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An Overview of Research on Bridge Surface Defect Detection Methods

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Abstract

After completion, bridges remain in operational states exposed to prolonged environmental elements such as wind, sun, as well as constant structural loads. Over time, these factors can result in issues such as corrosion, damage, and exposure of reinforcement bars in the bridge structure.If not addressed promptly, there is a high risk of bridge collapse, leading to potential casualties and property losses.The surface quality inspection of bridges is a crucial component of bridge assessment, and traditional methods for such inspections often struggle to meet the demands of today's requirements for high-speed and high-efficiency detection.This article aims to outline a method for inspecting the surface quality of bridges using unmanned aerial vehicles (UAVs) as carriers, coupled with advanced image processing techniques for subsequent intelligent analysis.

Keywords

Intelligent Detection; Epigenetic Defect; Concrete Bridge.

1. Introduction

Bridges play a critical role in national development and public well-being. They not only hold a significant position in the national economy but are also essential for ensuring smooth transportation via roads and railways. Typically, conventional bridges have a lifespan ranging from 80 to 120 years.With the enhancement of the country's transportation capacity, the infrastructure of bridges has become increasingly sophisticated. China's level of bridge construction has now attained a leading position globally.Due to the extended service life of bridges, many of them are entering a fatigue phase. Once in operation, bridges are subjected to various forces and vehicle loads over an extended period. Coupled with the natural aging of construction materials, multiple defects and damages may arise. Concrete structural ailments such as cracks, honeycombs, and pitting are common in bridge engineering. While they remain within certain safety thresholds, without regular quantitative monitoring, surpassing these safety limits may lead to severe and destructive incidents such as concrete spalling and water seepage.Crack detection stands as a crucial aspect in the assessment of the apparent quality of bridges. Cracks not only impact the aesthetic appeal of the structure but also diminish the stability of the bridge.In order to effectively reduce or prevent the occurrence of the aforementioned safety incidents, it is essential to systematically carry out safety inspections on prefabricated beam bridges. Timely identification of abnormal signs and issuing warnings is crucial for swiftly and efficiently implementing scientifically sound emergency plans.

With the emergence of intelligent image recognition technology and sophisticated digital image processing methods, some of the drawbacks associated with traditional detection methods have been addressed.For example, the use of unmanned aerial vehicles as carriers for bridge inspection has become a popular topic in recent years. However, due to the complexity of bridge structures, there are stringent safety requirements for the flight of UAVs. If the UAV is manually controlled, there are certain positions that may not be directly observable to the human eye, making it challenging to

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precisely control the UAV's flight trajectory. This difficulty in control could potentially lead to collisions between the UAV and the bridge, resulting in hazardous incidents.Bridge inspection is a recurring task that requires regular examinations and maintenance. The inspection routes are typically predetermined, and when using drones for inspection, the drone's path generally remains consistent. Therefore, research into autonomous navigation, constant-speed cruising, and obstacle avoidance for drones in complex environments can enhance the practicality of using drones in bridge inspection. This automation aims to maximize efficiency and achieve the greatest benefits in bridge maintenance and safety.

2. Comparison between Traditional Detection Methods and Intelligent Detection Methods

2.1 Advantages and Disadvantages of Traditional Detection Methods

In order to timely grasp the health status of bridges, practitioners of bridges in China have formulated the "Code for Maintenance of Highway Bridges and Culverts", which stipulates bridge inspection as shown in the table below:

Table 1. Regulations on Bridge Inspection

Inspection Method	Operation method
Regular inspection	Daily visual inspections are conducted to assess the current state of the bridge deck, upper structure, lower structure, and ancillary structures. These inspections involve observing for any visible signs of defects or damage. Typically, these inspections are carried out at regular intervals according to a predetermined schedule.
periodic inspection	Longer intervals between inspections involve comprehensive examinations of the bridge's main structure and ancillary structures. These detailed inspections aim to assess the technical condition of the bridge, collect and organize technical data, and provide information for evaluating the bridge's grade and determining its operational status. This thorough examination is crucial for understanding the overall health and performance of the bridge over an extended period.
special inspection	Following the regular inspections, a thorough examination is conducted to inspect and collect data on bridge defects. This includes identifying the causes of defects, assessing the severity of damage, evaluating the current load-bearing capacity of the bridge, and determining the bridge's ability to withstand natural disasters. This in-depth analysis is a primary task in establishing the technical condition of the bridge, providing critical insights into its structural integrity and safety aspects.

