

## Development and validation of a serious game system for Endoscopic submucosal dissection training

Ikeda, Yuichiro  
Kyushu University

Moriyama, Tomohiko  
Kyushu University Hospital

Kudo, Kuriko  
Kyushu University Hospital

Matsuguma, Hiroyuki  
Kyushu University

<https://hdl.handle.net/2324/7385508>

---

出版情報 : International Journal of Asia Digital Art and Design. 28 (3), pp.33-42, 2024. アジア  
デジタルアートアンドデザイン学会  
バージョン :  
権利関係 : © 2024 Asia Digital Art and Design Association



# Development and validation of a serious game system for Endoscopic submucosal dissection training

Yuichiro Ikeda

Kyushu University

lkeda-joho@kurume-it.ac.jp

Tomohiko Moriyama

Kyushu University Hospital

tomohiko.moriyama.153@m.kyushu-u.ac.jp

Kuriko Kudo

Kyushu University Hospital

kudo.kuriko.091@m.kyushu-u.ac.jp

Hiroyuki Matsuguma

Kyushu University

kuma@design.kyushu-u.ac.jp

## Abstract

Endoscopic submucosal dissection (ESD) is a technique for endoscopic resection of lesions and is used in many cases, including gastrointestinal cancers. However, ESD training has the following problems Time and effort required for preparation and training, which can be a burden for busy doctor. In addition, there are cases in which the training is not integrated as part of the endoscopist's hospital duties, so there is a need to develop a proactive and easy system to enable busy doctors to continue ESD training on a daily basis. Therefore, in this study, we developed and verified an ESD training system that endoscopists can implement without spending time, resources, and money. The system consists of a game interface that can be operated in the same way as an endoscope and a game designed for ESD training. After the system was developed, two groups of doctors, one with extensive ESD experience and the other with limited ESD experience, were divided into two groups for the same validation. As a result, it was verified that the system allows training during free time in the office without time and effort for preparation, and that the gamification element of the system makes the training fun and continuous.

**Keywords:** Serious Game, Endoscope Simulation, GameInterface

## 1 Introduction

An endoscope is a medical device used to examine and treat the digestive organs, such as the stomach, esophagus, and intestines. The advantage of endoscopy is that lesions inside the digestive organs can be seen without incisional surgery, and it is widely used in medical practice [1]. One of the endoscopic procedures is endoscopic submucosal dissection ("ESD"). ESD is a procedure in which an endoscope is used to remove lesions in the esophagus, stomach or colon by dissecting the submucosa from the lesion after incising the mucosa surrounding the lesion. With ESD, the inside of the GI tract is viewed on a video monitor through a camera lens attached to the tip of the scope, while electrocautery is applied through a forceps port attached to the tip of the scope to remove the lesion. However, ESD is considered to be more difficult than other endoscopic procedures. This is because routine endoscopy and lesion sampling is not only an unfamiliar procedure because the scope is rarely rotated to manipulate the forceps as in ESD, but also because the structural limitations of the endoscope make it impossible to move the electrocautery and camera lens separately, so the field of view moves along with the forceps, a feature that requires familiarity. In addition, complications such as gastrointestinal perforation and bleeding can occur, requiring non-human training to reduce the risk to patients in real clinical settings. Therefore, training in ESD is considered necessary.

According to "Current state of education and training for endoscopic submucosal dissection: translating strategy and

success to the USA" [2], it is recommended that beginning endoscopists should perform about 20 to 40 gastric ESD, which is relatively less difficult, in order to gain adequate skills in ESD. However, the number of gastric cancer patients is expected to decrease in Japan, [3] and the opportunities to perform ESD in clinical practice are expected to decrease. Therefore, the need for training is expected to increase in the future. Although simulators using resected pig stomach are the training methods for ESD in Japan, [2] this method requires a lot of time for preparation and cleanup, and the endoscopic instruments used for pigs cannot be used for humans due to hygiene concerns, such as infection. On the other hand, interviews with endoscopists revealed that although there are simulators that can provide ESD training, [4] they are not widely used due to the extremely high cost of implementation and running cost. Installation costs often exceed 1,000,000 yen in most cases, and running costs vary depending on the manufacturer's equipment, but cost about 7,000 yen per training session for consumables. Therefore, in this study, it is necessary to construct a system with as low an introduction cost as possible and no running cost. In some cases, ESD training is not integrated into endoscopists' in-house duties, and busy doctors often engage in training after work hours or when they are free from work. Therefore, in order to make ESD training more routine and ongoing, it is necessary to devise ways to make ESD training less time-consuming and labor-intensive to prepare for and conduct. Furthermore, to encourage people to play in their spare time during busy work hours, it is desirable to have specifications that allow people to play casually, as if they were playing a game.

We propose a method using gamification as one of the approaches to address these issues in training.

The purpose of this study is to develop a training game system that will enable beginners of endoscopy to train continuously in their free time at work by incorporating elements that motivate users to train and by designing a system that requires as little preparation labor as possible.

In this study, after developing such a training system, we verified the labor burden of preparation, the usefulness as training, and the user's motivation to train due to the game nature.

