Initiative to Increase the Efficiency of Levee Inspections Utilizing New Technologies, Including AI (Research period: FY 2019–)

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1. Maintenance of river levees

River levees are extensive and large embankment structures. Ensuring proper maintenance and management is crucial because any partial loss of their functionality could result in significant damage during a flooding event. Furthermore, as the levee constitutes an embankment structure, it is susceptible to deformation over time due to variations in consolidation settlement. These variations are caused by the characteristics of the levee materials, properties of the foundation ground, or the historical context of the levee construction. Deformation can also result from other factors, including the impact of running water during floods, stormwater infiltration, river use, vehicle traffic, small animal burrows, tree roots, and other contributing elements. If left unchecked, these deformities could seriously affect the levee function and lead to disasters. Therefore, regular inspections are crucial. Furthermore, it is essential to perform comprehensive condition assessments following exposure to external forces, such as floods and earthquakes, while taking into account the design assumptions. Nevertheless, deformations on levees arise from diverse factors in various locations, and visual detection of deformations, such as widespread subsidence and slope bulging, can be difficult. Moreover, there is a significant shortage of inspection technicians, emphasizing the pressing need to transfer the expertise of experienced technicians. In such situations, it is crucial to recognize the importance of creating inspection and assessment methods for river levees that are both effective and less labor-intensive and actively strive to find solutions.

2. Enhancing management efficiency through new technologies

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is advocating digital transformation (DX) in the infrastructure domain. In the river sector, DX initiatives are underway across a series of operational processes, including surveys and planning, design, construction, and maintenance and management of river facilities, aiming to enhance operational efficiency. Specifically, in the maintenance and management phase, images and 3D point cloud data obtained through unmanned aerial vehicles (UAVs) and other devices are utilized to comprehend the deformation of river channels and levees. This aids in enhancing the efficiency of maintenance and management operations, including river patrols and inspections.

Consequently, we have been researching and developing artificial intelligence (AI) technology to effectively identify levee deformations, aiming to resolve the issues mentioned earlier. This research is being carried out through the commissioned research program as part of the public recruitment program for the river erosion technological development project. Our research aims to achieve the automatic detection of embankment deformations through AI using point cloud data and image data. In prior studies, AI has been employed to successfully identify 12 types of deformations in embankments as outlined in the Guidelines for Inspection and Assessment of River Management Facilities and River Channels, including Levees. For instance, when specifically targeting erosion on an actual levee, the program successfully identified the majority of deformations observed during visual inspections **(Figure1).**

The AI program took approximately 10 minutes per kilometer (excluding measurement time) to identify deformations. This is shorter than the conventional visual inspection, which typically took around two hours, highlighting the potential for improved work efficiency with the AI program. Nevertheless, the AI-based deformity identification program exhibited instances of detecting deformations where none were present, known as "false positives." This suggests that further improvement is needed to enhance the accuracy of the program.

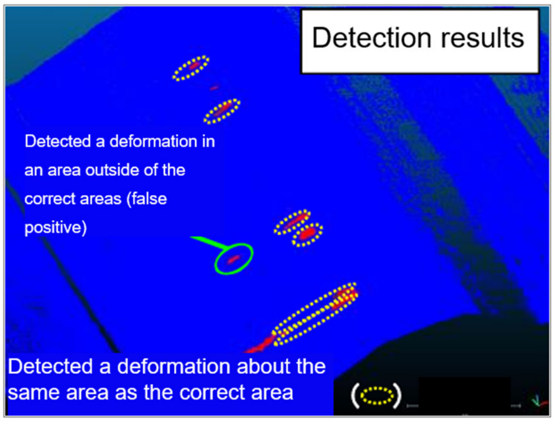

Figure 1. Example of identifying deformations with AI

3. Efforts to link the identified deformities with the effective execution of inspection tasks.

Technological development, as well as measurement accuracy, are expected to further improve in the use of AI for inspection and the use of image data and 3D point cloud data captured by UAVs for the identification of deformations. This is expected to lead to the easy identification of deformations, which have been difficult to capture. Conversely, these new technologies might identify numerous deformations that may not pose significant threats of disasters. Therefore, a new challenge arises in establishing evaluation criteria to determine whether detected conditions should be marked as deformations. In an attempt to address these challenges, we aim to enhance inspection efficiency by identifying deformations that could lead to disasters. To achieve this, we organized and examined actual damage to establish connections between various deformations observed at disaster sites, such as levee failure—potentially seriously jeopardizing the levee's function—and the causes of disasters.