Currently, the primary method of inspection relies on a combination of visual inspection by human operators and the use of bridge testing equipment. This traditional inspection method has a lower safety margin, slower detection speed, and limited inspection coverage. With the increasing number of bridges, the workload for bridge inspections is also growing. The traditional inspection methods struggle to meet the demands for efficiency in the present scenario.Below is a brief description of commonly used traditional inspection methods: Firstly, there is visual inspection conducted directly by personnel. This method is not only characterized by low safety and efficiency but may also result in instances of oversight or misjudgment. Additionally, the measurement scope is limited, making it a time-consuming and labor-intensive process.General auxiliary tools like aerial work platforms and climbing ladders have limitations in height, are inconvenient to carry, and pose operational risks. Consequently, there is a prevalent issue of overlooking critical areas in bridge inspections. Additionally, non-destructive testing techniques such as ultrasonic testing, infrared thermography, and radardetection offer more comprehensive information by probing the internal structure and materials of the bridge.Large inspection equipment such as bridge inspection vehicles can ensure

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effective inspections, but they are in short supply and cannot be used frequently. Additionally, whether it is a truss-type bridge inspection vehicle or a basket-type bridge inspection vehicle, they typically occupy roads during operation, causing significant traffic disruptions. As a result, these vehicles are mainly employed for routine and special inspections rather than regular use.

2.2 The Advantages and Disadvantages of Intelligent Detection Methods

Therefore, intelligent and simplified bridge inspection technologies have emerged, utilizing modern technological tools such as drones and climbing robots to replace traditional manual inspections. This not only enhances operational efficiency but also ensures safety.Today, the unmanned aerial vehicle industry is rapidly advancing, and UAV remote sensing technology has become quite mature. Drones equipped with optical and thermal cameras are widely employed in various inspection fields. In bridge inspection, drones can carry highly precise imaging devices to capture images of bridge damage. These images are then analyzed using algorithms to assess the surface image features and determine the extent of bridge defects. Utilizing drones for bridge visual quality inspection offers several advantages compared to traditional inspection methods:

1) Drones do not occupy lanes, and they do not cause any disruptions to traffic on the bridge.

2 Drone operation is simple and easy to learn, requiring fewer personnel, thus reducing the workload and operational complexity.

3) Drones offer higher precision, efficiency, and speed, leading to more objective and accurate inspection results compared to traditional methods.

Based on the advantages mentioned above, it can be observed that employing drones for the surface quality inspection of bridges is a future development trend.When drones are used for bridge inspection, in order to accurately assess the presence of defects, it is necessary to capture clear images. This requires the drone to approach the inspected parts closely while avoiding collisions. The inspection area for drones is primarily the complex and variable low-altitude space around the bridge, which includes elements such as bridge cables, piers, abutments, and suspension rods, as well as designated no-fly zones and hazardous areas in different locations.If the flight path is not planned in advance, not only can the drone be damaged due to collisions, but more critically, safety accidents may occur. Therefore, in the inspection of bridge defects, ensuring both efficiency and safety in detection, the research on automatic cruise and obstacle avoidance control for drones is of paramount importance.

3. The Research on Inspection Methods Using Drones as Carriers.

3.1 Research Approach to Inspection Methods

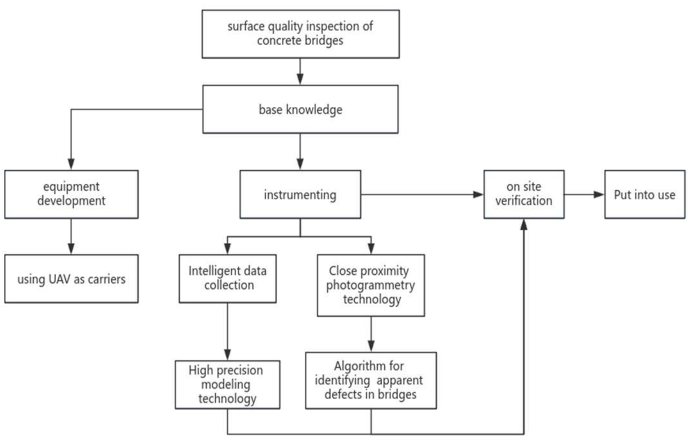

Figure 1. technical route

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After a comprehensive review of various types of bridge inspection devices both domestically and internationally, it is evident that convenient and rapid inspection devices are in the minority. This article primarily focuses on the combination of image processing technology and drone-based bridge crack detection techniques.Firstly, the drone path is planned to achieve comprehensive coverage of the bridge surface, including the surface, underside, piers, and abutments. Image processing algorithms are then employed to compare captured images with existing datasets, extracting crack features. Finally, the data undergoes further processing. The specific technical roadmap is outlined as follows.