## 2 Related Work

### 2-1. current training methods

In "Current state of education and training for endoscopic submucosal dissection: translating strategy and success to the USA" [2] written by Thomas R. McCarty et al., it is stated that ESD originated in Japan and has spread with the Japanese educational system. In Japan, the educational format includes conferences, training, and experience with more difficult lesions, starting with less difficult lesions such as the stomach, and gradually moving on to more difficult lesions under the guidance of a medical advisor.

### 2-2. Examples of Serious Games in the Medical Field

In "Evaluation of App-Based Serious Gaming as a Training Method in Teaching Chest Tube Insertion to Medical Students: Randomized Controlled Trial" [5] written by Patrick Haubrocket et al., a serious game was used as a training method for teaching thoracic tube insertion to medical students. The authors concluded that the use of serious games, in addition to conventional training methods, is an effective method of training for thoracotomy and should be incorporated into the learning curriculum. The results suggest that serious games are an effective training tool not only for thoracotomy, but also for other medical procedures.

As shown in 2-1, training is a step-by-step process, but there are many problems in the training environment, such as cost and time availability, as well as the decrease in the number of gastric cancer patients. Therefore, a game that enables ESD training, as shown in 2-2, is considered to be a useful tool for learning ESD techniques.

## 3 Operating requirements for ESD training

### 3.1 Preliminary Survey on ESD and Endoscopy

Prior to the study, we experienced actual endoscopic operation using a model of the gastrointestinal tract for training at Kyushu University Hospital to understand the operation of the endoscope and the role of each part of the endoscope. In addition, we surveyed endoscopists about the operational requirements of the equipment needed for ESD training. The results of this survey are described below.

ESD is performed using an endoscope, and the operations performed by the physician can be broadly divided into two parts: the angle part and the scope part.

### 3.2 Angle operation

The first operation is to bend the tip of the scope by turning the angulation control knob on the control unit (hereinafter referred to as "angle"). As shown in Figure 1, there are two angulation control knobs (Up/Down control knob and Right/Left control knob) mounted on the angle, each of which can be operated in two axes: pan and tilt. The angle is basically operated by the left hand. In addition, we confirmed that the forceps port is located at the bottom of the camera, so that the scalpel and the like are positioned at the bottom of the angle of view of the camera, and that the tilt direction can bend the scope more than the pan direction in the angle operation, so that the vertical direction is important for ESD. In addition, it was found in the interview that the scope can be bent more in the tilt direction than in the pan direction in angle operation.



Figure 1 Operating part of endoscope angle.

### 3.3 Manipulation of the scope

The scope is inserted into the oral cavity, and the right hand grasps the scope and twists or pushes and pulls the scope. Pushing and pulling are used not only for excision of the lesion, but also for access to the lesion after it has been inserted through the oral cavity.

### 3.4 Interface Requirements for Operating Equipment

In ESD, the patient approaches the lesion, injects a drug into the submucosal layer below the lesion to lift it up, and then operates the scope and the angulation control knob to remove the lesion in a circular pattern around it. Therefore, it was found that the interface of the ESD training game requires a total of four operations: pan/tilt operation of the scope with the two angulation control knobs, and push/pull and twist operation of the scope inserted into the patient's oral cavity, as shown in Figure 1.

The operation interface that enables the operations described in 3.2 and 3.3 is considered to be essential for implementing ESD training games, but there is a problem that there are no common game interface devices such as keyboards, mice, and gamepads that enable operations similar to those of endoscopes. However, there is a problem that there are no devices that can be operated similarly to endoscopes among common game interface devices such as keyboards, mice, and

game pads. Therefore, it is necessary to develop an operating device ("controller") interface with functions necessary for ESD training as described in 3-1 to 3-3.

In addition, although this study is aimed at ESD training, the time and effort required for preparation are obstacles to conducting the training. Therefore, for use by doctors for training, it is desirable that set-up, clean-up, and play be completed in such a short time that it can be completed in the free time available for work and can be performed during busy work schedules. Furthermore, it is desirable for the setup process to be simple so that it can be carried out in the free time available for work. An example of this is simply plugging a USB cable into the computer.

### 3.5 Other requirements to be noted

The training for ESD requires that the trainees become proficient in endoscopic manipulation techniques and then become accustomed to the circular resection around the lesion, which is important in ESD.

In addition, the content of the game should be such that the trainees would want to play it continuously in their free time during their busy work schedule, and the content should be such that the trainees can perform the step-by-step training by themselves without an instructor accompanying them.

## 4 Interface design and development

As shown in Figure 2, this study requires a game for ESD training, an endoscopic interface for operating the game, and data transmission and reception between the interface and the game. In this study, the interface was developed first because it is a manipulation method that cannot be substituted for existing game interfaces such as a gamepad. This chapter describes the development of the endoscopic interface, and chapter 5 describes the game contents.

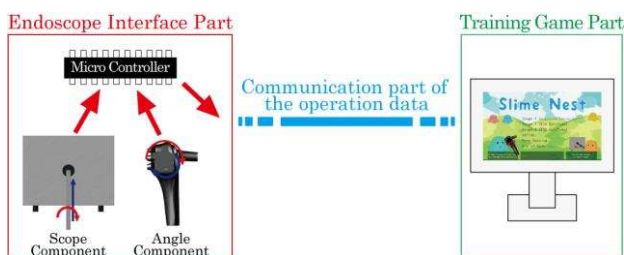


Figure 2 System configuration

### 4.1 Endoscopic Interface Development

The endoscopic interface consists of two components: the angle part (bottom right in red frame in Figure 2) and the scope part (bottom left in red frame in Figure 2). The angle part must be able to operate the two angulation control knobs as described in 3-2, and the pseudo-oral part must be able to twist and push/pull the scope as described in 3-3. It also needs to be easy to set up so that it can be easily used during free time on the job. The interface actually developed is shown in Figure 3. The right side of Figure 3 is the angle and the box on the left side is the scope part.



