Implementation of a Digital Twin for the Management and Monitoring of Transmission Facilities in Mountainous Areas

Jeon A.J. [1], Lee C.H. [1] and Kim H.G. [1*]

[1]Image Engineering Research Center, 3DLabs Co. Ltd., Republic of Korea

*khanai@3dlabs.co.kr

Keywords : digital twin, geoinformation, monitoring, satellite image

1. Introduction

1.1 Background

Transmission facilities are crucial infrastructure for delivering electricity over long distances, playing an essential role in national industry, households, and power grids. Maintaining these facilities in optimal condition is a challenging task, especially in areas with complex terrain and environmental factors. In mountainous regions, dense forests, steep slopes, and unpredictable weather conditions make regular monitoring and maintenance particularly difficult.

With technological advancements, digital solutions have become essential for infrastructure management. One such technology is Digital Twin, which replicates physical assets in a virtual environment to monitor the state of transmission facilities in real-time or near-real-time. Integrating satellite images and spatial data can make managing transmission facilities more efficient and safer.

1.2 Research Problem

Despite the importance of transmission facilities, managing them in inaccessible areas presents significant challenges. Existing methods rely on physical inspections, which are time-consuming and labor-intensive. Predictable natural factors such as tree growth and landslides add complexity to transmission line management, especially in mountainous regions.

Without an efficient, technology-driven monitoring system, transmission lines face severe risks from tree encroachment, natural disasters, and equipment failures. Failure to address these issues promptly can lead to power outages, economic losses, and accidents.

1.3 Objective

The objective of this research is to develop a Digital Twin solution to manage and monitor transmission facilities efficiently in mountainous areas. The specific goals are as follows:
Design a 3D Digital Twin that accurately reflects the physical characteristics of the transmission facilities and their surroundings.
Integrate satellite images and spatial data for real-time and periodic monitoring of transmission facilities.
Track and analyze data over time to detect changes or potential risks near transmission lines.
Provide multi-layer spatial information, including landslide risk maps, wildfire maps, residential and land use zones, and cultural and natural heritage areas, to support decision-making in transmission facility management.

1.4 Scope

This study focuses on developing a Digital Twin solution using open-source data such as Unreal Engine, Cesium, and Google 3D Maps. It also involves integrating satellite images from CAS500-1, KOMPSAT-3/3A, and WorldView-3 to implement transmission facility modeling, environmental factor integration, time series data analysis, and monitoring functions.

1.5 Significance

This research has the potential to revolutionize national infrastructure management. By providing innovative solutions for remote real-time monitoring, it offers a sustainable and efficient approach to managing transmission facilities. The technology reduces the need for physical inspections, shortens response times, and improves the reliability and safety of the national power grid. Additionally, applying Digital Twin technology to infrastructure management sets a significant precedent for similar technological advancements in various fields, including transportation, communications, and urban planning.

2. MATERIALS AND METHODS

2.1 Background

Various tools, data sources, and software were used to develop the Digital Twin:

1. Unreal Engine: A powerful tool for 3D rendering and real-time simulation, essential for developing the virtual environment.

2. Cesium and Google 3D Maps: These open-source geographic information providers offered terrain and environmental data to build the digital environment. Cesium, in particular, is known for its accurate 3D Earth rendering and time-dynamic data support.
3. Satellite Images: High-resolution satellite images from CAS500-1, KOMPSAT-3/3A, and WorldView-3 were integrated into the software to monitor transmission facilities and their surrounding environments.
4. Spatial Data Layers: A total of 39 spatial information layers were integrated:

- Landslide Risk Maps: Identifies areas with a potential risk of landslides.
- Wildfire Maps: Provides data on areas at risk of wildfires.
- Residential and Land Use Zones: Provides data on residential areas and commercial land use.
- Cultural and Natural Heritage Areas: Provides data on cultural and natural heritage zones.

2.2 Methods

1. Digital Twin Development: The first step involved creating a 3D model of the transmission facilities. Using Cesium and Google 3D Maps, transmission towers and lines were modeled to reflect their actual size and configuration. Unreal Engine was used to integrate these objects into a dynamic and navigable environment.
2. Integration of Satellite Images: Satellite images were processed and integrated into the Digital Twin. Analysis over time allowed users to load images from different periods and observe changes. This was crucial for monitoring risks such as tree growth or erosion
3. Alert System Implementation: A real-time alert system was implemented in the software. For example, if trees encroached on safety zones near the transmission lines, the system automatically notified the user. This feature helps prevent potential damage.
4. Time Series Data Analysis: Users could load satellite images from specific dates and use time series data analysis to observe changes over time. This was useful for detecting and mitigating environmental changes such as tree growth or landslides near transmission towers.

5. Spatial Data Layer Integration: The 39 spatial data layers provided essential information for decision-making. Users could visualize specific types of data, such as landslide risk areas or protected zones, by toggling the layers on or off.

Figure 1 : Digital Twin of Transmission Facility

3. Results and Discussion

The Digital Twin system demonstrated significant potential in managing transmission facilities in mountainous areas. Combining real-time satellite images, 3D modeling, and spatial data allowed facility managers to monitor transmission lines remotely and respond more effectively to risks.

1. Accurate 3D Models: The models of transmission facilities created in Unreal Engine were highly accurate in size and appearance, allowing users to inspect specific areas or facility components virtually.
2. Proactive Monitoring: The tree encroachment alert system operated effectively, notifying users when trees were too close to the transmission lines. This feature significantly reduced the risk of outages due to trees.
3. Time Series Data Analysis: Users were able to detect and mitigate environmental changes such as tree growth or landslides near transmission towers through time series data analysis.
4. Multi-layer Spatial Data Integration: The ability to overlay layers such as landslide risk maps and wildfire maps provided valuable insights for planning and decision-making related to transmission facility locations and maintenance.

4. Conclusion

This study presents an innovative application of Digital Twin technology for managing and monitoring transmission facilities in mountainous areas. By leveraging real-time data and advanced analytical capabilities, it effectively monitors the status of transmission facilities, offering a more efficient and responsive approach to infrastructure management.

Acknowledgments

This work is supported by the Korea Agency for Infrastructure Technology Advancement(KAIA) grant funded by Ministry of Land, Infrastructure and Transport(Grant RS-2022-00155763)