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Image Recognition Based Precursor Detection System for Landslide Prevention

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***Abstract*—In recent years, landslides caused by excessive reclamation and natural disasters have caused many lives and economic losses. Therefore, in addition to the most fundamental method of preventing ground landslides, being able to detect signs of landslides to a certain extent is also a way to prevent loss of life and finances. Currently, satellite imagery and aerial photography are the main methods for landslide detection. However, it is sometimes impossible to confirm the ground through this method due to trees and other obstructions. Therefore, some areas are calling on local residents to record the location and size of cracks and report them to local authorities if they think there are signs of landslides. In this paper, the purpose is to develop a landslide detection system. This system combines image processing and artificial intelligence, and is paired with a multi-functional head-mounted AR display to assist professional civil engineers in identifying possible stratigraphic landslide signs. The AR display marks directions to a set destination and records signs of landslides read in real time from the camera as it moves.**

Keywords—Vision Systems; Machine Learning; Decision Making Systems

I. Introduction

In recent years, landslides caused by natural disasters and over-cultivation have become quite common. Japan and Taiwan are also earthquake-prone and typhoon-prone areas. According to statistics, in 2023, 1,471 landslides have occurred in Japan[1]; In 2024, 1,732 landslide potential areas are predicted in Taiwan [2]. Therefore, how to prevent landslides, effectively detect landslide precursors, and promptly notify and evacuate people before disasters occur will be an important issue [3].

Recently, the mainstream method for detecting landslide precursors is to use satellite and aerial images to assess the possibility of landslides [4][5]. However, when using this method, it is sometimes difficult to see the obscured ground due to trees and other obstacles [6][7]. Therefore, it is necessary to confirm the signs that are actually present on the ground surface. Moreover, when conducting field surveys, since landslides may not occur in all locations, it is necessary to designate driving routes in areas where landslides are likely to occur. In addition, if people without professional knowledge can also recognize signs of landslides and then record the location coordinates of the discovered landslide precursors, then landslide investigation will become easier.

In order to improve the above issue, the purpose of this research is to develop a landslide detection system. The system uses a computers with image processing and artificial intelligence computing capabilities, and AR head-mounted displays with network communication capabilities and cameras to capture images/videos with GPS location information for landslide detecting, and display the route to the destination. AR head-mounted displays are used in mountain areas because it is dangerous to have both hands free and because smartphones have a narrow viewing angle.

II. System Overview

The proposed system consists of multiple equipment that includes high-performance computers capable of processing image data at high speeds and performing machine learning, AR head-mounted display, GPS receiver and camera. According to the function in the system, it is simply divided into data acquisition end, data processing end and user end. The overall system architecture is shown in Fig. 1. The data acquisition end includes the camera and GPS receiver. The data processing end is mainly responsible for image processing and image recognition, and stores all needed data, the data it saves includes image libraries used for machine learning, images/videos captured by cameras, and GPS of image locations. The user end is AR head-mounted display. When the user performs detection, the system uses images/videos captured by the camera to detect cracks in the ground. At the same time, the system also records the location where the image was captured, and then transmits the image and location data to the computer at the data processing end. Considering the uneven terrain that may be encountered during field surveys, sports HD cameras

