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Computer Vision-based Continuous Large-scale Site Monitoring System through Edge Computing and Small-Object Detection

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Abstract

In recent years, the growing interest in off-site construction has led to factories scaling up their manufacturing and production processes in the construction sector. Consequently, continuous large-scale site monitoring in low-variability environments, such as prefabricated components production plants (precast concrete production), has gained increasing importance. Although many studies on computer vision-based site monitoring have been conducted, challenges for deploying this technology for large-scale field applications still remain. One of the issues is collecting and transmitting vast amounts of video data. Continuous site monitoring systems are based on real-time video data collection and analysis, which requires excessive computational resources and network traffic. In addition, it is difficult to integrate various object information with different sizes and scales into a single scene. Various sizes and types of objects (e.g., workers, heavy equipment, and materials) exist in a plant production environment, and these objects should be detected simultaneously for effective site monitoring. However, with the existing object detection algorithms, it is difficult to simultaneously detect objects with significant differences in size because collecting and training massive amounts of object image data with various scales is necessary. This study thus developed a large-scale site monitoring system using edge computing and a small-object detection system to solve these problems. Edge computing is a distributed information technology architecture wherein the image or video data is processed near the originating source, not on a centralized server or cloud. By inferring information from the AI computing module equipped with CCTVs and communicating only the processed information with the server, it is possible to reduce excessive network traffic. Small-object detection is an innovative method to detect different-sized objects by cropping the raw image and setting the appropriate number of rows and columns for image splitting based on the target object size. This enables the detection of small objects from cropped and magnified images. The detected small objects can then be expressed in the original image. In the inference process, this study used the YOLO-v5 algorithm, known for its fast processing speed and widely used for real-time object detection. This method could effectively detect large and even small objects that were difficult to detect with the existing object detection algorithms. When the large-scale site monitoring system was tested, it performed well in detecting small objects, such as workers in a large-scale view of construction sites, which were inaccurately detected by the existing algorithms. Our next goal is to incorporate various safety monitoring and risk analysis algorithms into this system, such as collision risk estimation, based on the time-to-collision concept, enabling the optimization of safety routes by accumulating workers' paths and inferring the risky areas based on workers' trajectory patterns. Through such developments, this continuous large-scale site monitoring system can guide a construction plant's safety management system more effectively.

Keywords: Safety management, computer vision, real-time site monitoring, small-object detection, edge computing