Figure 3 Interfaces we have developed.

#### 4.1.1 Development of the angle section

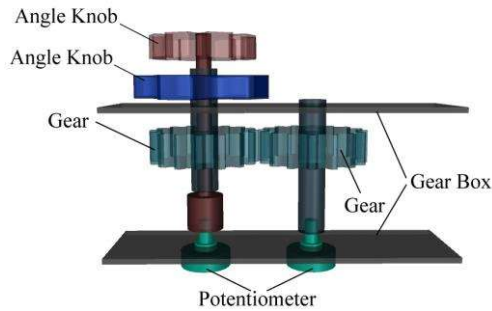
Two angulation control knobs must be used to operate the angle section. Therefore, it is necessary to acquire the rotation angles of the angulation control knobs in the endoscope interface. Therefore, it is necessary to obtain the angle of rotation of the angulation control knobs in the endoscope interface, and a potentiometer is used to detect the angle of rotation. A potentiometer is a component that can return a voltage or current that correlates with the rotation angle of the potentiometer knob, depending on how the circuit is configured. In the development of the angle section, the angulation control knob was coupled to the potentiometer, and the rotation angle was obtained by checking the voltage returned by the potentiometer.

However, since the two angulation control knobs have overlapping axes, the angulation control knob and potentiometer cannot be directly coupled. Therefore, as shown in Figure 5, the rotation of one of the angulation control knobs is transmitted to the potentiometer, which is located off-axis, by means of a gear.

In addition, significant differences from the actual endoscope in the operating area would affect the usefulness of the training. Therefore, since the shape and size of the knob and the feeling of resistance when turning it are important factors in operation, we photographed the actual endoscope simulator's knob and made the shape and size as close as possible. The resistance when turning the knob was tested by an endoscopist, and fine adjustments were made based on his/her evaluation.



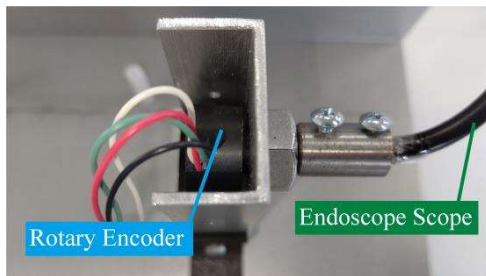
Figure 4 Potentiometer



**Figure 5 Implementation of 2-axis rotation of angle.**  
(In the gearbox in this figure, only the necessary surfaces are drawn.)

#### 4.1.2 Development of Scope Section

Scope manipulation is basically performed with the right hand, but since the manipulation involves twisting and pushing/pulling of the scope, the interface must be able to perform these two operations as well. We first implemented the twist operation. One of the requirements for the twist operation is that it must be able to rotate in both directions, rightward and leftward, with no restriction on the number of rotations. In this study, an optical rotary encoder was used for the implementation. The optical rotary encoder is a device that can detect the amount of rotation based on the waveforms of two built-in photodetectors. By connecting the rotary encoder and a cable prepared as a substitute for a scope, we realized a mechanism that can measure the amount of rotation of the scope. The rotary encoder can rotate infinitely and can also detect the direction of rotation, so it is considered to meet the necessary requirements.



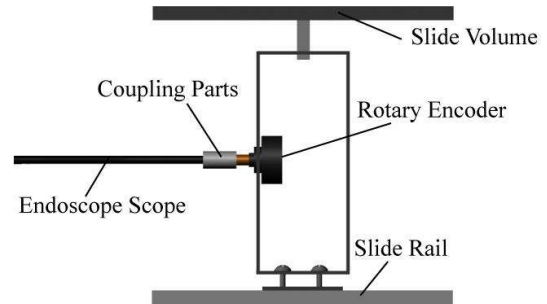
**Figure 6 Setup rotary encoder**

After the twist operation was implemented, the push-pull operation was implemented. In the Push/Pull operation, the endoscopist that it is desirable to be able to push/pull about 2-3 cm, which is required in the lesion resection process by ESD.

However, in actual endoscopic manipulation, a few dozen centimeters in length are inserted during insertion from the oral cavity. However, since this process can be experienced not only in ESD but also in the course of routine endoscopy, we did not include it in the operation, judging that it is not necessary to be able to move the scope in a wide range.

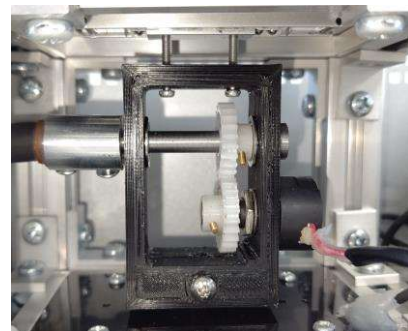
Therefore, we implemented this interface using a sliding volume. A slide volume is an electronic component that can measure movement in one direction, and in this study,

SL4515N-B103L15CM manufactured by Supertech Electronic was used. Since this slide volume can slide about 4 cm and is considered to meet the necessary requirements, we developed a mechanism that enables push-pull and twist operations by attaching the slide volume to the mechanism of a rotary encoder, as shown in Figure 7.



