Q&A From Webinar

Image-Based Bridge Defect Detection and Monitoring Technologies
Jian Zhang, Southeast University, China
14 Sep 2021

Q1: What is the minimum crack width that can be detected? Also, what's the impact of the image quality on the accuracy of the detection?

A: The minimum detectable crack width is 0.1mm. Finer cracks can be detected by changing to a higher resolution camera. The factors affecting the detection accuracy include image resolution, illumination conditions (dark light, shadow occlusion), image transmission and storage problems (video transmit in radio may have noise), motion blur, etc. because the deep learning based detection method is more robustness than traditional image process methods, the influence of illumination conditions and image noise is very small. For the problem of low image resolution, the image can be enlarged by super-resolution method, and the image blur can be removed by image processing method. In general, image quality degradation can be reduced by corresponding methods.

Q2: Could you explain a bit more how the defect localization was conduced?

A: We proposed a method that combined the SLAM algorithm and image matching algorithm, first the position of each key-frame during inspection was calculated using a mono-visual SLAM and then each frame contains defects will be matched automatically with key-frames so the position of the key-frame is the position of the defect.

Q3: Would you mind sharing some publications on climbing UAV that you've developed?

A: Shang, Jiang & Zhang, Jian. (2019). Real-time crack assessment using deep neural networks with wall-climbing unmanned aerial system. Computer-Aided Civil and Infrastructure Engineering. 35. 10.1111/mice.12519.

Q4: Could you please explain a little bit about your techniques to measure the crack width?

A: Please refer to our paper: Ni, Futao & Zhang, Jian & Chen, Zhiqiang. (2018). Zernike-moment measurement of thin-crack width in images enabled by dual-scale deep learning. Computer-Aided Civil and Infrastructure Engineering. 34. 10.1111/mice.12421.

Q5: What is the strongest wind condition where your UAV can work effectively?

A: The maximum wind speed we encountered during bridge inspection is about 13m / s, which is about a level 6 wind.

Q6: Are the different proposed options supposed to be included in a particular drone or as standalone software packages that can work with any drone package that an agency may be using? I am referring to the collision detect/allowing drone to touch the structure and the bolt detection/clarification, structure deformation, etc.?

A: At present, our algorithms and software need to be used with our developed UAV, because part of real-time detection works was on data transmission and radio hardware. In the future, we may open source some of our early work.

Q7: How can you determine the distance between the camera and the targets? If you do not know the distance, how can you calculate the displacements?

A: The target is a special made infrared target with known size and characteristics. The homography matrix can be used in the calculation, so there is no need to know the distance. Details can also be found from the answer to Question 10.

Q8: Could you please explain what's the tolerance for the cracks width of the bridge inspection specifications? Do you have an evaluation index for the bridge health condition or bridge construction quality

A: Different specifications have different requirements for the allowable crack width of bridges, and requirements are also for different bridge types and different parts of the bridge. The specification generally requires that the maximum crack in the key area of the bridge not allowed exceed 0.4~0.8 mm. Our equipment has a crack detection accuracy of 0.1mm, which is required to meet the specification requirements. There are methods available using information of cracks for structural condition assessment.

Q9: How do you scale images from floating UAV's for crack measurement?

A: Based on the characteristic that our wall-climbing UAVs can cling to the structural surface during inspection, the camera can be kept facing the structural surface, and the distance between the camera and the structural surface remains unchanged, so the scale of the captured image remains unchanged, and tilt correction is not required. For the UAV inspects while flying, we installed a laser ranging sensor on the camera to determine the image scale parameters by using the object distance.

Q10: For tracking multiple infrared targets with one camera, it will cause different measuring accuracy for different infrared targets due to different object distances. How did you deal with this problem? Did you measure each object distance for each infrared target for calculating the scale factors?