3.2 Intelligent Data Acquisition

Based on the common defects and diseases in existing concrete bridges and the principles of general detection devices, various sensors with handheld gimbals and drones are studied. This aims to achieve a finer and multidimensional collection of apparent data from concrete structures. The processed multi-source data is then displayed in multiple windows, allowing for comparative analysis within the same software. This approach facilitates digital representation and analysis.The comprehensive measurement of the intended concrete structure and its surroundings involves combining low-altitude photogrammetry with three-dimensional laser scanning. This approach utilizes close-range photogrammetry for detailed measurements of the structure's surface. By integrating data obtained through these three methods, high-precision models are constructed for specific building structures. This forms the foundation for identifying defects on the surface of concrete structures and achieving high-precision measurements of building structure dimensions.

3.3 Research on Close Photogrammetry Technology

Conduct research on two types of photogrammetric techniques: handheld gimbal equipped with visible light cameras for close range measurement of structures through zoom, and unmanned aerial vehicle close range photogrammetry. Conduct research on the identification accuracy of structural diseases and defects under different photogrammetric conditions (offshore distance, height, lighting conditions), and study the optimal solution for close range photogrammetry.

3.4 Research on Intelligent Identification Algorithm for Surface Defects of Concrete in Beam Bridges

To meet the needs of safety assessment and inspection of concrete structures, focusing on the visible or other material science visual characteristics of apparent defects and flaws in concrete structures (including cracks, damage, honeycombing, surface corrosion, exposed rebar corrosion, and other apparent defects), a study is conducted. This involves establishing an image dataset collected from existing engineering projects. The research is centered around deep learning-based algorithms for intelligent detection and identification of defects and pathologies. The ultimate goal is to achieve intelligent recognition and assisted measurement of concrete structure pathologies and defects.In order to validate the practicality of the equipment, it's essential to compare it with traditional inspection methods before further testing. Presently, the primary inspection methods involve visual inspection by humans, taking photographs, or a combination of manual inspection and photography during bridge inspections. When conducting this comparison, besides considering the portability of the new equipment, the primary focus should be on comparing the inspection results.The validation method could involve testing a specific area of the same bridge and comparing the detected data. Under identical conditions, taking the detection of bridge cracks as an example, if the new method identifies fewer cracks compared to the traditional detection approach, it indicates that the new detection method may have issues. In such cases, each stage of the research process needs to be systematically examined. On the other hand, if the results of the new method are faster and more accurate than the traditional approach, it suggests that the new detection method is more practical and can be implemented in routine bridge inspections. The validation process may include testing the same area of a bridge and comparing the data obtained from the respective inspections.

3.5 Test Plan

1) Development of Experimental Apparatus

To understand the current types of drones available on the market, choose a suitable one as the platform for the experimental apparatus. Conduct preliminary research on the no-fly zones in various regions of the country. Equip the drone with a high-resolution camera capable of autonomous 360° rotation to achieve comprehensive imaging capabilities.

2) Utilize the developed apparatus for on-site parameter detection.

This article proposes to plan the route for drone monitoring in two stages: first, detecting the bridge deck, and then inspecting the bridge abutments and piers. The objective is to identify any surface defects. Continuous monitoring at the same location will be conducted to validate the feasibility of the experimental apparatus. During the detection phase, efforts will be made to collect as much data as possible, categorizing and storing it to create a comprehensive comparative database for analysis.

3) Data Transmission and Processing

The process involves transmitting images captured by the drone in real-time to a dataset for comparison. Deep learning-based algorithms for intelligent defect detection and recognition will be researched. This aims to achieve intelligent identification of defects and damages in concrete structures. The algorithm will be designed to detect characteristics such as the length, width, and height of cracks. The database will then provide feedback on the comparative results to the drone. Utilizing the data, high-precision modeling will be conducted to accurately locate surface defects.

4. Summary

With the rapid development of drone technology and image processing techniques, various algorithms have become relatively mature. However, from an engineering perspective and considering the current state of bridge inspection, current research still has limitations. The existing issues are as follows:

1) At present, drones used in bridge inspection haven't achieved precise positioning and route planning. Drones equipped with cameras currently cannot achieve full coverage imaging of bridges. Additionally, due to limitations in drone battery power, it's challenging to complete inspections of entire bridges.

2) The quality of image capture is not sufficiently high. The imaging process may be affected by factors such as lighting conditions, shadows, and noise. There is also a lack of a comprehensive automated detection system from image capture to data analysis. The transmission and processing of images have not reached complete automation and intelligence.

3) Due to the relatively limited application of drone detection technology in bridge inspections, there is a scarcity of reference image features when identifying cracks. This shortage of features contributes to a higher occurrence of false positives and false negatives during the detection process.

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