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Fire Simulation And Disaster Prevention Education System By Mixed Reality

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Abstract
In a country with many natural disasters, disaster prevention education is a very important issue, and fire evacuation drills are conducted annually at facilities and schools. An increasing number of studies are developing disaster prevention training systems using virtual technology.This study examines the trade-off between computational resources and reality, seeks efficiency and cost reduction of fire simulation, and proposes a fire evacuation training system using mixed reality. "Burn" objects in the real space using the spatial recognition characteristics of mixed reality (Hololens), and reduce the time and effort to build virtual models It becomes possible to instruct users in real-time by using joint online. Simultaneous joint evacuation of multiple people can also be simulated, increasing efficiency as a virtual evacuation. Represents a flame that uses both texture animation and particle systems to match the contact surface. The sense of truth rises as long as the function of the equipment is not exceeded. According to the experience survey, it was confirmed that the impact and the extent to which the impression was impressive are effective as evacuation education. It can be used directly at home or in a public facility, and consumables and labor costs can be expected to be fairly low.
Keywords: *Trade off，Mixed Reality,Hololens, Fire Simulation, Disaster Prevention Training, Virtual Reality.*

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I. INTRODUCTION

In recent years, research related to disaster prevention is developing using virtual technology. Especially in Japan, the frequency of earthquakes is very high. Countermeasures related to disaster prevention and medical care are always serious and life-threatening issues[1)-2)]. However, during the earthquake, there was a large number of deaths caused by secondary damage as fire. In the fire, deadly toxic gases can deprive people of their activity in a short time, so the efficiency of evacuation is quite important[3)]. Pre-training is often performed to prevent anxiety disorders such as panic and helplessness.

Here, the method using the conventional virtual reality technology can construct difficult screenswith digital models. Since there are no restrictions on materials in the virtual space, it is possible to expect a more stimulating effect than reality. However, you have to make one scene and one object. And the stimulating effect on the same screen tends to decrease. The connection with reality is deeply related to the image abilities of the participants, and the effect depends on the quality of the screens.

Therefore, we are thinking about a solution that uses mixed reality to connect the real world and virtual space realistically. Mixed reality allows you to change what you see in real-time, reducing the steps to build a virtual space. It is proposed that the space recognition function of the mixed reality facility "Hololens" be used to calculate and represent the evacuation mark and emergency supplies recognition and fire screen in real-time. When it is used for disaster prevention drills, it shouldbe used both in school offices and factory floors, user can experience the evacuation of a fire realistically, it will be psychologically prepared, and as a disaster prevention drill, itneeds to improve efficiency in lower costs.Furthermore, it is possible to enrich the disaster prevention education system by methods such as multiplayer join in the online experience, training with virtual characters, odor and temperature sensation enhancement, special position sensor system, and 5G communication database collection.

The purpose of this research is to elucidate a fire simulation method by using mixed reality, construct a system that can be used for disaster prevention education, improve psychological stimulation effects, and reduce costs.For this purpose, we will study the trade-off between computational resources and reality, calculate the position to set the fire, and examine it while testing the realistic flame model and the stimulating effect of the screen in accordance with the development of mark recognition accurately. And to promote the development of disaster prevention education system in all directions.

II. RELATEDRESEARCH

In recent years, Japan has been developing in various areas due to disaster prevention issues. The cause is that 20.5% of the earthquakes of magnitude 6 and above that occur in the world occur in Japan, and the number of active volcanoes is occupied by 7.0% of the world[1)]. Besides, in the case of an earthquake fire between large cities such as Tokyo and Kyoto, if the fire probability is 0.00048, the probability of a room being burned will be about 0.9 for a 5000-community[2)]. Although efforts are being made in each area to reduce the mortality rate in Japan, disaster prevention is a life-threatening issue.

Here, the cause of emphasizing the importance of disaster prevention education is an important part of the education in which disaster prevention education lives because proper judgment at the disaster site can save lives[3)]. People who should be savedoften lose their lives by panic.

In 2017 Mizuno team[4)] proposed a method to automatically generate evacuation routes using virtual space. It solves the problem that the participants have too much freedom and can move even in a VR environment. But lack of reality and impact.