**Figure 7 Scope push-pull structure**

However, due to the problem of the movable range of the slide volume, the force is applied to the thrust direction of the rotary encoder when the force is continuously applied after the slide volume is pushed and pulled to the end. Since applying force to the optical rotary encoder in the thrust direction may cause damage or deterioration, we improved the mechanism as shown in Fig. 8. In the mechanism shown in Figure 8, a gear mechanism is implemented between the scope and the rotary encoder, and the force of rotation is transmitted to the rotary encoder via the gear, but the force of pushing and pulling is not transmitted by the gear, so that the load on the rotary encoder in the thrust direction is not transmitted.



**Figure 8 Mechanism for transmitting rotation to the rotary encoder**

#### 4.1.3 Development of sensor data processing part

In order to send the signals obtained in 4.1.2 and 4.1.3 to the PC running the game, it is necessary to convert all sensor data into numerical data based on voltage and pulse signals. We used a Microchip PIC16F1827 microcontroller to process the signals from each sensor.

However, the data obtained from the potentiometer and slide volume contained minute noise generated by the sliding elements inside the sensors, making it difficult to use them in the ESD interface, which requires precise operation. Therefore, a FIR (Finite Impulse Response) filter was used to remove the noise from the 10-bit AD (Analog Digital) conversion value

obtained with PIC16F1827. The reason for using an FIR filter is that it can be implemented with a PIC microcontroller with a small amount of computation, and the angulation control knob is used for fine position adjustment, so stability is required.

The rotary encoder used to measure the twisting operation was slightly shaken due to hand shaking and the weight of the cable, so the rotary encoder value was smoothed with an IIR (Infinite Impulse Response) filter.

#### 4.1.4 Oral Interface Exterior

To protect the interface control circuit board and the mechanism of the scope section from external factors, they were built into an aluminum case as shown in Figure 9.

However, there were surface wear marks due to the scope's contact with the sides of the holes drilled in the aluminum case during pushing, pulling, and twisting of the scope. Considering the thickness and material of the outer coating of the cable, the abrasion was not such that the cable would break in a short period of time, but since it would cause a deterioration of the appearance, the cable was protected with resin as shown by the red arrow in Figure 9 to prevent abrasion.



Figure 9 Interface for oral manipulation.

#### 4.2 Implementation of data communication between controller and game

Since the controller is used as a game interface, the communication method and speed must be such that the frame rate is not reduced due to bottlenecks in the communication process. In addition, one of the elements of achieving the objectives of this study is to minimize the preparation time as much as possible, we chose a method that can be easily connected to a computer. By using the microcontroller used for the interface and the serial communication cable KP-232R-5V together appropriately

USB terminal can be connected to a PC for communication and power supply. Therefore, the user only needs to connect a USB terminal to complete the preparation.

Both the KP-232R-5V and the microcontroller are capable of serial communication at 100,000 bps or higher, allowing sensor values to be sent at a speed that does not delay the simulation.

## 5 Interface design and development

### 5-1 Game Overview

The game created in this study is a training game for learning ESD operation. Therefore, it is necessary to implement elements that provide ESD training in the process of playing the game. Therefore, we designed a game in which the player repeatedly performs the ESD action of “detachment of the submucosa around the lesion”. We also replaced the elements of ESD with those of the game as shown in Table 1.

Table 1 Replacement of ESD elements with game elements

| ESD Element            | Game Element        |
|------------------------|---------------------|
| Electrocautery Scalpel | Sword               |
| Lesion site            | Slime               |
| digestive organs       | Natural Environment |
| Camera lens            | Game perspective    |

Examples of game scenes are shown in Figure 10 and Figure 11. As shown in Figure 10, the UI showing the progress of the game is placed at the top of the screen, and swords are placed at the bottom of the screen in all stages. The sword at the bottom of the screen is placed as a substitute for an electric scalpel, and the game is played by defeating slimes placed on the playing field. The slimes are placed because they look like slime when they swell after injecting saline into the submucosa of the lesion prior to resection, and because slimes are used as enemies in many games.

Figure 11 is an example of the actual operation. The specifications allow the user to defeat an enemy by sequentially tracing the dots around the enemy, as shown by the arrow lines in Figure 11. The sword mimics the electrocautery of an endoscope, and the game viewpoint and the sword move in tandem. This specification was chosen because the real endoscope cannot control the scalpel and camera separately.

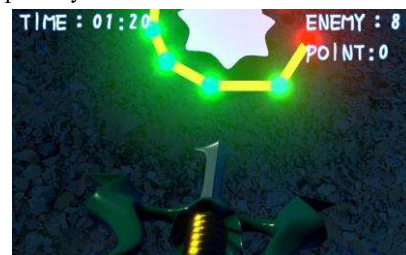


Figure 10 Placement of game elements

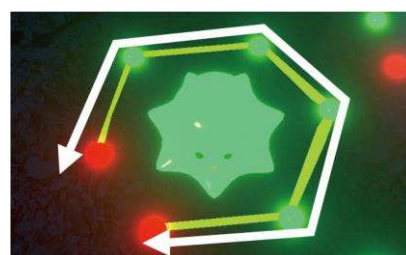


Figure 11 Example of Operation

### 5-2 Development environment and development process

The game was developed using the game development engine Unity[6]. A simple game that can be cleared by ESD-like operations was developed as a prototype, and then the game for test evaluation was completed by repeating the procedure of reflecting the reviews obtained through actual experience by endoscopists. The game is described below.

