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STRUCTURAL HEALTH MONITORING AND DAMAGES IN HARD-TO-REACH PARTS OF HIGH-RISE BUILDINGS BASED USING UNMANNED AERIAL VEHICLES

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Abstract. Non-contact optical methods for measuring cracks and damages in in hard-to-reach parts of high-rise buildings by remote diagnostics of hard-to-reach building surfaces using unmanned aerial vehicles are analyzed. The drone's high-resolution digital camera captures remote close-up photography of the damages surface of building under high light intensity levels.

Introduction. Cracks in concrete can lead to accidents in building structures [1, 2], therefore require constant monitoring to ensure public safety. The use of standard contact methods for diagnosing concrete structures requires installing equipment on their surface, which is labor-intensive and expensive [3]. Optical methods for detecting cracks in concrete structures are the most accessible and studied currently (see, for example, [4, 5]). Inspection of the surface of buildings using an unmanned aerial vehicle (UAV) is a current area of engineering in connection with the development of UAV technology [6-11]. This inspection is especially invaluable for diagnosing hard-to-reach areas of concrete structures, for example, for high-rise concrete buildings.

In an era marked by rapid urbanization and infrastructure expansion, ensuring the structural integrity of buildings, bridges, and other critical infrastructure is paramount. The conservation of such structures is important, not only from historical, cultural, and architectural points of view, but also because of their social dimensions. However, preserving historical structures is a complex task due to their high vulnerability to natural hazard events (e.g., earthquakes, floods, etc.), pre-existing state of degradation, unique structural and material characteristics, and low energy efficiency. Moreover, the effects of climatic change (e.g., heavy snow loads, rainfall, floods) on the structural integrity of built cultural heritage are progressively becoming more critical. Structural health monitoring (SHM) and damage assessment play crucial roles in safeguarding these assets against potential failures or disasters. Traditional methods often involve manual inspections, which can be time-consuming, costly, and sometimes hazardous. However, advancements in remote sensing technology offer promising solutions to overcome these challenges.

Remote sensing techniques. Remote sensing involves a number of technologies, including satellite imagery, LiDAR (light detection and ranging), and aerial photography. These technologies allow data to be collected from a distance to gain a complete picture of the condition of structures and the environment.

Aerial photography. Aerial photography involves taking images of structures using aircraft or drones (Fig.1). These images provide high-resolution visualization, making it easier to inspect individual components in detail. Aerial photography can quickly identify structural anomalies such as corrosion, erosion or fatigue of the material, allowing for timely maintenance.

Drones, also known as Unmanned Aerial Vehicles, have rapidly become an integral part of the construction industry, and their use in high-rise construction is no exception. These versatile aerial devices equipped with cameras, sensors, and advanced software have revolutionized the way we plan, execute, and monitor construction projects in the vertical realm. Drones offer a unique vantage point that traditional methods can't match, making them a game-changer in the construction of skyscrapers and other tall structures (Fig. 2).

Integration and Analysis. The integration of remote sensing data with geographic information systems (GIS) and advanced analytical techniques enhances the effectiveness of structural health monitoring and damage assessment. Machine learning algorithms can automate the

detection and classification of structural defects, streamlining the analysis process and improving accuracy.

Fig. 1. Aerial photography involves taking images of structures using using unmanned aerial vehicles

Fig. 2. Drones are Revolutionizing High-Rise Construction

Application. The use of remote sensing to monitor the condition of structures and assess damage is widespread in various sectors:

1. Civil infrastructure. Bridges, highways, dams and tunnels benefit from regular remote monitoring to identify potential vulnerabilities and prioritize maintenance work.

2. Oil and gas industry. Pipelines, offshore platforms, and storage tanks require constant monitoring to reduce the risk of leaks, corrosion, or structural failures.

3. Urban planning. Remote sensing data helps urban planners assess the condition of buildings and infrastructure, provide information for renovation projects and disaster preparedness initiatives.

Challenges and future directions. Despite its many benefits, monitoring the condition of structures using remote sensing still faces a number of challenges, such as the difficulty of interpreting the data, sensor limitations, and cost considerations. Future research should focus on improving sensor capabilities, developing standardized protocols for data analysis, and developing interdisciplinary collaboration to effectively address these challenges.

Conclusion. With the rapid development of society and the economy, significant infrastructure, such as roads, buildings, high-speed railways, and bridges, have been built all over the world. However, the increase in operating time and environmental loads have destabilized the structures, resulting in slow structural damage. Such damage, if not detected in time, can threaten normal structural operations, or even cause significant hazards. Therefore, the operational safety of urban infrastructures, as an important practical issue, has attracted increasing attention from multi-disciplinary fields, such as public security, earth obser- vation, civil engineering, and so on. However, since the urban infrastructure is widely distributed, the current manual periodic detection and on-site automatic sensor monitoring methods are spatially or temporally incomplete, and damage could remain undetected. Thus, there is an urgent need for developments in the field of remote sensing technologies that offer promising solutions to overcome these problems.

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