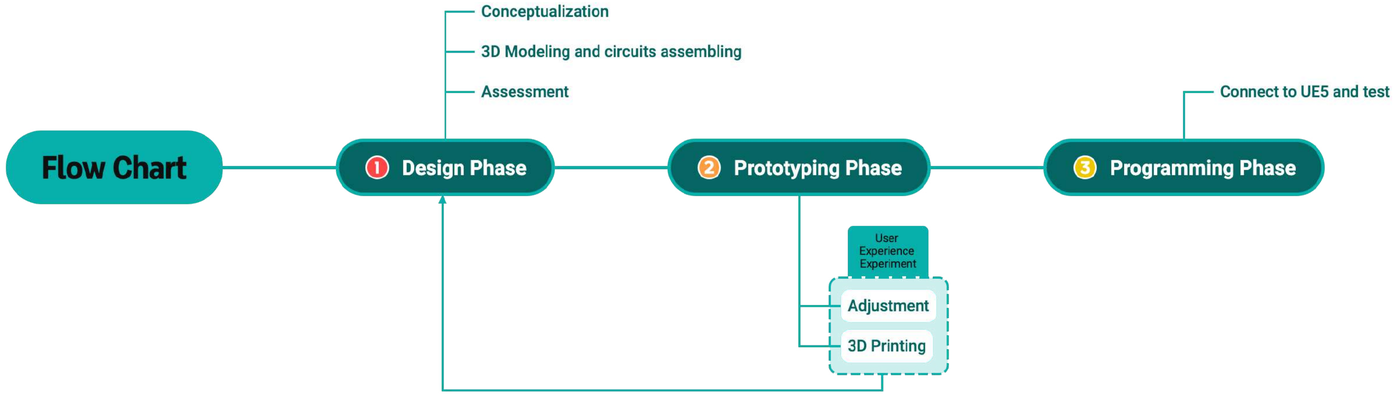
Pencil Grip: Similar to holding a pencil, used for precise, straight cuts. The scalpel is held between the thumb and middle finger, guided by the index finger.

Fingertip Grip: Offers more flexibility for curved cuts. The scalpel is held between the tips of the thumb, index, and middle fingers.