A: One camera that we developed can track up to 10 infrared targets at the same time. However, considering the factors of clear imaging and measurement accuracy, we usually install multiple cameras and choose lenses with different focal lengths for targets with different distances. For example, we use a 200mm lens for targets with object distances of 100~200 meters, and we use a 300mm lens for targets with distances of 200~300 meters. We can ensure that our targets are in a clear imaging range, and the accuracy of targets at different object distances can also reach the millimeter level. In addition, we use the object distance method and the known target size method to calculate the scale factor. When the object distance is not convenient to measure, we calculate the scale factor through the known size between several small point light sources on our infrared target.

Q11: What is the maximum expected deflection of the 300-meter railroad cable stay bridge for the train load? Is it supporting light rail or heavy rail?

A: The maximum deflection of the 300-meter cable stayed bridge under moving train was 124 mm, it was increased to 225 mm when the combination of moving train, temperature and shrinkage and creep were applied at this bridge. This bridge is designed as high-speed railway vehicles.

Q12: Do you think it can be tailored to be used for bridge inspection after fires? like comparing pictures of the bridge before and after a fire and track the damage?

A: For bridges after fire, obvious stains will be left on the concrete or steel surface due to flame and smoke, , which will bring challenges to the detection of surface defects. On the one hand, adding some defect images after fire to the deep learning database will bring benefits, on the other hand, the combination of RGB image and short-range laser scanning can greatly reduce the impact of surface stains on inspection accuracy.

Q13: Would you please explain the detailed specification of Lidar that was used in this research? The model and the manufacturer if it is fine.

A: The lidar we use to scan structural three-dimensional point clouds is VZ-400i from Riegl. Its effective distance is 800m and the maximum accuracy is 3mm.

Q14: Can you please tell if you use Infrared images for this research?

A: Instead of using infrared images for displacement calculations, our camera uses active infrared point light sources mounted on the main beam to illuminate the camera mounted on the pier. The infrared light has strong penetration, and the image sensor of the camera captures these infrared light sources to achieve real-time tracking. In addition, we install filters on our lenses that only pass through infrared light above 850nm, thus eliminating the interference of natural stray light.

Q15: How many minutes does it take to detect a defect in Non GPS for a bridge with how long a span?

A: It takes about 40 minutes to inspect the surface of a 150 meter high bridge tower, about 1.5 hours to inspect the bottom surface of a 300 meter span bridge, and about 1 hour to inspect the surface bolts of a 120 meter steel truss bridge.

Q16: What are the processes that can be done on the data you get from crack widths? Are there methods to make a global evaluation of the system dynamics using these data? or they are just used in local evaluations?

A: The first step is to get the crack images of a bridge by cameras, then a deep learning-enabled quantitative crack width measurement method can be employed to get the crack widths from images. In the detection and mapping phase, dual-scale convolutional neural networks are designed to detect cracks in complex scene images with validated high accuracy. Subsequently, a novel crack width estimation method based on the use of Zernike moment operator is further developed for thin cracks. The effect of cracks on global structural dynamic characteristics is not obvious, and cracks reflect more local information for local evaluation. The fusion evaluation method of detection information (e.g., crack) and monitoring data (e.g., acceleration) is a great research direction in the future.

Q17: Wondering whether you are working on any methods to detect subsurface level defects. In other words, do you have methods to identify cracks/deteriorations that are not visible to the outside.

A: With regard to the detection of internal cracks or defects, the method based on acoustic waves is the main method. We are currently trying to use shock echo and ultrasonic methods for detection.

Q18: Can you please discuss what happens with microwave radar monitoring? What does the microwave radar look for and pick up?

A: The transmitter of the microwave radar generates a set of linear frequency modulated continuous wave signals, most of the signals are transmitted to the transmitting antenna (the remaining part is transmitted to the receiver as the local oscillator signal), which is transmitted to the measured target by the transmitting antenna, and then passed through the measured target. The target reflection generates an echo signal, and the receiving antenna receives the echo signal, and then the receiver mixes the echo signal and the local oscillator signal. The signal data obtained by the signal processor filtering and sampling the mixed signal contains the distance information and vibration information of the measured target. The real vibration of the vibrating target can be obtained by combining the vibration information and the elevation angle measured by the built-in gyroscope.