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Revamping Bolt Inspection in Oil and Gas Industry: Edge-Deployed Robotic Machine Vision Model applying Knowledge Distillation

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Extended Abstract

The oil and gas industries are widely recognized as a domain with the greatest potential for workplace hazards, largely due to the intricate and demanding machinery and equipment involved in its operations. Given the complex and dangerous nature of equipment involved, this industry demands stringent safety protocols to protect the well-being of the human operators and prevent accidents. Inadequate maintenance of the machinery not only poses a threat to safety of human operators, but also has the prospective to cause significant damage to the environment.

To effectively analyse the defects in the industrial bolts in real-time, the development and deployment of edge-deployable Artificial Intelligence (AI) model on a robot [1] is paramount. In this regard, the main focus is to explore the application of robots for conducting industrial machine inspection to identify any potential damage to the components and assist in the process of predictive maintenance. Specifically, the inspection of industrial bolts [2] which acts as a fastener in critical components such as pipeline flanges and pressure vessels.

However, the challenge is the limited availability of data of bolts with abnormalities, especially broken and loosened ones. To address this challenge and to build a robust edge-deployable AI model on robots, transfer learning paradigm [3] was investigated, where the models are pretrained on large open-source datasets. An ImageNet pre-trained Vision Transformer (ViT) [4] was considered and fine-tuned on tiny, proprietary bolt dataset.

Evidently, ViTs have shown promising results on several benchmark datasets and outperformed many state-of-the-art image classification algorithms, although they require huge computational power and storage. Therefore, deploying a large ViT model on a low power, low memory edge device is extremely challenging. To mitigate this issue, Knowledge Distillation technique [5] was leveraged. Knowledge Distillation facilitates the transfer of knowledge learned from a bigger, complex model called teacher to a smaller, simple model called the student. The advantage of this approach is that the learned student model can be deployed on edge devices in robots [6] and can still produce accurate results in real-time.

In conclusion, deploying machine vision models for industrial inspection of bolts in the oil and gas industry on the edge devices embedded in robots, can bring several advantages in terms of safety and efficiency. A custom AI model with 100k parameters has been developed successfully and was able to achieve 88% accuracy using the effective combination of techniques such as knowledge distillation and vision transformers. This alleviates to overcome the difficulties posed by the limited availability of training data and computational resources, while making edge deployment in robots feasible. The robust AI model thus built can provide real-time decision-making capabilities and improved accessibility to machines in hazardous areas. Eventually, providing an effective, efficient industrial inspection system and preventing potentially dangerous situations, thereby reducing the risk of equipment failure, benefiting human operators in terms of safety and businesses in terms of saving operational costs.

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