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Digital Twin for Advanced and Continuous Monitoring of Infrastructure Assets Using Remote Sensing and Non-Destructive Testing

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The structural integrity of transportation infrastructure is critical in ensuring public safety, economic stability and societal advancement. The demand for versatile, scalable and real-time monitoring solutions becomes exponential as these assets age, get used more and face environmental pressures. Conventional inspection methods, such as visual inspections and static evaluations, while valuable in localized applications, have significant limitations, including dependence on the expertise of specialized operators, time consumption, and an inability to provide dynamic insights across extensive networks [1]. In this regard, Digital Twin (DT) technology has emerged to provide a virtual replica of physical assets in real-time with data from multiple sources [2]. Supplementing DTs, remote sensing techniques including Multi-Temporal InSAR (MT-InSAR) and high-resolution satellite images can easily identify structural displacements in the millimeter scale region over extensive region.

Satellite constellations, provide periodical updates with high spatial and temporal resolution, allowing a near real time monitoring of infrastructure without the need for ground-based instrumentation. These advancements are further enhanced by Building Information Modeling (BIM), which supports the creation of dynamic digital models encompassing all data relevant to the management, maintenance, and optimization of transportation infrastructure. This research presents a comprehensive approach to integrating Digital Twin technology with satellite remote sensing, BIM, and non-destructive testing methodologies. The study highlights the potential of combining near-real-time satellite data, field inspections, and advanced visualization techniques to develop a scalable, network-level monitoring system for critical assets such as bridges and viaducts. These results reiterate the value of high-resolution satellite missions along with next-generation technologies for enabled predictive maintenance and structural integrity management, supporting the sustainable and resilient transportation infrastructure development.

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