In 2008Takebe team[5)] carried out a fire evacuation simulation toward teachers.According to the literature, all evacuation of the school's designated route was completed, but in the event of an unexpected fire,all the people were failing to evacuate. Since there is a possibility that the evacuation route may have unexpected situations and cause panic, it is necessary to conduct a simulation that can handle a wide variety of situations.

NTT FACILITIES Research[6)] has created a tsunami and fire evacuation simulator for outdoor use by improving the functionality and lowering prices using VR/AR, and you can conveniently experience assembling with a smartphone and glasses. When an experiment is conducted at an elementary school in Mitaka City, Tokyo, it has an AR function and it has educational meaning for disaster recognition, but there also have some weak points that the simulated screen is not impact enough and the connection to the real-life is insufficient.

In 2019 Itamiyateam[7)] developed a simulator application that virtually fires and extinguishes the fire with AR, for cost reduction in fire extinguishing training. It needs a real fire extinguisher with virtual water spray training, but it may be more suitable for firefighters than the general public,and it was lack of impact in smoke and flame.

MR connects the real world and virtual space like AR, it can calculate and express complex screens like VR in real-time witha strong impact. 3D model reproduction in the room has evolved into an automatic processing method, and precision is increasing[8)]. The great advantage of "Hololens" [9)] is that holograms can be expressed with high precision and the current position can be calculated using a 3D map while recognizing the surrounding space.

III. SIMULATEFIRE

3.1 Proposals for fire evacuation drills

When conducting evacuation drills according to the evacuation route, it is necessary to express fire and smoke in a fairly wide area and move over long distances. Here, we consider large-scale disaster prevention drills that are as realistic as possible with limited computational resources.

As shown in Figure 1, there are several possible evacuation drill routes depending on the fire. However, it is almost impossible to represent all the flames in the facility due to limited computational resources. The saving of computing resources is solved by the method that the part other than the user's view is not displayed on the display. Since the system settings are used indoors, it is rare to see it at a distance of 10 meters or more and it is difficult to see normally, so the number of flames is limited to match the user's current position, and the flame is expressed only within 10 meters of the user. Also, if the number of flames is small, the impact is insufficient, so smoke that emphasizes the atmosphere of the fire scene is required. Install smoke only in front of the user to save computational resources. To increase reality, add a timer to increase the smoke density as time goes on from the beginning of the system. Furthermore, if the number of flames is small, the impact is insufficient, so smoke that emphasizes the atmosphere of the fire scene is required. Install smoke only in front of the user to save computational resources. To increase reality, add a timer to increase the smoke density as time goes on from the beginning of the system.

Furthermore, to emphasize reality, it is necessary to express evacuation instructions as naturally as possible, so as shown in Figure 1, set up evacuation marks at each important position so that there is no discomfort. The evacuation mark is not compulsory when guiding the user's evacuation behavior to the expected evacuation route. This added uncertainty to the disaster drill. If a fire occurs at a place other than the planned fire point, the user must make his judgment according to the fire position. Simulating a dangerous situation where there is a fire or an obstacle in the expected path makes it possible to train sober thoughts and determination.

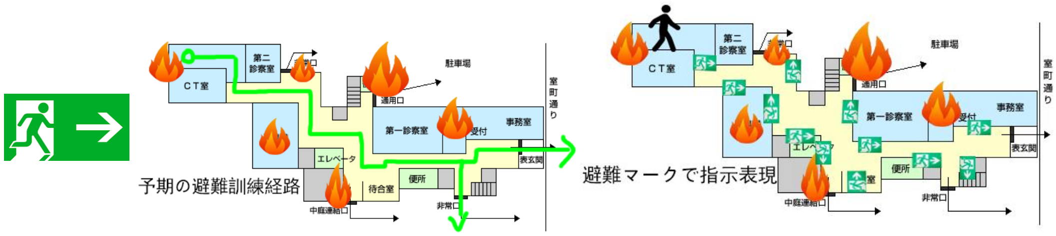


Figure1:Evacuation drills

3.2. System design

In the development environment of this research, one PC runs Windows 10 with software Unity3D (v2018.2). The hardware used was one Microsoft HoloLens, and the mark recognition used AR development SDK Vuforia Engine 9.0. Images and objects were created with Photoshop and 3ds MAX.