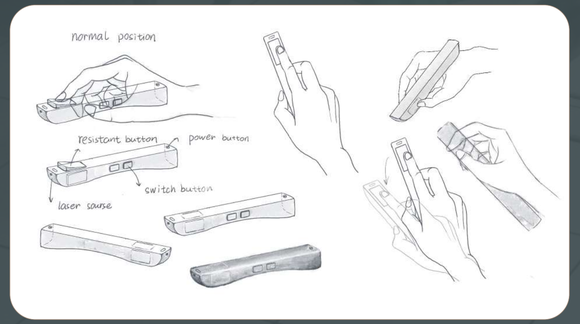


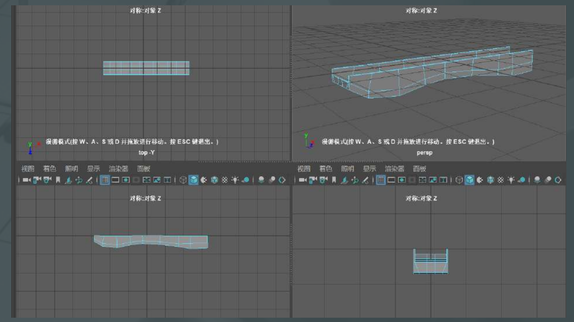
Design process flow chart



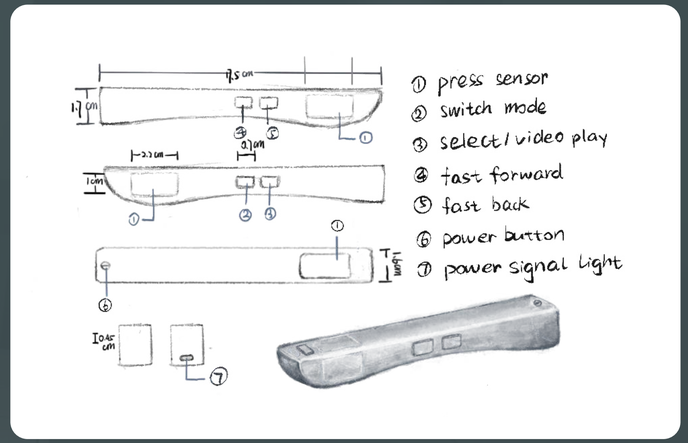
a. Design Phase

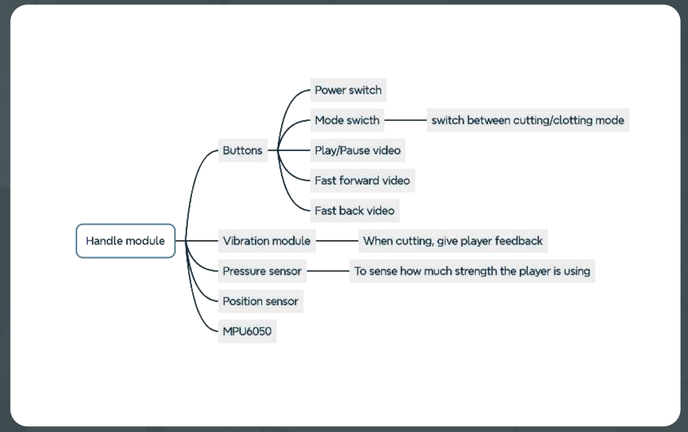
1. Based on the way the surgical scalpel is held, sketches were drawn, and these were then realized in Maya.





2. Handle module design: In designing specific functionalities, the focus is on creating features that are not only practical and efficient but also user-centric.





3. Arduino programming

HandleCore.ino

```ino
#include <Adafruit_MPU6050.h>
#include <Adafruit_Sensor.h>
#include <Wire.h>
#include <MPU6050.h>

// MPU6050 I2C address
const int MPU_ADDR = 0x68;

// MPU6050 registers
const int ACCEL_XOUT_H = 0x3B;
const int GYRO_XOUT_H = 0x43;
const int PWR_MGMT_1 = 0x6B;

// Sensitivity scale factors
const float ACCEL_SCALE_FACTOR = 16384.0; // For ±2g range
const float GYRO_SCALE_FACTOR = 131.0; // For ±250°/s range



const int buttonPin = 12;     // button pin
const int ledPin =  13;  //led
const int switchPin_1 = 11;
const int switchPin_2 = 10;
const int switchPin_3 = 9;
const int switchPin_4 = 8;
int s_pin = A3; // press_sensor pin

int buttonState = 0;
boolean LedState = false; //LED state
boolean buttonUp = false;  //button state

int switchButtonState_1 = 0;
int switchButtonState_2 = 0;
int switchButtonState_3 = 0;
int switchButtonState_4 = 0;
boolean switch_1_Up = false;
boolean switch_2_Up = false;
boolean switch_3_Up = false;
boolean switch_4_Up = false;

char incomingByte = "";
int motor = 6;

void setup()
{
  Serial.begin(9600);
```