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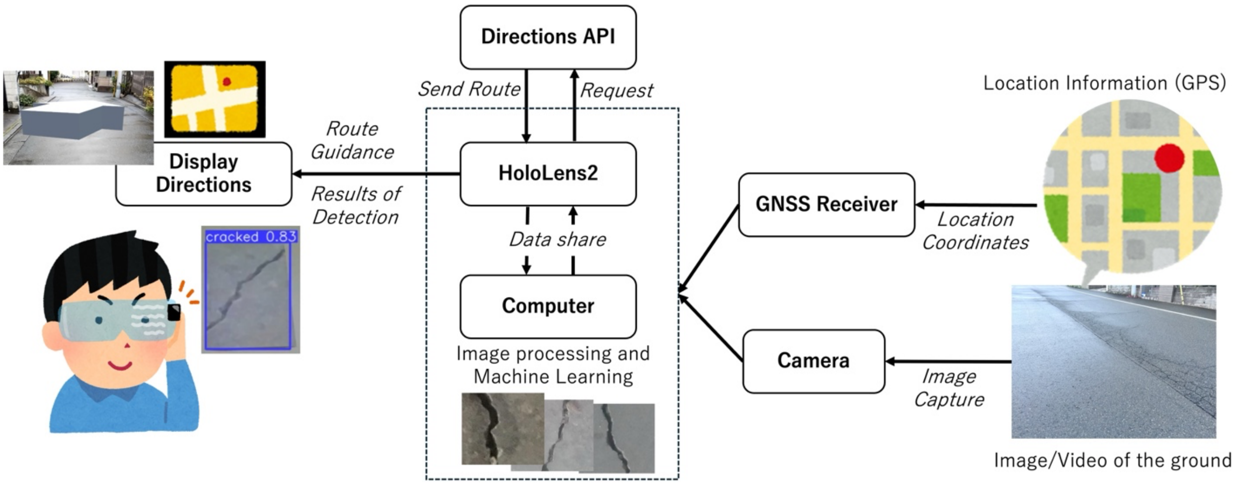

Fig. 1. System overall diagram

with shockproof and waterproof functions have become the first choice. Therefore, this research used HERO7 Black produced by GoPro [8]. In addition, most of the devices currently used in this study have wireless communication capabilities (including wireless networks and Bluetooth), but do not have built-in GPS receivers yet. Therefore, GNS 3000 manufactured by GNS Electronics GmbH was selected as a dedicated GPS receiver [9], and then Bluetooth was used to return the obtained GPS information. display.

The image recognition is used to detect cracks, and the detected cracks and their location coordinates are linked and saved in the database of the data processing end. This research uses YOLOv5 [10] as the image recognition algorithm. YOLO (You Only Look Once) is an existing machine learning algorithm known for its high-speed computing processing speed. It is especially famous for object image recognition. Due to its fast processing speed, it is also often used for real-time image recognition.

If the user wears the AR head-mounted display, the system will display the detected ground cracks and record the user's location. In addition, if the function of specifying a destination is used, the direction guidance function will be activated and instructions for walkable routes will be displayed. This research uses HoloLens2 [11] manufactured by Microsoft as an AR head-mounted display. HoloLens 2 is a mixed reality device that has the functions equivalent to a simple laptop, such as the ability to perform basic computer operations and includes camera and voice capabilities. In addition, it also has many built-in sensors, such as accelerometer, gyroscope, magnetometer, depth sensor, 6DoF tracking, spatial mapping, etc. for spatial detection; As well as motion detection functions such as head tracking, eye movement detector tracking, hand tracking, etc.

III. METHODS

The function developed in this research is roughly divided into two parts, one is the main landslide detection, and the other is the direction guidance function. This section explains the data currently used to develop landslide detection, the training model used, and the machine learning method used in this study. The content and display method of the currently developed direction guidance function are also explained.

A. *Landslide Detection*

This research uses YOLOv5 as the machine learning method. Therefore, the training model used is created through supervised learning of YOLOv5. Considering the purpose of this study, the current research stage starts with the detection of cracks in the road surface. Since actual images are not yet available, the training images used to build the training model at this stage are obtained from Kaggle Inc. [12]. There are a total of 40,000 images acquired this time, 20,000 of which are images of road surfaces with cracks, as shown in Fig. 2; and the other 20,000 images are images of road surfaces without cracks, as shown in Fig. 3. The training images and evaluation images use the same batch of data. The training images and the evaluation images are divided in a ratio of 8:2. Then, the evaluation images and the test images are divided in a ratio of 8:2.. The pixel size of the image used is 227 pixels high and 227 pixels wide. When performing the training phase of machine learning, the set number of epochs and batch size are 50 and 15 respectively.