The place where the line of sight hits the object is the viewpoint. Determine if the fire-causing object on the ground is insight. After determining that it is a hit, first activate smoke. Express the evacuation mark clearly when looking at it. There are two judgment conditions to ignite, and the current flame quantity ‘n’ is set to 25 because of the function limitation of the equipment. Then, the accurate ignition positionis determined. If both are satisfied, voice data and flame expression are started at the same time, and flame information is stored in the array. Since HoloLens does not have a GPS sensor, the distance between the array element position and the current camera (HoloLens equipment) position is determined so that the fire is always expressed only around the user position. When it exceeds 10 meters, the array element and its flame are extinguished, the number of possible flames is increased, and then the process returns to the judgment of the ignition condition. The system continues until the user stops the software directly.

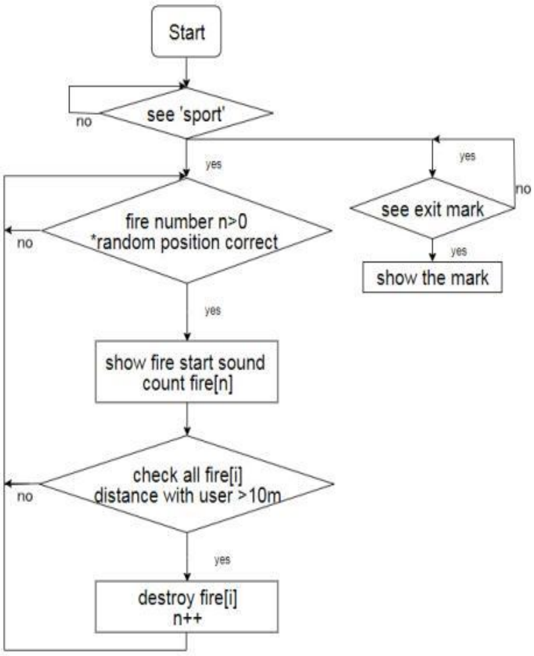
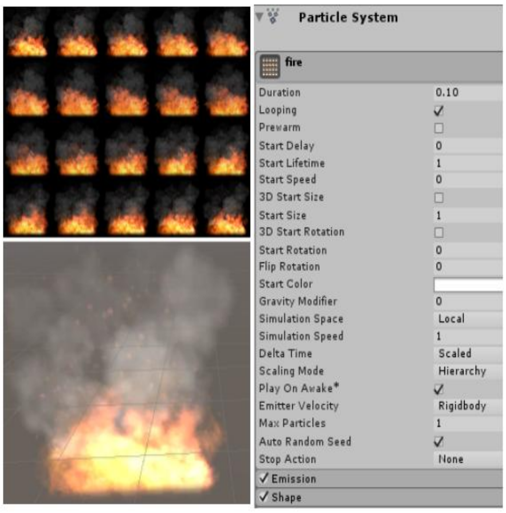


Figure2:system design

3.3 State of flame

The expression of the flame is an important part of considering the trade-off between computational resources and reality. To express the flame, consider use the texture animation at the first, but it is difficult to express the ideal effect for a detailed model due to overlapping motions like a flame. Therefore, consider using the particle system of unity. The particle system certainly takes computational resources, but it requires a minimal amount of reality representation.



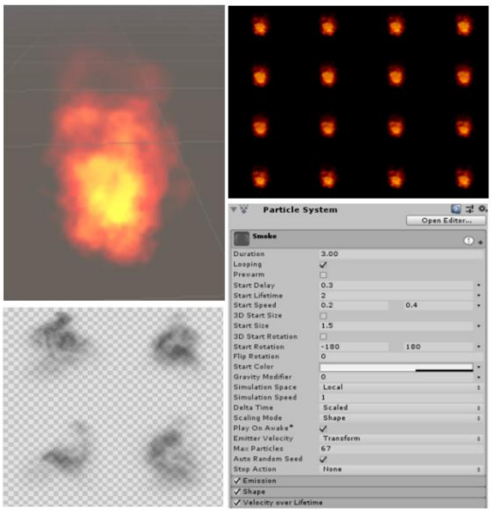
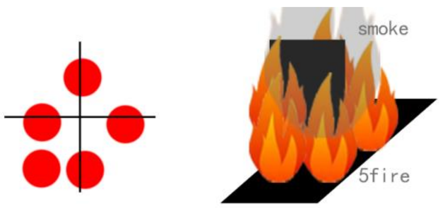


Figure3:space fireFigure4:fire and smoke

As can be seen in Figure 3, using the particle system with 20 consecutive images as a material can express a flame. Depending on the material, there is a problem that the shape is flat and the 3D effect is insufficient. Although it can be expressed normally when used on a flat surface such as the ground, it may not fit on a slender, slanted object such as a chair.

