UAV based Inspection Framework for Crack Detection in GPS Denied Environment

Muhammad Imad, Muhammad Wicaksono ᴷ, Soo Young Shin*

imadsafi08@kumoh.ac.kr, muhammadwicak97@kumoh.ac.krᴷ, wdragon@kumoh.ac.kr*

Department of IT Convergence engineering
Kumoh National Institute of Technology

Abstract

Utilization of advanced robotic systems, specifically unmanned aerial vehicles (UAVs), has demonstrated efficacy in identifying structural damage in various infrastructures, such as bridges, buildings, and nuclear power plants. In tunnel environments, however, challenges arise due to the absence of GPS signals, increasing collision risks. To address this, we propose a GPS-free self-localization algorithm utilizing onboard data, accompanied by a segmentation neural network for precise defect detection. Field tests affirm the framework's effectiveness, underscoring its potential for application in tunnel inspections.

Keywords : Tunnel Inspection, Deep learning, Autonomous Navigation, Defect segmentation.

I. Introduction

Tunnel inspection is essential for evaluating tunnel safety and devising maintenance plans. The choice of technology and method for inspection significantly influences the accuracy of a tunnel safety assessment and the magnitude of maintenance work required [1]. As tunnels age, deterioration occurs owing to environmental factors, poor maintenance, and inherent structural weaknesses [2]. Cracks are the most common form of damage in tunnels, typically progressing from small to large, and may eventually result in catastrophic failure [2].

Recently, the utilization of automated inspection systems and robotics has shown promise for revolutionizing the traditional inspection industry. The use of commercially available unmanned aerial vehicles (UAVs) for inspection purposes has garnered significant attention owing to their flexibility and mobility. Despite these advantages, the use of traditional UAV inspection systems in tunnel environments presents several challenges, particularly in the absence of light and GPS signals, which can result in increased collisions [3].

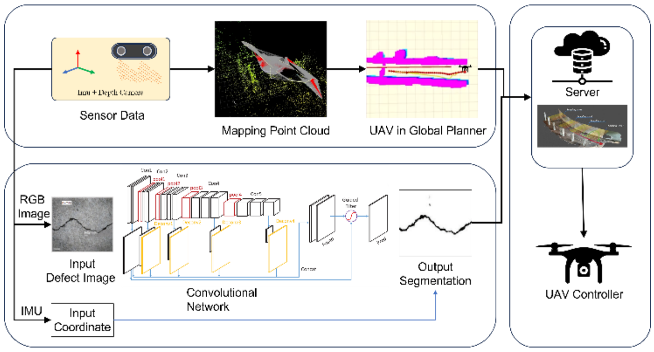

Fig. 1 Overview UAV Defect detection with SLAM architecture.

To address these challenges, a flying robot framework with crack-detection capabilities was proposed, followed by the development of a GPS-free self-localization algorithm based on data from an onboard computer, camera, and inertial measurement unit (IMU). The efficacy of the system was validated through a field test, which confirmed the feasibility of implementing the proposed framework for tunnel inspection.

Ⅱ. Proposed System

The proposed model comprises flying robot autonomous navigation and crack-detection frameworks, as shown in fig.1. Initially, an Unmanned Aerial Vehicle (UAV) autonomously navigates along a predetermined path. Subsequently, a high-definition

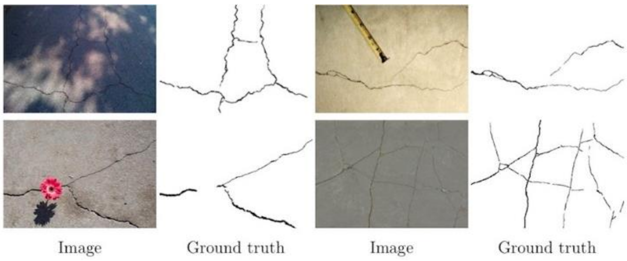

Fig. 2 Some representative samples in our benchmark database.

camera mounted on the UAV was employed to swiftly identify and locate crack areas within the tunnel. To accomplish this objective, a deep hierarchical convolutional neural network (CNN), known as DeepCrack [4], was utilized to predict pixel-wise crack segmentation in an end-to-end manner. DeepCrack comprises extended Fully Convolutional Networks (FCN) and deeply supervised Nets (DSN). We formulate crack segmentation as a binary image labeling problem, where "0" and "1" represent "non-crack" and "crack," respectively. Recognition algorithms deployed on UAV require specialized training datasets. Hence, the crack detection model was trained using a dataset comprising 537 RGB color images with manually annotated segmentations. All segmentations were obtained by presenting the subjects with a binary image. The images were divided into two primary subsets: a training set with 300 images, and a testing set with 237 images. Each image was accompanied by a pixel-wise segmentation map that precisely covered the cracked regions. All the images had a fixed size of 544 × 384 pixels..

Ⅲ. Result Implementation

The present study has successfully demonstrated the mobility capabilities of the flying robot in real-time tests, as well as the effectiveness of the crack-detection model, which was evaluated on a publicly available dataset, as depicted in fig.₩ref{fig2}. The results indicated that the proposed system exhibited a high level of robustness with regard to both panoramic crack image classification and refined crack segmentation. It is noteworthy that, as drones possess dual-mode localization capabilities (vision and IMU), all captured images are accompanied by location information, enabling workers to identify and locate damages rapidly and accurately when performing repair work. In all instances, the crack classifier achieved a true positive rate of 96.5%, whereas the crack segmentation model attained an accuracy of over 93.6%.

IV. Conclusion and Future Work

This study proposed a flying robot-based framework for automated crack inspection in tunnel environments. An image classification algorithm and crack segmentation algorithm were developed to process panoramic images captured by an unmanned aerial vehicle (UAV). The implementation of the proposed system enables safety managers to monitor the distribution of cracks within the tunnel environment effectively, thereby enhancing the reliability of tunnel safety assessments.

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