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Best Practice on Inspecting the Abnormal State of Bridge (Engineering works) Establishment with Augmented Reality (AR) Mechanism

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Abstract

In the current world, with the massive scale of SOC construction, it is difficult to diagnose and check all of a bridge's abnormal states with even the experts' eyes for maintenance. It is because we should spend huge costs and time on maintenance. Still, there are not many alternative ways to inspect bridges remotely regarding accuracy or reality. Therefore, we remark on the advantages and disadvantages of previous methods through practices in SOC maintenance. To inspect the abnormal state of the Bridge, we suggest inspecting bridges with an Augmented Reality (AR) mechanism to reduce cost, human resource consumption, and the risk of work. Through the proposed approach, we expect that it provides ways to solve massive construction problems with software-based technologies.

Keywords: *Augmented Reality, Building Information Modeling, Social Overhead Capital*

1. Introduction

After our industrialization with the continuous development of machinery and technology, the industry worldwide is progressing rapidly. As the industry develops, Social Overhead Capital (SOC)—social infrastructure for manufacturing and production, such as roads, ports, bridges, and railroad piers—also increases [1]. Since the early 1980s, Korea has undergone rapid socio-economic development. These infrastructures have developed over the past 40 years, and our maintenance and repairs are needed. Therefore the required financial resources increase exponentially [2]. To maintain these infrastructures, the government and industry are researching to develop technologies that lower maintenance costs and increase efficiency along with maintenance projects for SOC. Academics are accelerating research on technological development, considering not only economic factors but also environmental factors.

In the early days, it was only possible to check with the eyes to collect all the information necessary for the maintenance and repair of the SOC. Because of the large area of the bridge, numerous workers were in charge

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of these investigations. However, as society and the economy grow, the cost of maintenance increases. In addition, in the maintenance business of SOC, the accident rate increases because the scale of bridges is massive, and workers work for a long time in high places or dangerous environments [3].

To solve these problems, we analyze the causes through cases in other countries, examine the current situation in Korea, and discuss our direction to be improved. In this paper, chapter 2 introduces research and circumstances of this topic from other countries. In Chapter 3, we discuss recent problems in certain circumstances. In Chapter 4, we conclude with future research areas.

2. Related Works

2.1 Smart Infrastructure Technologies (Smart City Project in Australia)

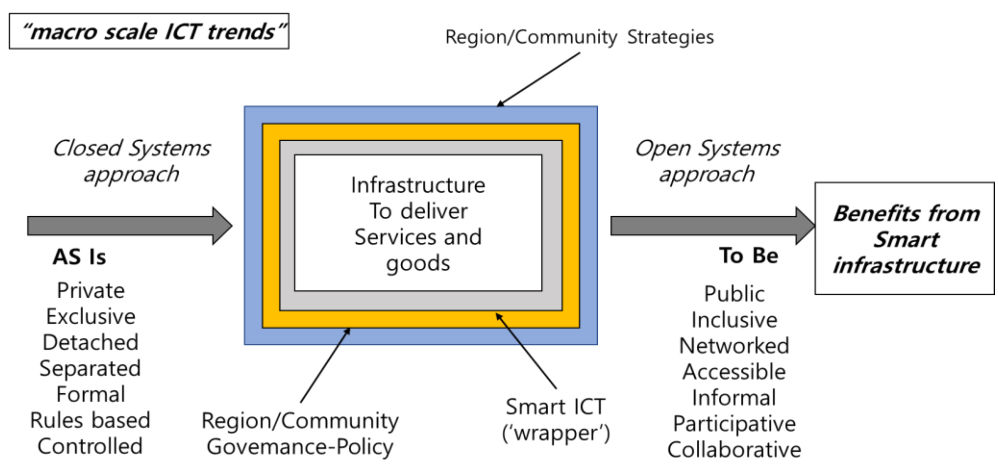

Figure 1. Smart Infrastructure Expectation Diagram with Marco Scale ICT Trends

Australia Smart City Project is building ICT-based systems across Australia that can design, configure, operate, and manage major SOCs in Australia from the planning stage. This is because more than 70 percent of the population lives in Australia. In this project, they gathered international and domestic stakeholder opinions on the future role of smart ICT in advancing infrastructure development and operations in Australia to analyze the current situation.