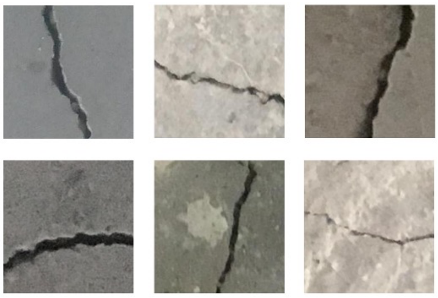

Fig. 2. The acquired images of road surfaces with cracks from Kaggle

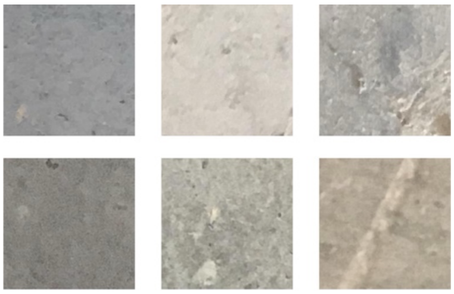

Fig. 3. The acquired images of road surfaces with cracks from Kaggle

The training results are shown in Fig.4 and Fig. 5. The horizontal axis in Fig. 4 is epoch and the vertical axis is loss. In Fig. 5, the horizontal axis is epoch and the vertical axis is accuracy. The changes in the loss value of train and the change of val loss value is illustrated in Fig.4. From this result, it can be seen that the value of train decreases with the increase of epoch, and the value remains stable. val is stable in each epoch, but loss values fluctuate relatively large. Next, Fig. 5 shows the variation graph of precision and recall. From this result, it can be seen that the values of precision and recall fluctuate relatively large in the area below 20 epoch. But, as the number of epochs increases, the values of precision and recall gradually tend to remain stable. However, the continuous trend of these two values close to 1.0 also indicates that this machine learning result has the possibility of over-learning.

B. Direction Guidance Function

The goal of this research is to use an AR head-mounted display, the HoloLens2 manufactured by Microsoft, to display detection results and provide user direction guidance. Since HoloLens2 does not have a built-in GPS receiver, after the GPS receiver obtains the current location, it will connect to the data processing end via Bluetooth, and share the current location information with HoloLens2, and then use the Directions API produced by Google [13] to calculate the route. Currently, because the system is still in the development stage, the directional guidance function is basically tested using a smartphone equipped with the same execution system as HoloLens2.

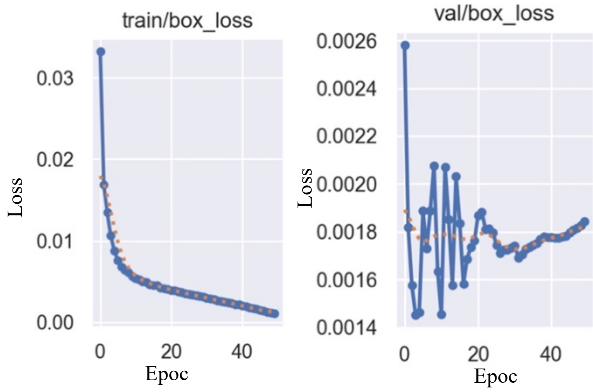

Fig. 4. The results of loss value of train and val

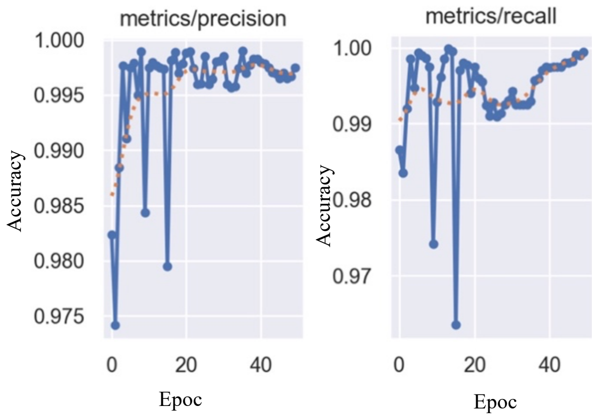

Fig. 5. The results of precision and recall

Regarding the direction guidance function developed in this research, first, the user is allowed to set the destination location they want to reach, which is the GPS coordinates of the destination location. Then, while connecting to the Directions API, the current location obtained from the GPS receiver, which is the GPS coordinates of the current location, is sent to the Directions API.