HandleCore.ino

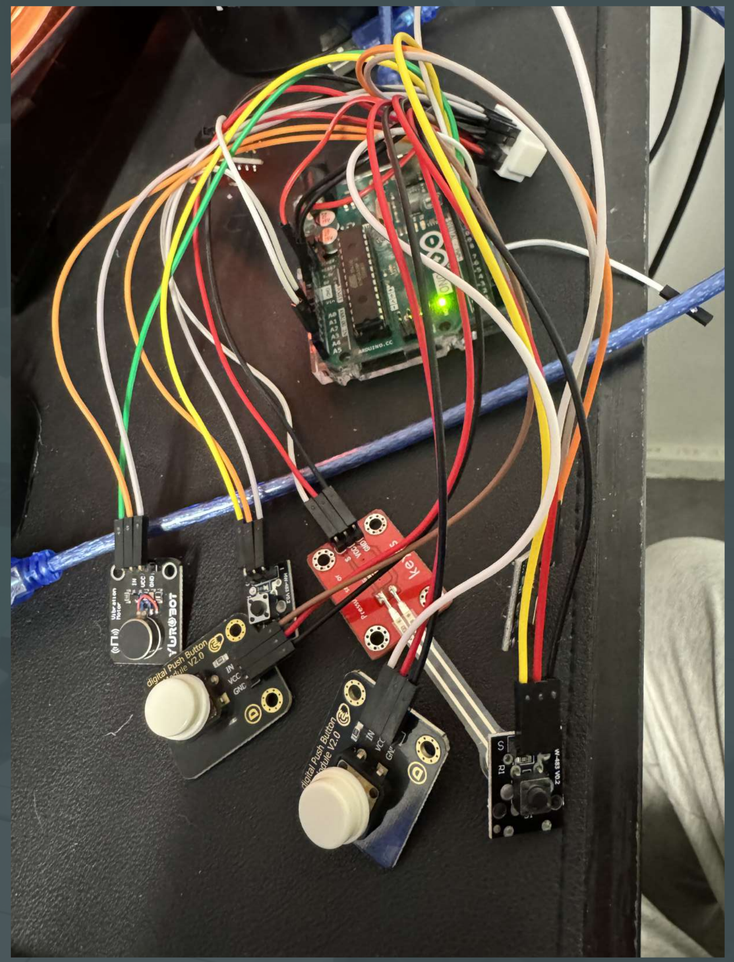
```ino
{
  Serial.begin(9600);

  pinMode(s_pin,INPUT);
  pinMode(ledPin, OUTPUT);
  pinMode(buttonPin, INPUT);
  pinMode(switchPin_1, INPUT);
  pinMode(switchPin_2, INPUT);
  pinMode(switchPin_3, INPUT);
  pinMode(switchPin_4, INPUT);
  pinMode(motor, OUTPUT);

  Wire.begin(); // Initialize I2C
  Wire.beginTransmission(MPU_ADDR); // Start communicating with MPU6050
  Wire.write(PWR_MGMT_1); // Write to power management register
  Wire.write(0); // Set to zero to wake up MPU6050
  Wire.endTransmission(true);
}


void loop() {

  buttonState = digitalRead(buttonPin);

  //MPU6050
  Wire.beginTransmission(MPU_ADDR);
  Wire.write(ACCEL_XOUT_H); // Start reading from ACCEL_XOUT_H
  Wire.endTransmission(false);
  Wire.requestFrom(MPU_ADDR, 14, true); // Request 14 registers

  // Read accelerometer data
  int16_t ax = Wire.read() << 8 | Wire.read();
  int16_t ay = Wire.read() << 8 | Wire.read();
  int16_t az = Wire.read() << 8 | Wire.read();

  // Skip temperature data (2 bytes)
  Wire.read(); Wire.read();

  // Read gyroscope datas
  int16_t gx = Wire.read() << 8 | Wire.read();
  int16_t gy = Wire.read() << 8 | Wire.read();
  int16_t gz = Wire.read() << 8 | Wire.read();

  // Convert to international units
  float ax_mps2 = ax / ACCEL_SCALE_FACTOR * 9.80665;
  float ay_mps2 = ay / ACCEL_SCALE_FACTOR * 9.80665;
```