Figure 1 shows an expectation diagram of macro-scale Smart Infrastructure. The existing closed system approach has closed and exclusive characteristics by controlling the infrastructure based on rules. As a result of collecting opinions from stakeholders in Australia and various countries, it was converted to match the direction of policies and strategies between regions and to establish infrastructure through Smart ICT to deliver services and goods. Then, Australia's infrastructure has the characteristics of Inclusive and public through a more open system approach. This project can expect the corresponding development of local communities and urban environments through research. In addition, through the improvement of Australia's domestic economy, it is possible to build several forms of smart ICT (e.g., information modeling software) support infrastructure with the potential to deliver more than $9 billion per year. However, experts remark that for these smart ICTs to work effectively, they need support through open and interoperable data, sound governance and policies, government leadership, and coordination with dedicated resources. Currently, intelligent infrastructure development is slow and obtuse, but smart ICT is presented as a valuable strategic technology for the change and development of domestic society.

2.2 The Living Bridge Project (United States)

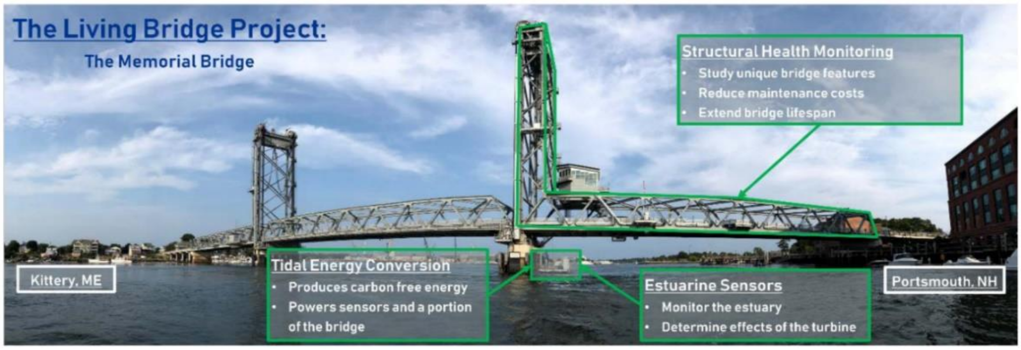

Figure 2. Structural Health Monitoring System Project on Memorial Bridge, United States

The Living Bridge Project is a large-scale project in which the state government, owner, academia, and community jointly participate in the Memorial Bridge in Portsmouth, New Hampshire, USA. Figure 2 shows the memorial bridge's appearance connecting Portsmouth, NH, Kittery, and ME, along with a brief introduction to this project. This project contributes to building an innovative and sustainable user-centered transportation infrastructure by collecting and analyzing various indicators through experts in structural, mechanical, marine engineering, sensing technology, social sciences, bridge design, measurement, data collection, and assistance [5]. The project is being researched through interdisciplinary research with expertise in structural performance, traffic patterns, operational and environmental changes, social sciences, and energy conversion.

