A surface crack recognition and repair system for small and medium-sized bridges

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Abstract: As an important part of transportation, bridges play an important role in the national economy. As the number of bridges continues to increase, their maintenance and repair tasks continue to increase. In order to solve the problem of limited application scenarios and high cost of existing bridge maintenance vehicles, this paper proposes a surface crack recognition and repair system for small and medium-sized bridges, which is low in efficiency and affects traffic. It uses survey UAVs to collect bridge surface defect information, uses image processing technology to identify cracks, and the maintenance vehicle automatically navigates to repair the bridge deck crack at the location of the crack.

1. Introduction
Cracks are one of the important hidden dangers that threaten the safety of bridges. Small cracks on the surface of the bridge may develop into destructive and deep cracks, which can also cause the corrosion of steel bars in the concrete to accelerate concrete aging. Traditional manual identification of diseases is limited by shortcomings such as large workload and low efficiency. Error detection and missed detection are prone to occur in detection, and as the number of bridges to be checked continues to increase, the shortcomings will be further amplified[1]. While non-destructive testing techniques represented by acoustic emission and infrared thermal imaging can detect internal diseases of bridges, they have limited applications in automation scenarios. This system is composed of two parts: survey UAV and maintenance vehicle. The survey UAV determines the optimal flight path according to the bridge information during work, automatically cruises to collect the bridge surface defect information, and efficiently and accurately identify cracks through image processing technology and neural network algorithms. The maintenance vehicle automatically navigates to the location of the crack according to the crack location information, and fills the crack with repair materials to complete the automatic repair process of the bridge crack. It is a bridge crack repair method that integrates high-precision identification, precise positioning, real-time transmission, and timely repair. This system can realize the automation and intelligent repair of cracks, and provide technical support for repairing bridge cracks.
2. Crack information collection and processing

2.1. Collection of bridge surface defect information

2.1.1. Determination of flight path. In order to use UAVs to detect bridges efficiently and safely, it is necessary to reasonably plan the flight path of survey UAVs when inspecting bridges. The main factors that affect the path planning of the survey UAV are the endurance of the UAV, the recognition rate of the camera, and the surrounding environment. After selecting the type of UAV and camera, the parameters are fixed values, and the flight path of the survey UAV mainly depends on the surrounding environment.

When surveying UAVs collect video streams, they first obtain the length, span, and width of the bridge from related units, and then use a unit-decomposed full-coverage path planning algorithm to analyze the optimal flight path. Set target points on key parts of the bridge as key detection objects. Combined with the environment acquisition process, the environment is modeled by the grid method, and then the bridge to be detected is decomposed into multiple sub-areas by the unit decomposition method, and then the sub-areas is traversed by the two-point method and the binary tree search method to realize the detection of each part of the bridge[2].

2.1.2. Determination of flight distance. When the survey UAV is flying close to it, it will be disturbed by aerodynamic effects and cause imaging instability and collision with the bridge. Therefore, it is necessary to determine the minimum safe distance for stable imaging and avoid collision when the survey UAV detects the bridge.

In the natural environment, the factors that affect the imaging stability of the survey UAV include the airflow of the outside wind field and the vibration of the original structure of the UAV. Through wind tunnel experiments, the minimum safe distance and stable hovering time under different working conditions are obtained. The non-contact measuring instrument is used to measure the displacement of the camera in the hovering state, and the hovering holding time is judged, and the MTF modem function is used to evaluate the imaging quality of the survey UAV. Combining the hovering holding time of the survey UAV and the imaging stability to determine its minimum safe distance[3]. Through field experiments, the measurement of the stable flight safety distance of the survey UAV to detect the bridge is verified to meet the imaging quality and safety requirements under actual wind speed conditions.

2.2. Image processing and crack recognition

2.2.1. Selection of data transmission method. Considering that the actual situation of the bridge is complicated, the 5.8GHz frequency band used by traditional UAVs has poor penetration and is not suitable for complex situations. This system uses SPI-5G communication for data transmission. The system consists of three modules: sending module, receiving module and server module. Adopting C/S architecture design, building a cloud server to solve the problem of receiving module requesting video data for the absence of available public network IP, using the server as a relay station, the sender first transmits the signal to the server, and then the receiving end requests the server data.

Survey UAVs and maintenance vehicles can transmit the detected bridge deck defect type and location information, as well as machine power and other health status information, to the host computer in time during the work process, and the host computer will further process the received information. Figure 1. is a flow chart of data transmission.

![Data transmission flow chart](image)
Automatic cruise mode and manual operation mode can be selected when survey UAVs and maintenance vehicles are working. Under normal weather conditions, survey UAVs and maintenance vehicles use automatic cruise mode to detect bridge defects. When encountering bad weather or complicated environment, the operator can manually operate the machine according to the machine status displayed by the host computer to ensure the safety of the machine.

2.2.2. Video stream characteristics and preprocessing. It is difficult for survey UAVs to maintain stability during the process of collecting video streams and the collected images are blurred due to the influence of noise. In addition, in order to ensure the flight safety of survey UAVs, it is far away from the bridge, resulting in image resolution very low, it is necessary to preprocess the images collected by the survey UAV.