HandleCore.ino

```ino
  float az_mps2 = az / ACCEL_SCALE_FACTOR * 9.80665;
  float gx_dps = gx / GYRO_SCALE_FACTOR;
  float gy_dps = gy / GYRO_SCALE_FACTOR;
  float gz_dps = gz / GYRO_SCALE_FACTOR;


  if (buttonState == HIGH && buttonUp == true) {
    LedState=!LedState;
    digitalWrite(ledPin, LedState);
    buttonUp = false;
  }

  else if(buttonState != HIGH && buttonUp != true){
      buttonUp = true;
  }


  //if power switch is on
  if(LedState == true){
      ///Serial.println(analogRead(s_pin));

      switchButtonState_1 = digitalRead(switchPin_1);
      switchButtonState_2 = digitalRead(switchPin_2);
      switchButtonState_3 = digitalRead(switchPin_3);
      switchButtonState_4 = digitalRead(switchPin_4);


      if (switchButtonState_1 == HIGH && switch_1_Up == true) {
        Serial.println("signal 1");
        switch_1_Up = false;
      }
      else if(switchButtonState_1 != HIGH && switch_1_Up != true){
        switch_1_Up = true;
      }

      if (switchButtonState_2 == HIGH && switch_2_Up == true) {
        Serial.println("signal 2");
        switch_2_Up = false;
      }
      else if(switchButtonState_2 != HIGH && switch_2_Up != true){
        switch_2_Up = true;
      }

      if (switchButtonState_3 == HIGH && switch_3_Up == true) {
        Serial.println("signal 3");
        switch_3_Up = false;
      }
      else if(switchButtonState_3 != HIGH && switch_3_Up != true){
```

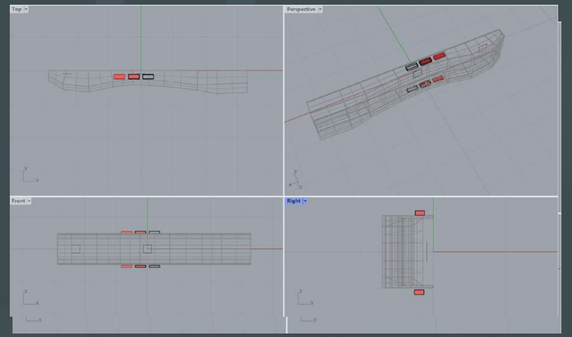
HandleCore.ino

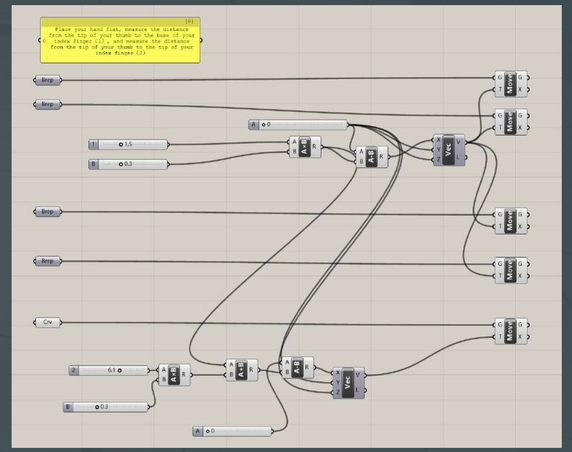
```ino
      if (switchButtonState_4 == HIGH && switch_4_Up == true) {
        Serial.println("signal 4");
        switch_4_Up = false;
      }
      else if(switchButtonState_4 != HIGH && switch_4_Up != true){
        switch_4_Up = true;
      }


      if (Serial.available() > 0) {
          incomingByte = char(Serial.read());
          if(incomingByte == '1'){
            analogWrite(motor, 50);
          }
          else if(incomingByte == '2'){
            analogWrite(motor, 100);
          }
          else if(incomingByte == '3'){
            analogWrite(motor, 150);
          }

          else if(incomingByte == '0'){
            analogWrite(motor, 0);
          }

      }
      Serial.print("Accel X: "); Serial.print(ax_mps2); Serial.print(" m/s^2");

      Serial.print(", Accel Y: "); Serial.print(ay_mps2); Serial.print(" m/s^2");

      Serial.print(", Accel Z: "); Serial.print(az_mps2); Serial.println(" m/s^2");

      Serial.print("Gyro X: "); Serial.print(gx_dps); Serial.print(" °/s");

      Serial.print(", Gyro Y: "); Serial.print(gy_dps); Serial.print(" °/s");

      Serial.print(", Gyro Z: "); Serial.print(gz_dps); Serial.println(" °/s");



  }
  else {
    analogWrite(motor, 0);
  }
```