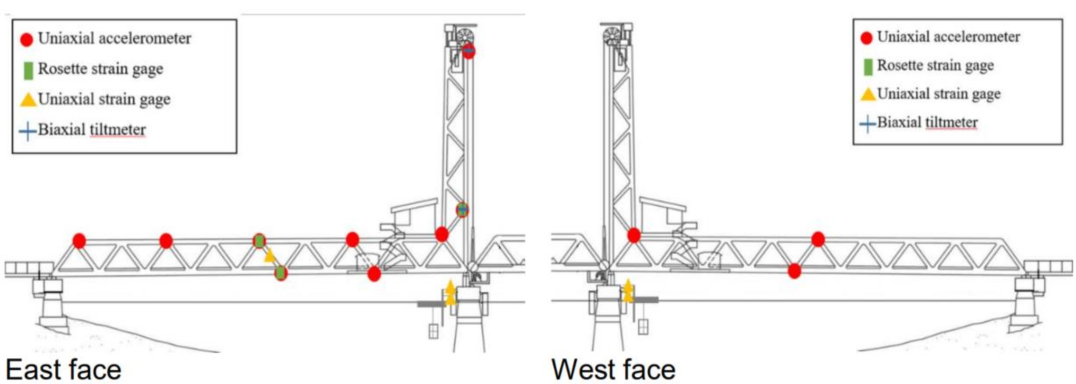

Figure 3. Memorial Bridge Model with Sensors

To collect data, as shown in Figure 3, sensors are mounted on points marked with colors and symbols to gather information necessary for the maintenance and repair of SOC. Figure 3 shows installation sensors to collect pier status information through Uniaxial Accelerometer, Rosette strain gage, Uniaxial strain gage, Biaxial tiltmeter, etc., on the memory bridge [5]. In this way, the sensors installed on the bridge transmit information to the center so stakeholders can access and study the collected information through real-time information on the bridge.

2.3 Self-Repairing Cities Project: United Kingdom

The self-repairing cities project, in which the University of Leeds, University College London, the University of Southampton, and the University of Birmingham participate, begins with three case studies:

'Perch and Repair,' 'Perceive and Patch,' and 'Fire and forget.' A project aimed at solving problems. All three challenges aim to minimize the consumption of human resources and perform inspection, diagnosis, repair, and preventive tasks while people sleep.

'Perch and Repair Remote Challenge' is a challenge to develop a device that performs the work remotely at the point where repair work is needed on the street [6]. 'The Perceive and Patch challenge' is a challenge that can automatically inspect, diagnose, repair, and prevent defects and damage around highways by monitoring highways via drones. With a designed hybrid robot, the 'Fire and Forget challenge' aims to continuously perform inspection, repair, weighing, and reporting tasks within a designated space (Live Utility Pipe). The challenge aims to have no human work on the streets of UK cities by 2050 [6].

The core of this project is to assist with necessary maintenance work on city streets by utilizing robots and ICT equipment and to continuously perform inspection, diagnosis, repair, and prevention tasks even while people are asleep, increasing work effectiveness. In addition, overcoming this challenge helps workers to identify and diagnose the condition of the street on a non-face-to-face, non-destructive basis.

3. Inspecting the Abnormal State of Bridge Establishment with an Augmented Reality (AR) Mechanism

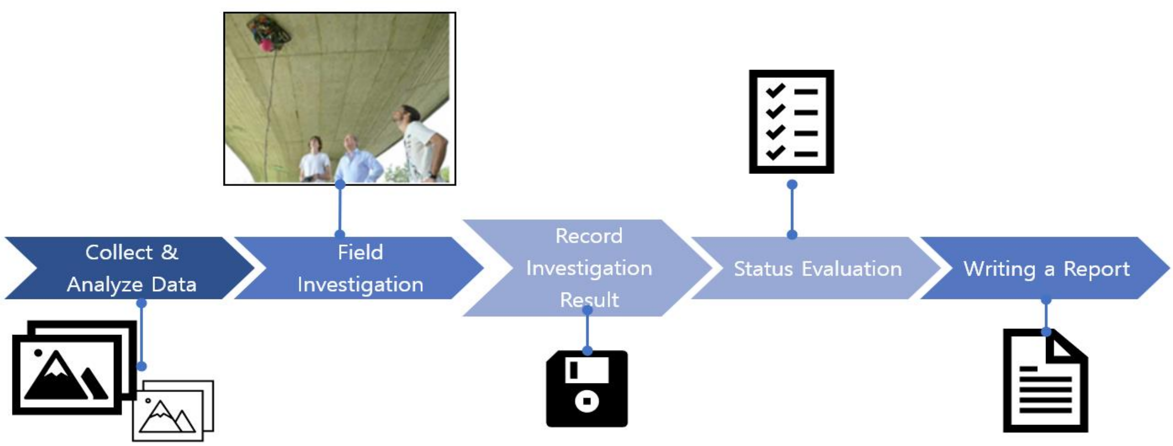

Figure 4. Facility Safety Inspection Diagnosis Process

Large-scale projects apply processes to eliminate potential safety hazards for efficient and safe SOC maintenance and repair. Figure 4 shows the Facility Safety Inspection Diagnosis Process. The starting point in this process is to collect and analyze data.