By calculating the route from the current location to the destination location, confirm whether a suitable route can be obtained. If the route is determined, next, use the built-in magnetometer to obtain the direction the user is facing. The direction obtained at this time is the absolute direction. Then, based on the coordinates of the obtained route, the angle between the current location and the next target location is calculated through the following formula (1):

$$\theta = \tan^{-1}2(x_2 - x_1, y_2 - y_1) \qquad (1)$$

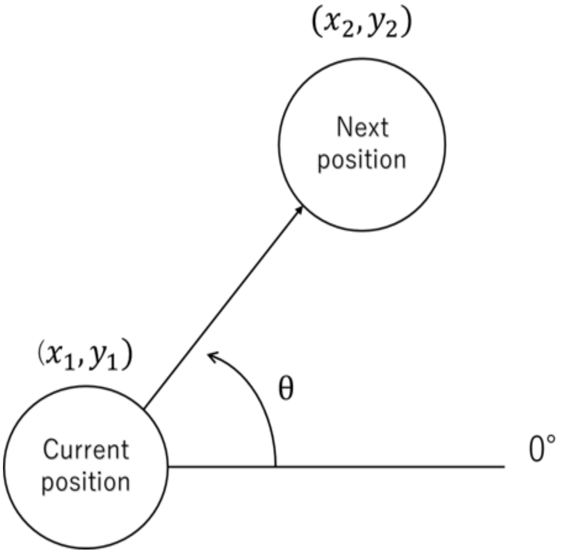

Fig. 6. Angle acpuisition overview

$(x1,\ y1)$ is the coordinates of the current location obtained by the GPS receiver. $y1$ is the latitude, and $y1$ is the longitude. $(x2, y2)$ is the coordinates of the path point closest to the current position calculated through the Directions API. $x2$ is the latitude, $y2$ is the longitude. Fig. 6 illustrates an overview of the method of obtaining the angle from the current position to the next path point.

As mentioned above, the user uses the function to confirm the route to the destination. When the user moves, the directional guidance function will use AR directional arrows along the route and rotate the AR directional arrows according to the direction.

IV. Results and Discusssion

Now, the overall system of this research is still in the initial construction stage. Here will introduce the initial results of the landslide detection function and direction guidance function currently being developed, and conduct a preliminary discussion on the current results.

A. Landslide Detection

At this stage, when considering wide-area detection, the range may be too large, resulting in excessive use of computing power, or unnecessary use of computing power, etc. These conditions may cause a delay in detection or a decrease in accuracy. In addition, because it is still in the testing phase, the detection is not performed immediately, but based on videos that have been shot and saved.

Regarding the road surface image used to test the detection function, considering the crack detection accuracy and detectable distance, the distance between the camera and the ground is about 0.9~1.0 meters, and the width of the path in the video is about 3.0 meters. The camera used when taking pictures has a resolution of 4K, 3840 pixels wide and 2160 pixels high. In addition, in order to avoid misjudgments, the detection threshold during measurement is set to 0.6.

The detection results of one of the frames this time are shown in Fig. 7. The operational experimental results show that long cracks were detected in multiple sections, and there were also undetected cracks. Furthermore, the system did not detect multiple cracks that were connected or distributed over a large area.