### 5-3 Game content composition

The scene composition of the game content is shown in Figure 12. The stages were composed of three stages. The reason for the three-stage structure is that the game is designed to gradually increase in difficulty from Stage 1 so that players can gradually become accustomed to ESD through playing the game. The features of each stage are as follows

**Stage 1:** This stage is designed for users who are not familiar with ESD and endoscope operation to get used to endoscope operation.

**Stage 2:** This stage is designed for users who are not familiar with ESD and endoscope operation to get used to ESD operation.

**Stage 3:** Same operation as ESD as in Stage 2, The purpose of this stage is to train the students to perform ESD operations that are more difficult than those in Stage 2.

The following sections 5-4-1 through 5-4-6 describe each scene.

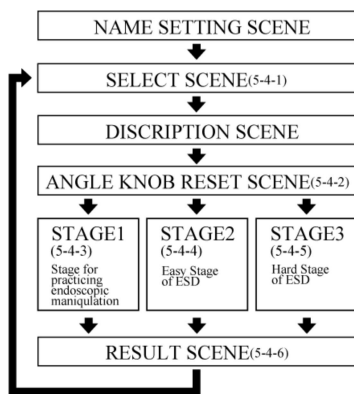


Figure 12 Scene Composition

#### 5-4-1 Stage Select Scene

Figure 13 shows the stage select scene.

In the select scene, it is necessary to use the endoscope interface to switch stages and proceed to the next scene. In this game, the selection is switched according to the angle of the angulation control knob as shown in Figure 14. The next operation can be performed by twisting the scope once. The purpose is to allow busy doctors to select their favorite stages in their spare time by allowing them to move to all stages from the select scene.



Figure 13 Select Scene

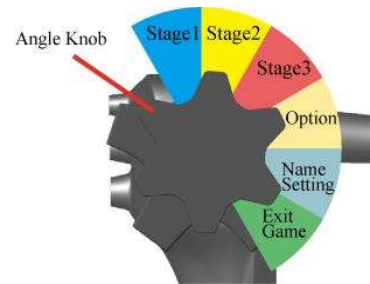


Figure 14 Switching selections in the select scene

In the context of the game, the scope must be twisted at least one full turn in order to advance to the next scene. In order to ascertain that the scope has been twisted once, a method was implemented that acquires and stores the angle of the scope at the time of scene transition, and determines the angle based on the difference from the current twist angle.

However, when the user removes their hand from the scope or returns the scope to its original angle after twisting the scope in order to proceed to the next step, the system erroneously detects that the scope has been turned in the opposite direction and unintentionally returns to the previous explanation. To address this issue, the scope was modified to allow the user to advance one-third of a turn when moving forward, while preventing them from reverting to the previous explanation until they have turned the scope at least one full turn in the opposite direction when moving backward. This approach ensures that, upon releasing their hand from the scope, any rotation due to the torsion of the scope or its own weight does not exceed one full revolution, preventing a false detection. Furthermore, it has been observed that the user often releases their grip on the scope after completing a task for approximately 0.4 seconds, allowing the scope to rotate under its own weight, which in turn results in a high frequency of false detections. In order to address this issue, the scope has been modified to prevent operations from being accepted for a duration of 0.4 seconds after advancing, thereby reducing the occurrence of false detection. The optimal duration of 0.4 seconds was determined through a process of fine-tuning during actual operation. This duration was found to be sufficient for both low false detection and a rapid response.

#### 5-4-2 Calibration Scene

Figure 15 shows a scene in which the angulation control knob is set to a neutral angle. Depending on the angle of the

angulation control knob at the start of the game, the tip of the scope is bent into a "C" shape, and if the game is started in this state, the user may misunderstand that the scope is not bent, resulting in inconsistent operations and confusion during the pre-test. Therefore, we added this scene before the game starts so that users can start the game after adjusting the angulation control knob to the neutral angle.



**Figure 15 Angulation control knob neutral angle setting scene**

#### 5-4-3 Stage 1

Stage 1 is a stage to familiarize the user with the operation of the endoscope as a preliminary stage of ESD training. Since it is difficult to recognize one's own orientation in the digestive organs when using a real endoscope, we designed a stage with the sky, the ground and a forest to make it easier to recognize one's own orientation. (Figure 16)

In addition, since it is difficult for novice endoscopists to perform ESD-like circular resection, we eliminated the ESD element and designed the stage so that the slime can be defeated simply by cutting it with a sword. This stage allows training only on the operation of endoscopic instruments.



