UNIVERSITI TEKNOLOGI MARA

CLOUD-BASED LIGHTWEIGHT DETECTION OF HARDHAT COMPLIANCE BASED ON YOLOV5 IN POWER CONSTRUCTION SITE

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ABSTRACT

Ensuring the safety of workers is of utmost importance at power construction sites. Wearing hardhats is critical to protect workers' safety. Unfortunately, some workers neglect to wear hardhats due to a lack of awareness. Therefore, it is necessary to provide real-time warnings when detecting workers without hardhats. Implementing deep learning-based object detection algorithms can facilitate the enforcement of hardhat-wearing compliance, thereby reducing work-related injuries and fatalities. However, these models typically have numerous parameters and computations, rendering them incompatible with embedded devices with limited resources. Furthermore, existing algorithms face challenges in complex work sites, such as detecting long-distance, occluded, dense, and low-light objects. Therefore, this thesis explores and studies public hardhat datasets, deep learning algorithms, power Internet of Things (PIoT), and edge computing to address the above issues. Based on You Only Look Once (YOLO) v5, A cloud-based real-time hardhat-wearing compliance detection system was proposed to detect workers not wearing hardhats in power construction sites. It utilized a lightweight object detector called hardhat-YOLO. First, a large-scale hardhat-wearing dataset, hardhat10K, was introduced to train the detection model effectively. Second, the lightweight backbone, RepGhostNet, was used to lightweight the YOLOv5s backbone to significantly reduce parameters and Giga Floating Point Operations (GFLOPs), thereby improving detection speed. Third, an improved Convolutional Block Attention Module (CBAM) module, Light-CBAM (L-CBAM), was effectively integrated into the new backbone to mitigate accuracy drops. Fourth, a refined Efficient Intersection over Union (EIoU) loss function, Prior-EIoU, was proposed to increase the convergence speed of the loss function and improve the recall, thereby reducing the missed detection rate. Finally, the hardhat-YOLO model was trained using the Hardhat10K dataset and deployed on the Jetson Orin Nano 4G edge computing terminal to detect no-hardhat-wearing workers. The hardhat-YOLO model achieved a Mean Average Precision (mAP50) of 83.5% at 50% IoU while significantly reducing parameters, GFLOPs, and size by approximately 50%, 53.2%, and 47.7%, respectively, compared to the YOLOv5s model. This made it a more lightweight and efficient design with only a minor reduction in accuracy. Furthermore, it achieved approximately 50 Frames per Second (FPS) using a live camera, meeting the real-time detection requirements. Experimental results demonstrate that the hardhat-YOLO model can accurately and efficiently detect hardhat-wearing compliance in real-time, ensuring its practical applicability in power workplace safety monitoring.

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CHAPTER 1
INTRODUCTION

1.1 Research Background

Electricity is crucial for national development and everyday life. As the national power industry grows, the coverage and complexity of electric power systems are increasing. The State Grid Corporation of China (State Grid) oversees an extensive power transmission area, which includes numerous power construction, operation, and maintenance sites. In recent years, State Grid have gradually deployed node equipment with video processing capability to perform intelligent monitoring in the distribution power station [1]. Power construction is a high-risk activity, and worker safety is paramount. Power work sites involve various electrical equipment, requiring operators to strictly follow safety regulations, including the mandatory use of hardhats.

A hardhat comprises a shell, lining, chin strap, and additional accessories. It employs a liner of expanded polystyrene (EPS) foam on the inside of the helmet shell, in addition to the harness suspension. For front, back, and side impacts, this EPS liner provides the primary means of impact force mitigation [2]. The hardhat's shell effectively disperses the impact force from falling objects. The interior of a hardhat further buffers and absorbs impact forces, ensuring the worker's head is protected. Further, many head and neck injuries are caused by falling from a height or being struck by vehicles and other moving plants and equipment. Therefore, the hardhat is essential personal protective equipment (PPE) designed to protect the head from injuries during production, construction, and transportation. The compliance of hardhat-wearing is vital to ensure maximum safety.

The State Grid defines a major accident as one that causes the death of more than 10 but fewer than 30 people, or serious injuries to more than 50 but fewer than 100 people, or direct economic losses of more than 50 million yuan but fewer than 100 million yuan. Therefore, the State Grid integrates IoT technology to establish the Power Internet of Things (PIoT), enhancing power grid efficiency and safety management.

The overall architecture of the Power IoT adheres to the technical principles of "accurate perception, edge intelligence, unified IoT, and open sharing". It standardizes the access of various types of collection terminals through platforms such as the IoT