As shown in Figure 4, smoke and flame are expressed separately. A single smoke can express its density and position over time and match the characteristics of the fire.

The arrangement shown in Figure 5, a small material is used for the flame, and five flame bodies with one smoke are stacked to make one set. It's like a chair, which can accommodate blocking surfaces and irregular objects.



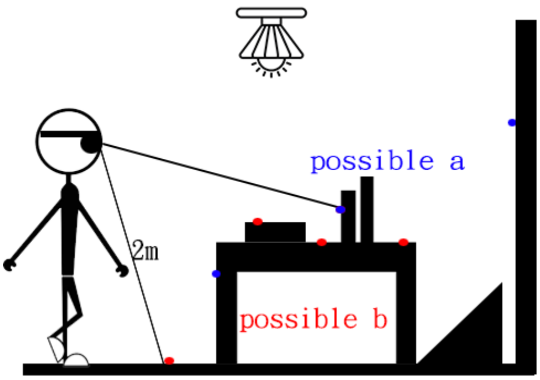


Figure5:Fire structureFigure6:positions

3.4 Judging position determination

MR can recognize the space, but it also recognizes the ground and walls as obstacles. So, here we build an ignition system that uses the coordinates of the camera.

To simulate a fire, the selection of the location of the fire is a very important part. Determine which areas are hard to burn and which are easy to burn. Ceilings, walls, and high hangings can be burn, but they are infrequent and difficult to express.Frames and rods, which are thin and vertical, are often iron and hard, so they are burned less frequently. Objects such as tables, chairs, and beds that have a gentle deformation and a large surface area have a high burning rate and are easy to express. Depending on the function of the equipment, it may not be possible to display within 1-2 meters from the equipment position. Then, to enhance the sense of presence, it is decided to randomly represent the flame as close to the participants as possible.

As shown in Figure 6, the lighting position simulates the line of sight from the equipment. The point ‘b’ that hits the vertical axis at random within 6 meters from the hitting point ‘a’ and within 2 meters from the equipment position is determined. It is established that the plane with point ‘b’ does not hit an obstacle within 0.01 meters of the periphery.

3.5 Predetermined ignition position

When performing disaster prevention drills, there are many cases where ignition positions are set in advance to add difficulty and special conditions. A flame poster is attached to such a special position, and when the user approaches the poster, the poster screen is recognized and a large flame is ignited. This flame is set so that it will not disappear once it is ignited, regardless of the flame number n, so that other co-training devices can be seen.

3.6 Simulate joint evacuation

The conventional virtual disaster drill is a single-person evacuation drill that simulates a fire scene using one experience device. However, when it comes to reality, there are many fires in public facilities, so there are many emergencies and it is more difficult to evacuate. In disaster prevention education, many evacuation drills are often conducted.

A joint online system that uses a large number of Hololens devices is required to simulate disaster prevention drills in which many people can participate.

First, share the screens of many Hololens devices. Using the Microsoft development document "HoloToolkit-Sharing-240", the coordinates and screen of the host device can be shared with the host IP. Other devices run SharingService.exe to change from localhost to IPv4 address. With this, the flame is ignited centering on the coordinates of the host device, and the instruction of the evacuation mark is also expressed in its original position. In this way, it becomes possible to simulate a gathering of people and their judgments, like a fire scene.

IV. EXPERIMENTS AND RESULTS

4.1 Experimental scene

Figure7:Experimentscene

Figure8:Chair

Actually putting the system in HoloLens and seeing the effect, as you can see in Figure 7, the expected basic functions can be realized overall, and the impact is quite strong. I found some problems with it. It takes more than 20 seconds to start. The location of the flame may not be in front of you, but you can immediately hear a sound simulating a fire. There is a lot of smoke, it looks good on a computer, but it is not well represented on the HoloLens screen.