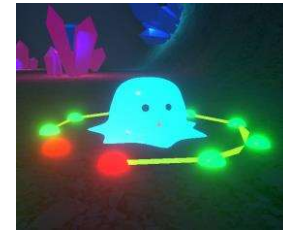
**Figure 16 Overhead view of Stage 1**

#### 5-4-4 Stage 2

In stage 2, the points placed around the slime (hereinafter referred to as "excision markers") are cut in a circular pattern. This operation is similar to the actual ESD, since ESD is also performed by marking the position to be resected. (Figure 17) The color of the resection marker changes according to its state. As shown in Figure 18, the marker to be cut next is red, the marker that has already been cut is blue, and the markers for other resections are green. This is intended to make it easier to understand not only which resection marker should be cut next but also how many markers need to be cut before the slime is defeated.

In Stage 2, the resection markers are arranged in simple shapes ranging from rectangles to octagons, which is less difficult than the circular resection.

In addition, unlike Stage 1, the stage is designed to resemble a cave, and is intended to train the ability to grasp the state of the scope, which is required in actual endoscopic operations.



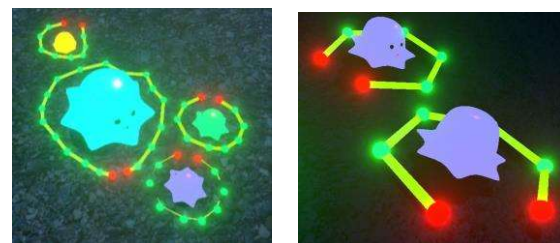
**Figure 17 Stage2**



**Figure.18 Resection marker for user to cut**

#### 5-4-5 Stage 3

In Stage 3 (Figure 19), the number of resection markers is increased compared to Stage 2, and the markers are arranged in ovals and circles with waves. Although the stage 3 Figure 19 is the same as stage 2 in that the resection markers are cut in a circle, it is a more difficult stage due to the complexity of the number and arrangement of the resection markers. The implementation of this stage is based on the assumption that complex shapes are more beneficial for training purposes than monotonous circles.



**Figure 19 stage3 (stage2 on the right for comparison)**

#### 5-4-6 Results Scene

Figure 20 illustrates the results scene. In this scene, the user's score and the top three scores in the past are displayed. The purpose of this feature is to motivate the user to play the game repeatedly by eliciting a sense of competition among endoscopists by comparing their own scores with those of other endoscopists. Additionally, we have constructed a system in which titles corresponding to the scores are displayed along with the scores. The objective of this system is to motivate players to repeatedly engage with the game in order to surpass their own records and attain the associated titles. Scores increase in proportion to the number of slimes defeated. However, since the score is uniform for users who have defeated all slimes, users who clear the game within the time limit will receive points in proportion to the time remaining.



Figure 20 Result Scene

## 6. Evaluation verification and result

### 6-1 Plan for Evaluation and Verification

The evaluation and validation process verified that the system reduces preparation time and effort, that the gamification element makes participants want to train even during their busy work schedules, and that the system is useful as training. The reason for verifying that the system reduces preparation time and effort is that the labor and time cost of preparation is one of the major barriers to conducting training. The reason for the gamification element was to allow busy doctors to enjoy training while they work, since training is not part of the job description at many medical institutions. The reason for verifying that the system is useful as training is that this system is intended for ESD training and should not be just a game with no training effect.

### 6-2 Evaluation Procedure

Given the time and effort required for preparation, we have devised a method whereby participants can experience the setup of the system. This allows us to ascertain whether the

problem has been solved by the system. After playing the game, the trainees experience a series of steps up to the removal of the system. A questionnaire is administered to the trainees during and after the experience.

### 6-3 Subjects

Eight endoscopists at Kyushu University Hospital were selected to serve as evaluation subjects for this system. An evaluation experiment was conducted. The eight subjects consisted of four doctors with experience performing endoscopic submucosal dissection (ESD) and four doctors without such experience. (In the following text, the doctor with experience performing ESD is referred to as the "experienced doctor" and the doctor without such experience is referred to as the "inexperienced doctor.")

### 6-4 Evaluation method

The primary evaluation techniques employed were heuristic evaluation and a four-level choice format. The value of the subject matter was assessed through a heuristic evaluation, with two options of positive or negative, and the value of the subject matter was evaluated through a four-point scale.

### 6-5 Evaluation Items

The evaluation questions are presented in Table 2. Questions 1–5 are designed to ascertain the feasibility of setting up and playing the system in leisure time. Questions 6–14 are intended to assess the system's capacity to provide step-by-step and continuous training in the game portion. Question 16 collects data on the number of training experiences of endoscopists. The final two questions (17 and 18) inquire about the user's willingness to utilize the system as a whole.

TABLE 2 Evaluation Questionnaire Items

| No. | Category | Question  | Choices                                       |
|-----|----------|---|---|
| Q1  | E        | How much free time do you have during work hours?   | Approximate times of long and short free time |
| Q2  | E        | Is the time required to set up and take down this system short enough to be done in your free time?   | F   |
| Q3  | E        | Is the time required to set up and take down the system easy enough to do in your free time?  | F   |
| Q4  | E        | Are the games in this system easy to play in your free time?  | H   |
| Q5  | G        | Do you think it is possible to play intermittently in your free time by being able to select each stage from the title?   | H   |
| Q6  | G        | Stage1 is designed to familiarize the player with the endoscope operation, so it is constructed by the sky and the ground so that the player can easily recognize his/her own direction and so on. Do you think this element is useful for a newcomer to familiarize himself/herself with endoscopic manipulations?         | H   |
| Q7  | G        | Stage2 is designed to cut a simple shape as a pre-training for cutting a circular shape for ESD. This is because we focused only on cutting into a predefined shape because we thought it would be easier to start with than a circular shape. Do you think these elements are useful as a starting point for ESD training? | H   |
| Q8  | G        | Stage2 is a cylindrical stage unlike stage1. Is this useful for training the ability to know one's own orientation?   | H   |
| Q9  | G        | Stage3 is different from stage2 in that it is a circle or a slightly broken oval. This is implemented because we think that a slightly complex shape is more useful for training than a monotonous  | H   |