b. Prototyping Phase

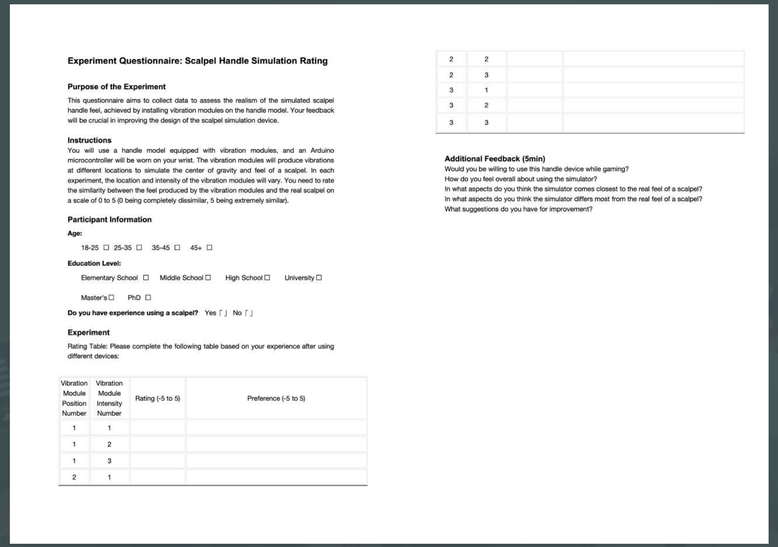
When prototyping, I found that the pressing area of Arduino chip is too small that its position largely affects user experience as size of hand varies from person to person. As a result, I decided to use Rhino programming to make adjustments to the position of buttons and pressing position according to the size of user's hand.





Hypotheses: When the vibration intensity of the module is constant, the user experience is closest to a real scalpel when the module is at position 2 (closer to the hand). When the position of the vibration module is constant, the user experience is closest to a real scalpel when the intensity of the module is at 2.

Experiment questionnaire



Experiment Questionnaire: Scalpel Handle Simulation Rating

Purpose of the Experiment

This questionnaire aims to collect data to assess the realism of the simulated scalpel handle feel, achieved by installing vibration modules on the handle model. Your feedback will be crucial in improving the design of the scalpel simulation device.

Instructions

You will use a handle model equipped with vibration modules, and an Arduino microcontroller will be worn on your wrist. The vibration modules will produce vibrations at different locations to simulate the center of gravity and feel of a scalpel. In each experiment, the location and intensity of the vibration modules will vary. You need to rate the similarity between the feel produced by the vibration modules and the real scalpel on a scale of 0 to 5 (0 being completely dissimilar, 5 being extremely similar).

Participant Information

Age:

18-25 ☐ 25-35 ☐ 35-45 ☐ 45+ ☐

Education Level:

Elementary School ☐ Middle School ☐ High School ☐ University ☐

Master's☐ PhD ☐

Do you have experience using a scalpel? Yes 「」 No 「」

Experiment

Rating Table: Please complete the following table based on your experience after using different devices:

Vibration Module Position Number	Vibration Module Intensity Number	Rating (-5 to 5)	Preference (-5 to 5)
1	1		
1	2		
1	3		
2	1		
2	2		
2	3		
3	1		
3	2		
3	3		

Additional Feedback (5min)

Would you be willing to use this handle device while gaming?
How do you feel overall about using the simulator?
In what aspects do you think the simulator comes closest to the real feel of a scalpel?
In what aspects do you think the simulator differs most from the real feel of a scalpel?
What suggestions do you have for improvement?

c. Programming Phase

With the Unreal Engine SerialCom plugins, the serial port communication can be realized in Unreal Engine5.

