Conceptual Design of a Simple Earthflow Detector for Resident Disaster Prevention

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Abstract. The earthflow disaster is massive in scale and fast, causing damage to mountain towns and traffic. Field observation instruments developed for the earthflow warning, such as wire rope stress detection, ground sound sensing, and detection of relative motion. Evacuate residents of dangerous areas through broadcast systems and disaster prevention personnel. Residents have no direct access to relevant information, and information lags and incompleteness reduces trust. The design of the simple detector detects the movement of the soil layer with a tilted, areal breakpoint measurement. Cooperate with global data APP to improve the performance of early warning. The inexpensive sensors included positioners, inclinometers, and soil moisture detectors. Combine these data provided a suitable local response and become a medium for self-help and mutual help. The unmanned aerial vehicle take pictures along the preset specific path when triggered providing the first-hand disaster data.

1. Introduction
Climate change has caused many earth-rock incidents in Taiwan in recent years [1]. Taiwan receives an average annual rainfall of 2502 mm, tracked, and evolution of complex active landslides. The LiDAR investigated the landslide sediment production and riverbed erosion [1]. Through analyzing the disaster when the typhoon, heavy rain, earth flow, government, and the public can quickly carry out disaster prevention activities [2]. In 2018, heavy rains in California caused earth and stone flow [3], and the number of casualties reached 100. Spatial patterns of earthflow velocity within the transport zone were controlled mainly by the slope of the underlying failures; the temporal patterns were climate-driven changes in surface moisture balance.
The case study found that the early warning system still has defects, and there are obstacles between the information and the public. The application of information and geospatial technologies such as remote sensing and geographic information systems (GIS) has greatly contributed to landslide hazard assessment [4]. Hazard assessment, such as landslide susceptibility analysis, runout modeling, landslide monitoring, and early warning, were reviewed [5]. The degree of activity of earth and rock flows is closely related to the quality of the ecological environment. Rainfall-initiated landslides involve highly dynamic hydrologic, earth surface, and ecological processes [6]. The flow plays in mitigating instability is elucidated. Debris flows in areas with poor ecology occur frequently. Increasing the vegetation coverage of the basin to create a sheltered forest can reduce the frequency of debris flow. The localized rainfall is easy to neglect disaster prevention. The landslide may block the sudden interruption of the downstream river water in the upper reaches, which is a precursor to the occurrence of the debris flow.
Earthflow often occurs in areas with complex geological structures, fractures and folds, and strong earthquakes. The surface rocks broken, collapsed, staggered, landslides, etc., providing a rich source...
of solid matter for the formation of earth and rock flows. Rock formations are loose, and the areas between soft and hard are most vulnerable. Local observations can reduce defects in early warning systems, and information in the place of residence can remove distrust among the population. Local observations need to monitor rainfall in nearby watersheds, monitor landslides in gullies and loose rock in gullies, landslides blocking rivers, and triggering outbreaks. When the debris flow is formed upstream, an early warning issued to the downstream regions (Figure 1).

Figure 1. Concept design winner

2. Warning system and design
Although advanced early warning systems were proposed, the price is high and needs to be promoted. The monitoring equipment for landslides is complex to deploy. The probability of occurrence caused residents to misunderstand the warning. The notification system used wide-area data, rainfall in the entire area, or remote records. Therefore, local people feel disconnected from the situation by false alarms. The stratigraphic changes are closely related to the local terrain. Establishing local parameters, combined with the data of large areas, will provide accurate warnings. The field observer integrates a stress detector, tilt, and moisture detector (Figure 2). A well-balanced suite that provides high temporal and spatial resolutions on both measurement and slope scale is necessary [7]. High sensitivity to landslide movements indicates the array is suitable for early warning. Establish local soil parameters and conditions that prefers simply for weather-induced landslide risk [8]. A coherent framework analyses early warning, based on the landslide model and the warning model. Have the warnings been issued on time? Was their duration adequate? Are there false or missed alerts in this example? The answers to these questions are not trivial. The mobile app provides direct information to a resident who helps to disaster prevention.
Figure 2. The monitoring system is deployed flexibly according to weather conditions [7]

2.1. Concepts
The design goal is to collect local information in a multi-distributed simple sensor to improve accuracy; it is convenient to install and obtain data for a long time. The dimensions are ergonomic, and the solar low-power Design keeps working in the field. Recyclability increases utilization, and the positioner assists in recycling after earth flow. Multi-depth humidity detection increases accuracy. The complementation of the inclinometer and the open circuit increases the probability of discovery. The detector installed in a high probability area (upstream of the river, landslide), and the hole of the same diameter excavated with a soil drill. After the detector placed in the calibration and information upload test, it enters the autonomous modes which transfer data regularly.

Figure 3. The concept-I, detecting displacement of the formation with the break of the rope.

Refer to the concept-I (Figure 3), the housing is made of plastic, and the conduit and upper sensing transmitter are detachable. The base is flip-top to prevent rain erosion. There are holes of different depths on the catheter for collecting soil data at different depths. The conduit contact with the soil through a screen that keeps the soil in line with the water. The armor-shaped scales can be separated,
and the wires are connected, and the cables broke to trigger an alarm. The alarm sounder has limited power and performs digital communication of the Internet of Things.