|     |   |   |                       |
|-----|---|---|-----------------------|
|     |   | circular shape. Do you think this is useful for training?   |                       |
| Q10 | G | Do you think Stage2 and 3 is useful as a training for ESD to cut a lesion in a circular or oval shape?  | H                     |
| Q11 | G | Do you think it is possible to use Stage1 to Stage3 in a gradual step-up manner?  | H                     |
| Q12 | G | After playing the three stages, in what order did you find them difficult and why?  | Sort by<br>difficulty |
| Q13 | G | Would you like to play repeatedly to beat your best time by the score function?   | H                     |
| Q14 | G | Do you want to practice more by comparing your score with others?   | H                     |
| Q15 | U | Do you think this system is useful for doctor who have no previous ESD experience to practice basic endoscopic manipulation? (Questions: rotation Up/Down control knob, rotation Right/Left control knob, scope twist, scope push/pull) | H                     |
| Q16 | - | Please describe the approximate number of times you have experienced ESD training.  | Experience<br>Count   |
| Q17 | U | Would you like to use this system in your spare time?   | F                     |
| Q18 | U | Would you like to use this system repeatedly?   | F                     |
| Q19 | G | The slime in the game was inspired by a lesion inflated with saline solution. If you have any comments on this point, please circle the one you think is good or bad.   | H                     |

• The category "G" refers to gamification, "E" refers to effort and time consumed, and "U" refers to willingness to use the system. In Choices, H refers to a two-choice evaluation of usefulness, and F refers to a four-point scale.

#### 6-6 Result

The results are presented in Figure 21. In question 1, the shortest amount of free time available during work was 5 to 30 minutes, while the longest amount of free time available was 30 to 240 minutes. The longest answer was 240 minutes, with the remaining seven respondents indicating that they had less than an hour of free time available.

In response to question 2, which inquired as to whether respondents could install and remove equipment during their free time, the three experienced doctors and all inexperienced doctors selected either 4 or 3.

Question 3, which inquired as to whether respondents could easily set up and take down the system in their spare time, was answered 4 or 3 by all experienced doctors and three inexperienced doctors.

All respondents, regardless of experience, answered affirmatively to questions 4 and 5, which inquired about the ease of engaging in leisure activities at work. Questions 6 through 10 pertained to the design of the game for user training at each stage. In question 6, all subjects, including both experienced and inexperienced doctors, indicated that the stage design of stage 1, which comprises the ground and the sky, is beneficial for facilitating user direction comprehension.

In question 7, three experienced and four inexperienced doctors rated the stage design of a simple shape, such as a rectangle, as useful for training before cutting the ESD into a circular shape.

In question 8, which inquired as to the potential for the stage 2 design to develop the capacity to comprehend the orientation of the scope, all three experienced and inexperienced doctors indicated that it was beneficial. The experienced physician who asserted that it was not beneficial posited that the actual ESD was fixed and exhibited a limited range of patterns.

To ascertain the value of a more complex form of resection for

training purposes, we posed the question in question 9. Three experienced doctors and all inexperienced doctors responded that it was beneficial. The surgeon who indicated that the game was not useful stated that he believed the circular shape alone was sufficient. Question 10 inquired whether the Stage 2 and Stage 3 games were useful as training for ESD circular incisions. All surgeons, both experienced and inexperienced, rated the game as useful.

Questions 11 and 12 inquired whether it was possible to progress by playing levels 1-3 in sequence. All respondents answered "yes" to question 11, but only one respondent, both experienced and inexperienced, answered that the difficulty level increases in the order of level 1, level 2, and level 3.

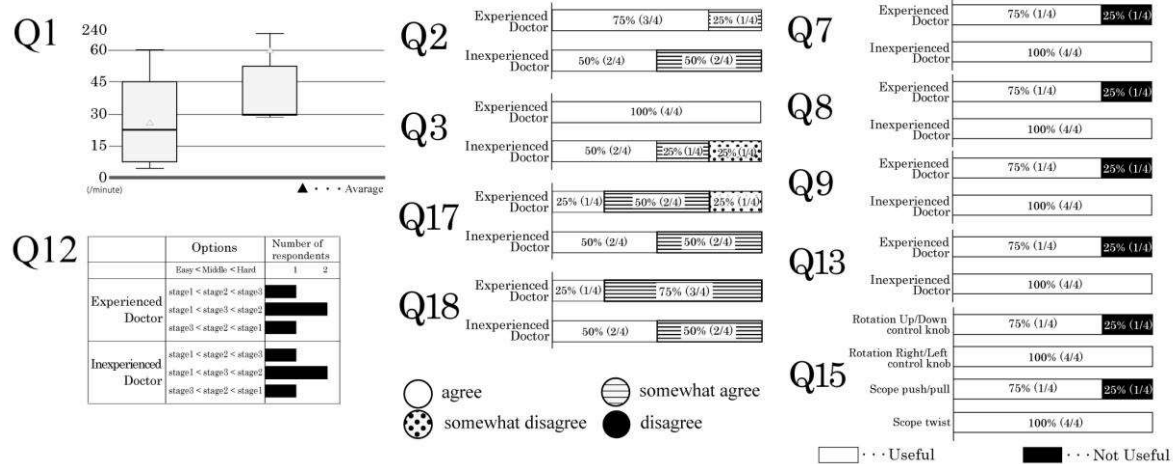
Questions 13-14 asked about the motivation for using the score scene. The results showed that 3 experienced and 4 inexperienced respondents answered "useful" in question 13.