In the early days of SOC maintenance and repair, a method of finding problems by directly identifying them with the eyes was used to find defects or problems in extensive facilities to maintain large facilities. This work is usually used as a basis for experts to diagnose the state of SOC. However, since collecting and analyzing data must be performed every time a safety inspection or diagnosis is completed, there is a disadvantage because it requires many human resources and costs accordingly. In addition, safety accidents frequently occur because bridges are usually constructed at a high position from the ground. Therefore, experts tend to climb directly to a high place with the naked eye or avoid work that poses a safety risk. To overcome these disadvantages, the industry is overcoming these problems by grafting AI, ICT, and communication technologies into SOC's maintenance and repair process. In addition, it is required to apply the digital twin concept and overcome the problem using ICT technology.

3.1 Database Indexing Mechanism with Building Information Modeling Method

Building Information Modeling (BIM) is one of the standard methods for transmitting data that abstracts physical building information. It is a digital transformation system that integrates all information generated during the life cycle of a facility into a three-dimensional model to link construction information and procedures in a standardized manner. It enables a digital twin [7].

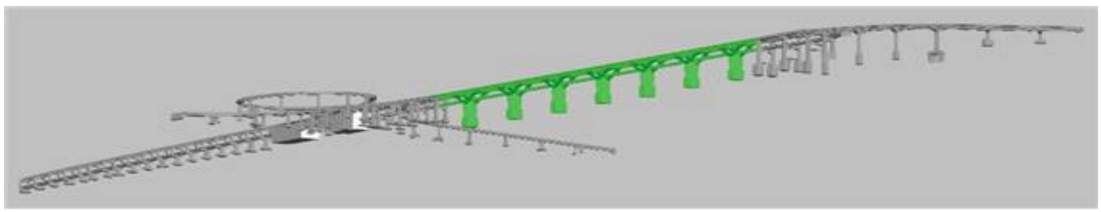

Figure 5. Example of Abstract Building Information for Cheong-Dam Bridge

Figure 5 shows an abstract three-dimensional model of the Cheong-dam Bridge built in Korea. This abstracted building information should be stored in a database and indexed according to the type of actual construction parts.