4 Dynamics

4.1 Positive feedback

For none medical professional players, this game has an educational value. During the process, they might appreciate how the game provides insight into surgical procedures and human anatomy appreciating the opportunity to learn about medical procedures in a risk-free environment.

For medical professionals, this is a learning feedback process, where one can understand new surgical cases and master techniques during the process. The system's prompts and evaluations can help players adjust better and provide appropriate encouragement.

4.2 Setback

The idea that some surgical procedures present a significant level of difficulty is an acknowledgment of the complexity and unpredictability inherent in real-life surgeries. When translated to a simulator environment, particularly with the addition of an emergency event mode, this complexity is simulated and amplified. It presents a formidable challenge to the player, or trainee, who must not only identify and locate the lesion accurately but also respond to unexpected complications that can arise during the operation.

The challenge is not simply one of knowledge but also of dexterity, decision-making, and adaptability under pressure. This reflects the real-world scenario where surgeons must be prepared for any eventuality. In a simulator, this is an opportunity for medical professionals to practice these skills in a controlled environment. The value of such training is that it allows for safe experimentation and learning from mistakes without real-world consequences.

Moreover, these difficult scenarios in a simulator encourage repeated practice. The deliberate and repeated engagement with challenging situations is designed to build a trainee's competency and confidence. It's a form of deliberate practice that is known to be effective for skill acquisition in complex fields.

The simulator's feedback system plays a crucial role in this learning process. It provides immediate and objective assessment of each action, from the precision of an incision to the management of an unexpected hemorrhage. This feedback allows users to recognize their errors, understand the consequences of different approaches, and adjust their techniques accordingly. Over time, this process is meant to help refine their skills, making them more adept at handling the high stakes and pressure of actual surgical procedures. The encouragement offered by the system, often in the form of scores or progress tracking, serves to motivate and engage users, turning the grueling process of skill acquisition into a more rewarding experience.

4.3 Debate

Willingness to share medical resources

Whether the shared resource platform can be implemented requires further exploration; it may cause hospitals of various types to change their positioning and share their private medical resources publicly.

Adaptation to VR learning surroundings

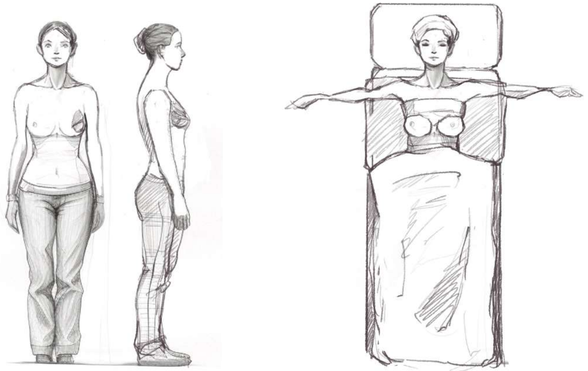
Not everyone can adapt well to the operational process in a VR environment, which may bring about dizziness and discomfort, and some may consider the VR operation to be a cumbersome process.