As you can see in Figure 8, you can see the effect of arranging five flames. The flame model can be expressed as a cutoff that matches the chair, and the effect of enclosing the chair is achieved.

Figure9:Evacuation mark

Figure 9 shows the evacuation mark installed on the evacuation route for guidance. It is possible to clearly express how the person should be alert when he or she looks at the evacuation mark. The direction is visible even in a bright flame.

For the MR fire simulation, we made it possible to “burn” things in the space where the participants were in real-time, and to experience the real fire scene. By using mixed reality, instead of imagining reality like VR, we directly simulated the disaster scene in the real world. The problem of lack of realism for the participants has almost disappeared and impact reality has been realized.

4.2 Participant questionnaire survey

Execute a questionnaire survey to eight participants to examine the experimental results. Among them, one is 0-20 years old, six is 21-40 years old, and one is 41-60 years old. All participants are healthy participants with no particular psychological or physical disabilities. In addition to explaining the purpose of the experiment to the participants, the questionnaire survey was explained as "To conduct a user survey to judge the effect of a part of the disaster prevention training system by MR. Main experimental function: Fire simulator". Participants were allowed to test the proposed system wherever they like without limiting the place. Participants also consider the condition impact of virtual product experience and fire experience. We conducted a questionnaire survey and analyzed the extent to which reality, fear, and impact were impressive.

Figure10:Feeling of truth and fear

The results of the questionnaire analysis show the overall effect, and it can be judged that there is an impact. As you can see in Figure 10, more than 80% of the participants can feel real, but there is still a sense of discomfort than the real thing. And, regardless of the experience of fire, the fear of this simulation can be expressed in an appropriate degree. The fear can be controlled from the direction such as the amount of smoke and the amount of flame depending on the purpose of use. For example, when conducting disaster prevention education for minors, it may be necessary to refrain from the safety aspect to reduce the fear and implement it.

Figure11:Impression of simulation

The impressive impact is a very important part of disaster prevention education. The stronger the impression, the stronger the awareness of disaster prevention. Since we expect an evacuation experience that we can wear, we examined the memorable degree at the end of the questionnaire survey, and as shown in Figure 11, half of the participants feel that it is a very impressivefire experience, and half of the participants feel ordinary. We believe that the effect of evacuation education has been slightly improved.

Next, in the result analysis, the experience history of the virtual equipment and the impact of the fire experience is summarized and analyzed in a form. As can be seen in Table 1, those who have experience with virtual equipment are a little more satisfied than those who have no experience, but there is no major distinction. When applied to disaster prevention education, it can be used without virtual experience, but if conditions are met, it is more effective to carry out training in advance.

Table 1:Virtual experience

VR experience	Seriously help	good experience	Just feeling	only remembered	Useless
have	1	1	2	0	0
never	0	2	1	1	0

As shown in Table 2, the influence from the fire experience can be felt more by the fire experienced person than by the inexperienced person, but the impact is not so impressive. The cause maybe that the experienced person remembers the fire of memory and strengthens the sensation, but it may not be more impressive than the real fire. On the other hand, inexperienced people do not have such strong empathy when they experience it, but they may be quite impressive as their first experience.

Table2:Fireexperience

Fire experience	Close to real	High quality	ordinary	Discomfort	can't feel it
have	1	1	2	0	0
never	0	1	2	0	1

Fire experience	Seriously help	good experience	Just feeling	only remembered	Useless
have	0	1	2	1	0
never	1	2	1	0	0

V. CONCLUSION AND FUTURE

The proposed system realized large-scale disaster prevention drills with limited functions, and at the same time simulating the uncertainty of the fire site. Achieved cost reduction by improving the effect of disaster prevention training.

In the future, when using a multiplayer shared online, if add an interaction function and a leader, it will be possible to educate professional disaster prevention skills. In particular, with the development of 5G communication technology, collective disaster drills can be carried out not only indoors but also anywhere, and it is possible to collect problems of user expressions and evacuation routes in a database and contribute to the advancement of social disaster prevention systems.Furthermore, it is possibleto develop a technique that enhances the real sensation by adjusting the temperature with a sensor-equipped odor generator and a sensor system.

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