Regarding the possible reasons for the above undetected or incorrect detection results. The first possible reason is that the annotation of training images in the preprocessing stage is inappropriate. It may be that the cracks are not fully detected because the annotation work is done to annotate the training images with square segmentations. The second possible reason is that the images used for training were quite simple and almost without noisy, being images with only cracks cropped. In view of the above circumstances, one possible way to improve accuracy is to use polygon segmentation to annotate training images with possible crack shapes. Polygon segmentation is a method of dividing the detection target area into polygons. By using this technique, cracks is able to improve accuracy by capturing the contours. However, square bounding boxes require less inference computation than polygon segmentation, so if polygon segmentation is used, the computational effort may increase. Therefore, for detection efficiency, it may be necessary to reduce the movement speed during imaging. In addition, the detection results also showed drainage ditches, small cracks and narrow trench cracks. However, the detected objects need to avoid drainage ditches, small cracks and narrow crevices because these objects are not considered precursors to landslides.

Fig. 7. Execution result of landslide detection

B. Direction Guidance Function

Fig.8 shows the results of executing the direction guidance function on a smartphone. From the test results, it can be seen that the system receives the coordinates of the input destination from the Google Directions API, and uses a GNSS receiver to obtain a route from the current location to the destination. The test results also confirmed that based on the obtained route coordinates to the destination, the direction indicator rotates along the route coordinates from the current coordinates to the next point, and presents the route to the destination. Moreover, through the field testing, the operation of the direction guidance function was also confirmed to be operating properly.

However, because GPS signals are transmitted through satellites, there may be problems receiving signals when there are large obstacles above. Additionally, roads or indoor environments that are not stored in the Google Directions API database will not be available. Moreover, too many or too large directional signs may also reduce visibility of the road ahead, and the user may have difficultly seeing the direction indicator clearly due to lighting or environmental effects. For example, if the direction indicator overlaps with a cityscape, or there is a bright light or strong light in front of the user, it may block the user’s view or make the display difficult to see clearly. Finally, the built-in camera does not allow full forward movement when using the HoloLens2, so an external camera needs to be connected to the HoloLens2.

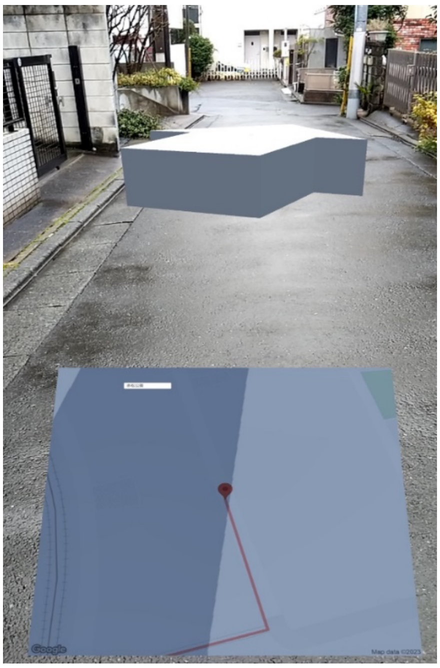

Fig. 8. Execution result of direction guidance function

V. Conclusion

The goal of this research is to develop a system that helps in predicting landslides. This paper develops and verifies the crack detection function and direction indication function, and verifies the operation of the developed functions.

Since this research is currently in its early stages of development, in addition to the problems identified so far, there are many issues that need to be addressed in the future. A known problem is that since the objects to be detected are all on the ground, the camera lens needs to be kept downward during detection. Therefore, the detection function and direction guidance functions will be incompatible if only use the camera of the head-mounted display. Because the camera of the head-mounted display cannot be adjusted in direction, the user cannot move in a natural posture. The solution to this problem is to use an external camera.

Another problem is that the crack detection feature is not accurate enough to detect long cracks. To address this issue, improvements will be considered, such as changing the method of machine learning or increasing the number of training images. In future research, external cameras will be connected to the head-mounted display to improve user visibility. Moreover, in order to improve the accuracy of image recognition, the training methods of machine learning and the training images used need to be improved. Furthermore, expert opinions will be added to increase the definition of predicted landslides for more accurate measurements.

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