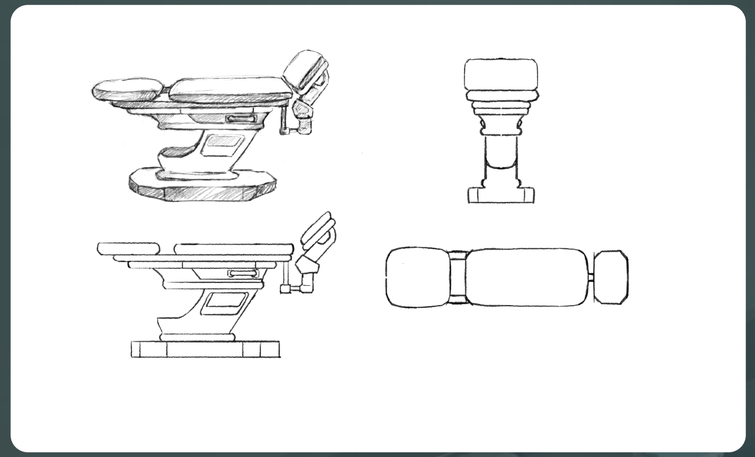
The extent of real-sense realization

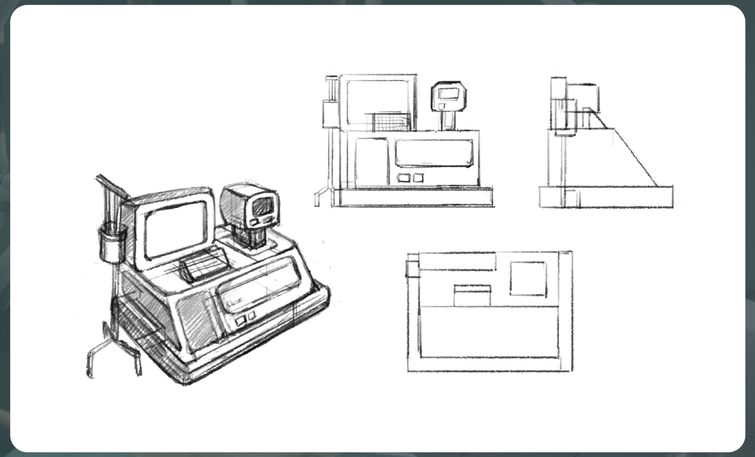
Each player's expectations for the authenticity of surgical simulation may vary.