3.2 DB Indexing Mechanism with Building Information Object for Cheong-dam bridge

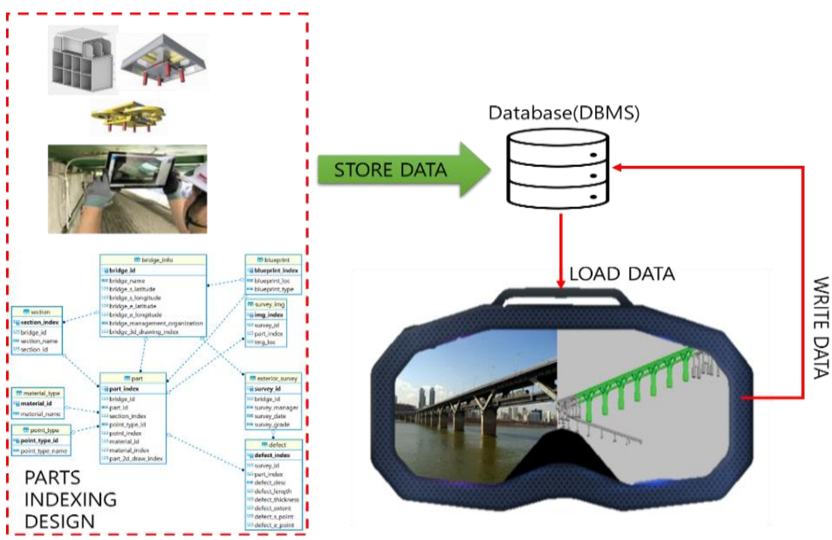

Figure 6. Example of AR Glass Mockup

AR technology provides great help in identifying and diagnosing the state of SOC by projecting the actual space and outputting the information collected through the camera sensor into the device. In addition, although all natural objects are launched and visible in AR devices, the screen is a virtual space, so it is easy to enlarge, reduce, and edit images [8]. But still, The usage of high-capacity 3D content in VR and AR services is restricted due to limitations in network performance and computing power [9]. These functions have the advantage of being utilized for maintenance, repair, design, and construction simulation. Figure 6 shows the comparison between the image in its current state and the original blueprint after displaying the image on the mockup of the AR device. Previously, only 2D cross-sectional inspections were possible using blueprints printed on paper or tablet PCs. Still, AR technology can be used to check the current state of bridge piers more three-dimensionally in 3D. At this time, developers must ensure stability and naturalness when implementing 3D objects in augmented reality [10].

Figure 7 schematically shows data's movement and function when users use AR devices. The user stores the image information scanned from the bridge in the Bridge damage DB and output the stored image data to the head-mounted device, which is a VR device. In addition, the original design drawing is output to the HMD device, and the problem is checked through correction and deletion and sent back to

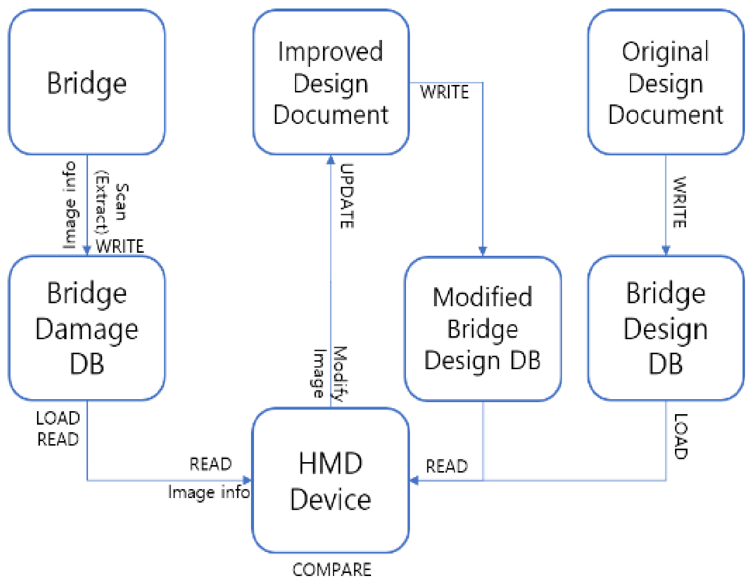

Figure 7. Data Flow Process Diagram for Bridge Images Inspection

the Modified Bridge Design DB. Through this process, various results worked while maintaining the original design may be stored and preserved.

4. Conclusion

In this paper, we remark on the technological trends and problems required for SOC maintenance and repair projects, analyze cases in other countries, and discuss what needs to be improved by reflecting on the current situation in Korea. As seen in many cases worldwide, technology is moving toward enhancing convenience using ICT. Existing methods install various sensors throughout the building and collect information from the sensors for monitoring. However, in the case of a crack in a bridge, the degree of cracking is determined by directly seeing it, so the method using this sensing technology still has limitations. In particular, since the scale of the SOC maintenance business is large, the costs incurred accordingly are very high. The approach using AR technology proposed in this paper contributes to lowering the work-environment risk of workers because they can freely move their hands in the working environment The task of recognizing and analyzing images is still the same, but the method of immediately logging problems and collecting information through the device contributes to speeding up maintenance. In the future, it is expected to provide a more convenient work environment by using sensing information using other ICT devices or by linking information obtained using various image recognition technologies (image recognition technology through drones, etc.) to work through HMD.

Acknowledgment

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