In particular, the authors conducted on-site inspections for 32 cases of levee failures, including slope collapses, which occurred between 2009 and 2021. Our examination focused on determining if we could select deformations that could serve as early signals of an impending disaster.

For example, after examining cases where rainfall-induced erosion and infiltration were probable main causes of levee failure, we identified the following on-site conditions **(Figure 2).**

- The river level during the disaster was significantly below the planned high-water level, suggesting that the disaster was likely triggered by heavy rainfall over a short duration.
- The levee crown in the damaged area was the lowest compared to the upstream and downstream sections, creating a situation where rainwater drainage easily accumulated at the top of the levee in that specific section.
- We observed numerous longitudinal cracks in the slope at the top of the levee, along with erosion in the levee shoulder and the upper section of the levee slope. (a)
- A road was constructed on the crown of the levee, equipped with pedestrian/vehicle separation blocks. The top of the levee had a drainage structure designed to release water through a blocked drainage hole to the slope opposite the damaged side. Unfortunately, the drainage hole was obstructed, resulting in inefficient water discharge. (b, c)
- The repeated overlaying of the road on the levee crown has led to the slope taking on a concave shape, resembling the roof of a temple. (d)

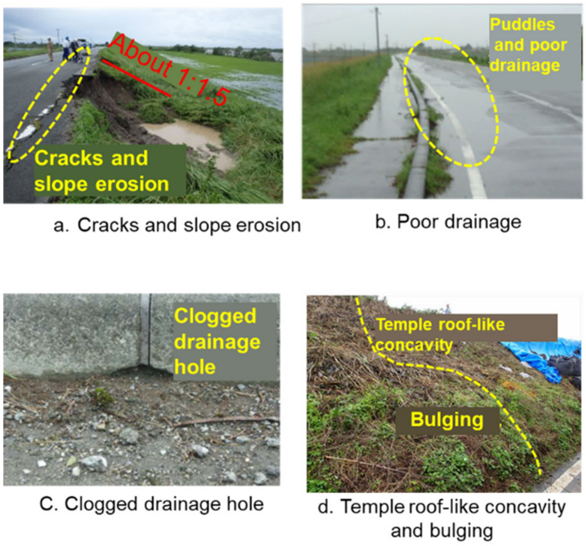

Figure 2. Deformation observed around the damaged area

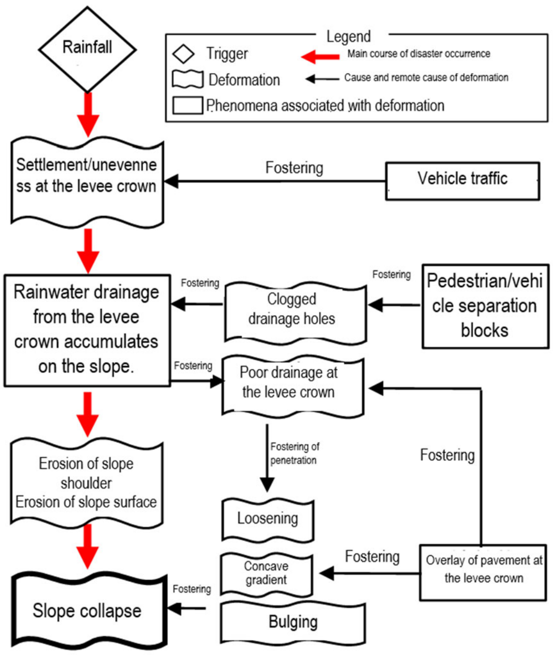

Figure 3. Chain of events leading to the slope collapse (estimated)

Based on the information above, the chain of events, from the formation of deformations found through the damage survey to the actual occurrence of damage, is organized as shown in Figure 3. We intend to employ the same process for other disaster cases and categorize them accordingly. The development of a successful AI model that prioritizes identifying deformations in areas with a higher likelihood of causing damage would enhance the efficiency of AI-based inspections.

☞**For more information:**

Tomura, Sasaoka. et al. Study on Efficient Deformation Identification of River Levees Using 3D Point Cloud Data and AI. Advances in River Engineering. Vol. 27.
https://www.jstage.jst.go.jp/article/river/27/0/27_PS1-35/_pdf/-char/ja