Aiming at the problem of blurred images of survey UAVs due to unstable flight and noise effects, this system uses median filtering, image graying, histogram equalization, edge enhancement, threshold segmentation and other processing to obtain a binarized image that reduces background interference while retaining high-frequency edge information. Aiming at the problem of low resolution of images taken by survey UAVs, this system adopts an improved algorithm for super-resolution reconstruction of aerial images based on neighborhood embedding, and uses wavelet transform combined with first-order and second-step features to extract features from low-resolution images, Use the method of low-rank matrix restoration to process the matrix composed of feature vectors to improve the correlation between the vectors and obtain a high-resolution image.

2.2.3. Use convolutional neural network algorithm to accurately identify cracks. Deep learning is widely used in the field of artificial intelligence. The existing convolutional neural network has a good performance in dealing with problems related to deep learning[4]. Aiming at the problems of low detection efficiency and unsatisfactory accuracy in the current known solutions, this system uses convolutional neural networks to compile a set of detection solutions suitable for bridge cracks, and performs crack identification processing on the information collected by the UAV, and obtains the length and width information of the cracks in the image, which improves the accuracy and intelligence of the survey UAVs in identifying cracks.

After image preprocessing is performed on the video stream collected by the survey UAV, the data will be saved in the designated folder in AVI format. Through mathematical processes such as convolution operation and weighting, the features are extracted to obtain the classification model. The back propagation stage is to continuously iterate, update the weight and reduce the loss function, and continuously learn to improve the detection accuracy. During recognition, the trained neural network weight file and other configuration files will be used in the detection program. When the detection instruction is issued, the program will obtain a real-time data set from the specified file directory to facilitate real-time crack detection[5,6].

3. Design of maintenance vehicle

3.1. Work process of maintenance vehicle

When the maintenance vehicle is working, it first performs automatic navigation according to the approximate position of the bridge deck crack transmitted by the host computer. After reaching the crack position, the shape, width, and length of the crack are accurately detected, according to the relevant standards stipulated in the "JTG H11-2004 Highway Bridge and Culvert Maintenance Code", the cracks larger than 0.3mm are filled with repair materials, and the road surface is flattened.

The maintenance vehicle adopts a dynamic path planning scheme based on the D* algorithm. In the unknown terrain, the map status is updated at any time according to the GPS data obtained by itself and the sensor's perception data of the surrounding environment, and the specific path to a target point is found under the current path. Once encountered a dead angle or obstacle, the system automatically rotates the angle and re-plans the path[7]. After the maintenance vehicle reaches the target point, the
repair material is filled into the crack under the monitoring of the host computer, and the plunger is pushed to squeeze the repair material in the cavity of the maintenance vehicle through the rotation and stretch of the electric push rod, and the repair material enters the rotatable nozzle device. Realize accurate filling of repair materials. After the filling is completed, in order to prevent the excess material from causing uneven road surface, the maintenance vehicle lowers the roller module to make mecanum wheels off the ground, and uses the roller module to flatten the road surface.

3.2. Mechanical device design
The maintenance vehicle is composed of a walking module, a defect detection module, an extrusion module, a road pressing module, a navigation and positioning module and a control module.

The walking module of the maintenance vehicle uses mecanum wheels, which can realize multi-directional movement. The defect detection module is installed on the front side of the maintenance vehicle, and the camera is installed obliquely downwards, which can not only observe the road surface in front of the maintenance vehicle, but also monitor the working conditions when repairing cracks. When the defect detection module detects a fillable bridge deck crack, the extrusion module can fill the repair material carried by the maintenance vehicle into the crack. The road pressing module is a liftable device installed at the bottom of the maintenance vehicle, which can flatten the excess part after filling with the repair material to ensure the road surface after the repair is smooth.

3.3. Filling material selection
The cracks and water seepage parts of the bridge should be waterproof and sealed, and reinforcement measures should be taken. A high polymer mortar material selected by this system meets the road and bridge culvert maintenance specifications, has good high permeability, water retention, crack resistance, acid and alkali resistance, and has fast curing, high compressive strength, and adhesion good performance, can be constructed on the wet base surface, and adhere firmly to the old concrete, not easy to fall off. The use of this material for repair is simple and environmentally friendly. It can ensure economy and solve the problem of high temperature and aging resistance of organic materials in reinforcement applications. The quality has been improved. It can also be used under severe conditions and is suitable for repairing and repairing damaged parts of roads and bridges.

4. Simulation and testing
This system is divided into two parts: survey UAVs and maintenance vehicles. In order to verify the feasibility of the program theoretically, we established physical models of the maintenance vehicle and survey UAVs, simulated the working status of the maintenance vehicle, and performed dynamic simulations on the maintenance vehicle, and finally determined that the theoretical design plan of the maintenance vehicle has a relatively high feasibility. In addition, we have produced the actual survey UAV and conducted a test flight, confirming that the survey UAV can perform flight inspection under normal wind load conditions. Figure 2. shows the physical model of the maintenance vehicle, and Figure 3. shows the actual photo of the survey UAV.
5. Summary
This article introduces a surface crack recognition and repair system for small and medium-sized bridges, and analyzes the detection and repair process of bridge deck cracks, which can solve the problems of high cost, long cycle and potential safety hazards in traditional bridge inspection. The video stream is collected by the survey UAV, the image is preprocessed and the crack is identified, and the maintenance vehicle is used to fill the small cracks with repair materials, which can effectively prevent the cracks from expanding, prevent problems before they occur, ensure the safety of the bridge, and extend its service life.

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