In response to question 15 regarding the usefulness of this system for ESD training for inexperienced doctors, three experienced doctors indicated that the system was useful for vertical manipulation of the angulation control knob and scope insertion, and all responded that the system was useful for horizontal manipulation of the angulation control knob and scope rotation. All of the inexperienced doctors responded that all of the maneuvers were useful.

Questions 17 and 18 asked about their intention to use the system. Three experienced doctors selected 3 or 4 and two inexperienced doctors selected 4.

In question 18, all experienced and inexperienced doctors selected 3 or 4. In question 18, there were some comments such as "If it were permanently installed, it could increase the score.", "I think this game is good, but if it has more stages to play it will be better", and "I think this game is good, but if it has more stages to play it will be better.

N = 8 (Experienced Doctor=4, Inexperienced Doctor = 4)



※Q4,Q5,Q6,Q10,Q11 and Q14 were omitted from the because all respondents in both groups answered “useful” .

Figure21 Evaluation result

## 7. Discussion

The results of Q2, Q3, and Q4 indicate that the problem of time and effort required to prepare for ESD training has been solved. This suggests that busy doctors can easily devote a little free time to training compared to conventional training. The results of Q17 and Q18 indicate that the users feel that they would like to continue using this system in their spare time. In terms of running costs, there are no running costs because this system has no consumable parts to wear out. Regarding the gamification element, the results of Q5 indicate that each stage has a gradual training process, as indicated by the results of Q11, and the results of Q13-Q14 indicate that the game makes players want to play repeatedly to beat their own best or other people's scores. Furthermore, the result of Q15 shows that this system is useful as an ESD training system. This indicates that this system is not just a game with ESD motifs, but a game content that can be used for training. In conclusion, this system is useful as a training system because it does not require time or effort for preparation, can be used in one's spare time, and can motivate users while increasing their motivation through the gamification element. In terms of future improvements, firstly, there are only three levels at present, so long-term use of the system, such as on an annual basis, may lead to boredom. Therefore, improvements such as increasing the number of levels, adding random elements, and creating a sense of accomplishment are needed to prevent players from getting bored. Some users felt uncomfortable with the size of the angle part of the interface, so it is considered necessary to improve the interface to make it easier to use by referring to actual endoscopes. In addition, this verification did not examine the training effects of long-term use or the frequency of use. It will be necessary to conduct verification by permanently installing the system at medical sites for a long period of time while improving the system.

## 8. Conclusion

As discussed above, the system developed in this study is useful for busy doctors to train ESD while maintaining

motivation in their free time. This system can meet the demand for training due to the decrease in gastric cancer in Japan, and we hope that it will contribute to the further development of ESD. In the future, it is necessary to conduct experiments with more inexperienced ESD doctors and improve the system for training. We will conduct additional verification and confirmation of the effectiveness of this system by examining the pre- and post-technical skills of a group of users who used this system and a group of users who did not use this system.

## Acknowledgments

We would like to take this opportunity to thank Kyushu University Hospital and all the people who participated in the evaluation experiment.

## References

- [1] Mitsuhiro Fujishiro, Takayuki Matsumoto, History of endoscopes: Contribution of the Japan Gastroenterological Endoscopy Society, Supplement Issue: History of Endoscopy: The 100th Anniversary of JGES, pp13-14, Volume34, IssueS2. May 2022
- [2] ThomasR.McCarty, Hiroyuki Aihara, Current state of education and training for endoscopic submucosal dissection: translating strategy and success to the USA, Gastroenterological Endoscopy, Vol. 63(3), Mar.2021
- [3] National Cancer Center, Statistical Information by Cancer Type Stomach (in japanese) [https://ganjoho.jp/reg\\_stat/statistics/stat/cancer/5\\_stomach.html#anchor5](https://ganjoho.jp/reg_stat/statistics/stat/cancer/5_stomach.html#anchor5).(access 2024/1/21)
- [4] KOTOBUKI Medical , The next generation ESD training system is born.(in japanese),<https://kotobukimedical.com/esd-training/G-master/>(access 2024/1/23).
- [5] Haubruck P, Nickel F, Ober J, Walker T, Bergdolt C, Friedrich M, Müller-Stich B, Forchheim F, Fischer C, Schmidmaier G, Tanner M, Evaluation of App-Based Serious Gaming as a Training Method in Teaching Chest Tube Insertion to Medical Students: Randomized Controlled Trial, Journal of Medical Internet Research 2018;20(5):e195
- [6] Unity, Unity.com, <https://unity.com/ja> (access 2024/1/21)