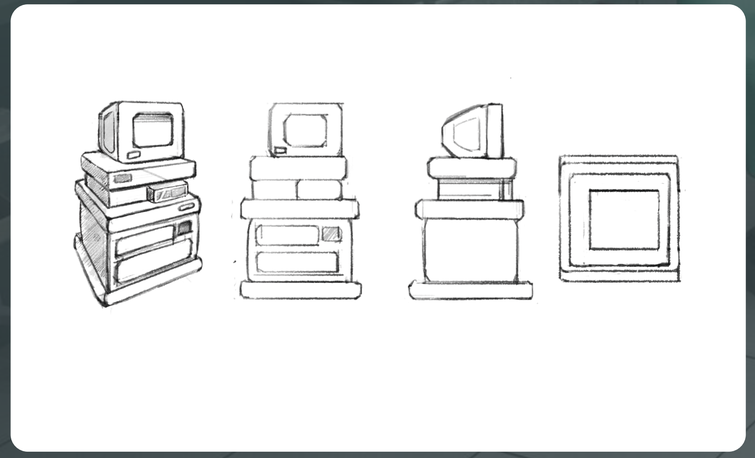
5 Aesthetics

5.1 2D ART

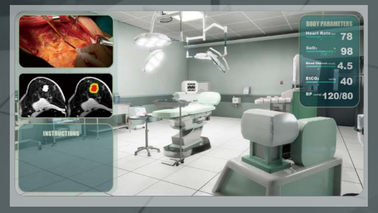








5.4 Game UI



5.3 Game Process

6 Reference List

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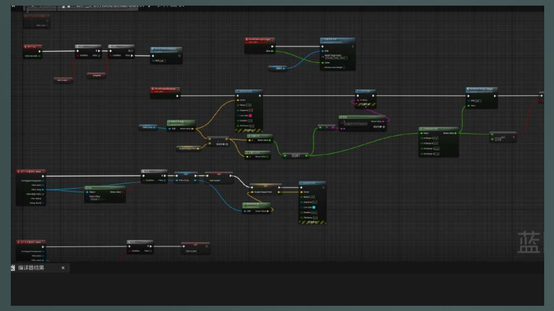
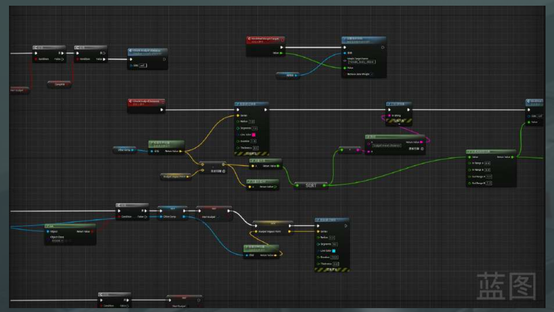
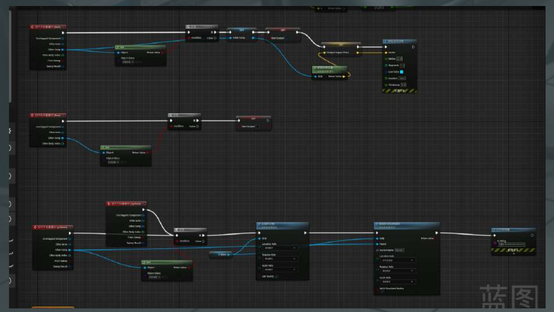
7 Game Blueprint

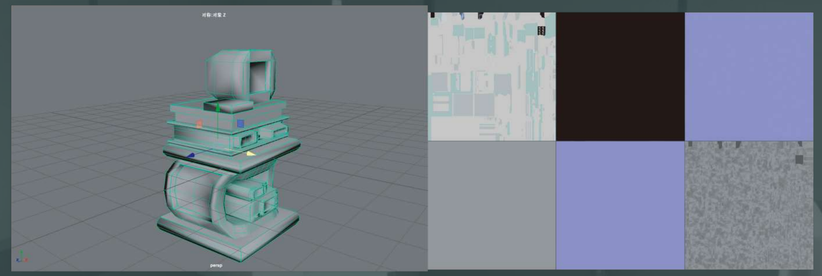


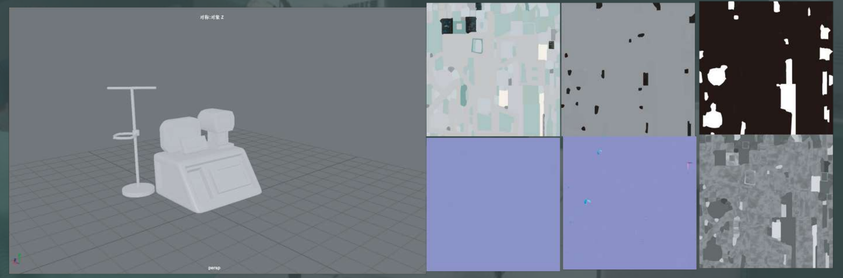


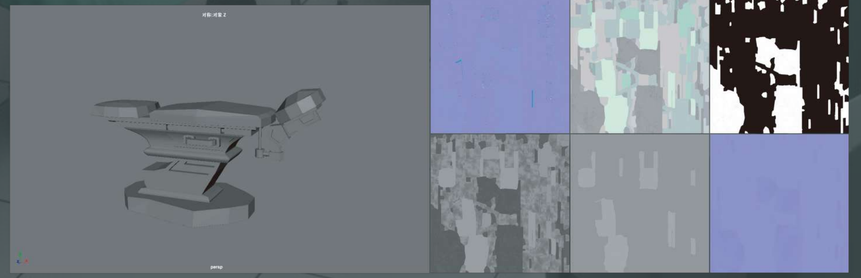


Detect the location and grab instruments and further detection for covering change on skin

8 Game 3D Modle







9 Game Demo