![Figure 4](image_url)

**Figure 4.** The concept-II, the drone attached to the detection node and take off when needed.

The concept-II (Figure 4) is a combination of a drone. The base at the top of the sensor station connects conduits, and the duct provides drone power. When the threshold reached, it vacates the flight along the high-risk area and transmits the image to the regional centre. The drone landed at the local center pre-set place and was dispatched back to the alert area after repair. The drone requires a high amount of power and can fly more than 15 minutes, providing valuable dynamic information. The problem with this concept is that long-term placement in the wild is rarely working correctly. The sound of the drone and the flicker of the light are not prominent, and the residents' warning cannot be provided. It can provide information through the connection with the command center, and the command center issues warning instructions in the disaster prevention system.

Who is going to control the drone? The disaster may have occurred at night, and the immediate control of the flight is not easy. We can set the path of the high-risk area in advance, such as the critical slope of the village or the upper reaches of the river. The drone will return to the pre-set endpoint after cruising the pre-set path. Long-term placement can cause failures, but we predict that the drone will be sent to the information collection point before the rainy season. The drone can provide first-hand information (mini-collapse, falling rock occurrence, water accumulation area) for a limited time. The microcomputer has a diameter of 30 cm and a price of around US$400, so there are still opportunities for installation under limited resources.

### 2.2. Scenario

The heavy rain warning was released; although it was not a typhoon, the village chief was careful to respond. There have been warnings in the past, and some residents complained after the unplanned evacuation. The village chief asked the disaster prevention team to apply for the large triangle detection group installed in the hillside area (Figure 5).
Figure 5. The Scenario of sensor node and APP

The rain came, and the disaster prevention team took the drone placed in the office and sent it to the detection point. After a rainy day, the detector found the tilt, and the humidity was above the threshold. After a few hours, I received a disconnect signal, indicating that the surface was moving! The disaster prevention team then issued a warning. In the image of the drone, there was congestion above the water source, and the water could not be vented. During the flight along the main road, the officer discovered an interrupted section. The village chief called the villagers to use the APP to take the preset route to the national refuge in the middle of the village. At this time, the elderly living alone called "going to the shuttle," and the disaster relief officer knew that the main road was no longer accessible, so he made a detour.

3. Implementation

3.1. Circuit

Conceptual implementations include soil moisture sensing, inclinometers, open circuit sensing, and buzzers (Figure 6). Humidity sensing is a strip electrode, and the inclinometer senses the attitude of the object and the condition of the formation. Slope changes require large deformations, and small relative movements achieved with open circuit sensing. The conductive strip connection triggers a warning signal when it is pulled to break. The circuit placed within chassis, the exploded view of the component display in Figure 7.

Figure 6. The circuit implement with Arduino, the bottom left are the temperature, humidity, and angle sensors.
Figure 7. Exploded view of the component, the sensing board controller is placed in the center of the cavity.

Figure 8. The layout of the App interface

The interface of the APP shows in the Figure 8, and the buttons below are menus, positioning, alarms, and information display. The content includes soil information, hazard index (the color depth represents the value of the value), meteorological data, user location. APPs used in emergencies, and the functions are not complicated, and the presentation is simplified for people of different ages to understand. Pre-occurrence message: Remind attention based on his location. The evacuation route needs a guide to find the concentration site.

4. Expert interviews and improvements:
Interviewee: Two doctoral students at the Institute of Soil and Water Conservation of Zhongxing University. After we have introduced the design ideas and models, they put forward professional opinions as follows:

1) A deep understanding of the disaster will enable you to find the point where the problem is detected. National disaster prevention plans have been divided into different warning zones to drill evacuation plans in hazardous areas.

2) The ability to charge is essential.
(3) The measuring instrument needs to have a recycling mechanism, including regular maintenance and post-disaster retrieval.

(4) Early warning notification systems are usually released as a whole, with no personal involvement.

(5) The connection between the test tube and the base needs to be modified because the metal ring cannot be electrically connected to the bottom and requires a two-pole contact.

Figure 9. Emphasizing recyclable design

The size of the top of the catheter is reduced and a curved handle is added (Figure 9). The ergonomics make the detector easy to install and maintain. The handle of the base moves up so that the hand can insert easily. Increase the rubber strip in the cassette structure (the junction of the top of the tube and the base) to avoid water ingress. The inclined angle of the lower case of the bottom is matched with the upper case to make the whole smooth. The built-in GPS positioning can transmit the drift position information to the center. The details are in below (Figure 10):

Figure 10. Regional sensing group and wide-area are interrelated
(1) Global center cloud computing: A network-connected national disaster relief center that senses and monitors at significant locations and uses cloud computing to determine the magnitude of the risk.

(2) Local office alarm: The regional office uses a simple micro-detector to determine the possible hazards for the local terrain. When the alert value reached, the app is sent to the local people and guides the evacuation route.

(3) S-node: Local low-cost detector, mainly used for data collection and storage. S-Host node: There will be one master node among the three nodes. The master node has long-distance communication capability and can transmit group information to the office. The data of the three nodes is averaged at the primary node to obtain a more reliable message. When the drone is set here, the observation of the specific route initiated by remote paging.

5. Conclusions
Field observation instruments developed for the earthflow warning. Evacuate residents of dangerous areas is a hard decision for disaster prevention personnel. Residents have very limited access to relevant information, and information lags and incompleteness reduces trust. The Design of the simple detector detects the movement of the soil layer with a tilted, areal breakpoint. APP can improve the performance of warning. Two conceptual designs provided and acquired opinions from expert. Solar panels placed between nodes occupy less space. Light and thin photovoltaic panels can be connected in parallel to obtain sufficient strength. At least three nodes connected in series at the master node. When a break occurs, it indicates that deformation occurs in the area. The unmanned aerial vehicle placed before the event will take pictures along the preset specific path when triggered, and will provide the first-hand disaster data in the village after flying back.

6. References
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