Industry 4.0: Wind Turbine Defect Detection

WHITEPAPER

TABLE OF CONTENTS

Executive Summary

The AI technologies landscape has changed over the last few years. As the backbone technology of machine learning, deep neural networks (DNNs) have quickly ascended to the spotlight. Every day, there are more applications that rely on deep neural network techniques across industries such as Automotive, Industrial, Medical, Energy and others.

Another technology with a changing landscape is drone imaging. Drones generate large amounts of data. Previously, the data generated was difficult to process. Combining drones and AI has solved the challenge of processing huge amounts of data generated by drones faster and accurately and deliver insights critical for business. Following the same principles, we have used both drone data and DNNs for wind turbine defect detection.

Introduction

Reducing the Levelized Cost of Energy (LCoE) continues to be a priority in the growth of wind energy sector. Operation and maintenance (O&M) costs usually constitute of 20-25% of overall onshore and offshore wind LCoE compared to 15% for coal, 10% for gas and 5% for nuclear. New technologies such as automation, data analytics, smart sensors, and artificial intelligence (AI), have been successfully used to reduce wind energy's O&M costs. These systems are intended to achieve more efficient service, inspection, and maintenance with minimal human intervention.

One similar prominent technologies is usage of drone-based inspection of the wind turbine. At present, drone inspections are being used effectively for structural safety monitoring of various infrastructures such as buildings, power plants, dams, bridges etc. This approach allows low-cost and periodic inspections, allowing for predictive maintenance at lower costs. Damage to the surface of wind turbines shows familiar visual characteristics that can be imaged by drones with optical cameras. Damages such as cracks, damaged vortex generators and edge corrosion are easily visible in their early stage of development. Sometimes, they may be a sign of significant internal structural damage.

Thus, we address the problem of damage detection by deploying a deep learning object detection framework. The main advantages of deep learning over other detection methods are:

- Automatically finds the most discriminate features for the identification of objects
- Process optimized to minimize the errors
- Extensibility of the model for additional class of defects

Platform for Inferencing

As a result of technological advancements in the field of wind energy, both the size and efficiency of wind turbines have increased in the last decade. This situation has led to an increased focus on issues such as fault identification in wind turbines. Condition monitoring and wind turbine failure detection algorithms are important systems which help reduce the maintenance costs and downtime of wind power plants. Wind turbines are located in remote areas, which makes reliability an important factor. Faults in wind turbines results in the need for repair and/or replacement which leads to loss of energy output. In some situations, failure in one component can affect other components, and even the entire wind turbine. Considering these factors, it is critical to identify and isolate faults in wind turbines at the earliest in order to take the appropriate steps to avoid undesired effects. This reduction in maintenance costs also makes wind energy more economically attractive relative to other energy sources.

	Intel(R) Xeon(R) Platinum 8256			
	No Optimization	With OpenVino		
		FP32	FP16	INT8
Inference time (ms)	1X	3X	3X	9X
FPS	1X	3X	3X	9X

Table 1. Inference Time Before and After Intel® Distribution of OpenVINO™ on Intel® Xeon® Platinum 8256 CPU

The trained defect detection model was optimized to run on an Intel® Xeon® Platinum 8256 CPU @ 3.80GHz and an Intel® Xeon® Platinum 8153 CPU @ 2.00GHz. The Intel® Xeon® Platinum 8153 CPU supports 2 AVX-512 FMA units and three Ultra Path Interconnect links with a maximum memory capacity of 768 GB. Optimization was done using Intel® Distribution of OpenVINO™ toolkit to get better performance on the target hardware. Table 1 shows the resulting inference times before and after the implementation of the Intel® Distribution of OpenVINO™ toolkit.

Solution Approach

We used Deep Neural Network based object detection model that detects the visible defects on blade surfaces of wind turbine blades for missing teeth in VG (Vortex Generator) panel and blade edge corrosion. The image captured from the Drone are of high resolution. In the image, the size of the defect compared to the whole image is too small as the pictures are taken from a distance. The model was fine-tuned to better detect small defects. We used various augmentation techniques to increase the quantity of available data to train the model.

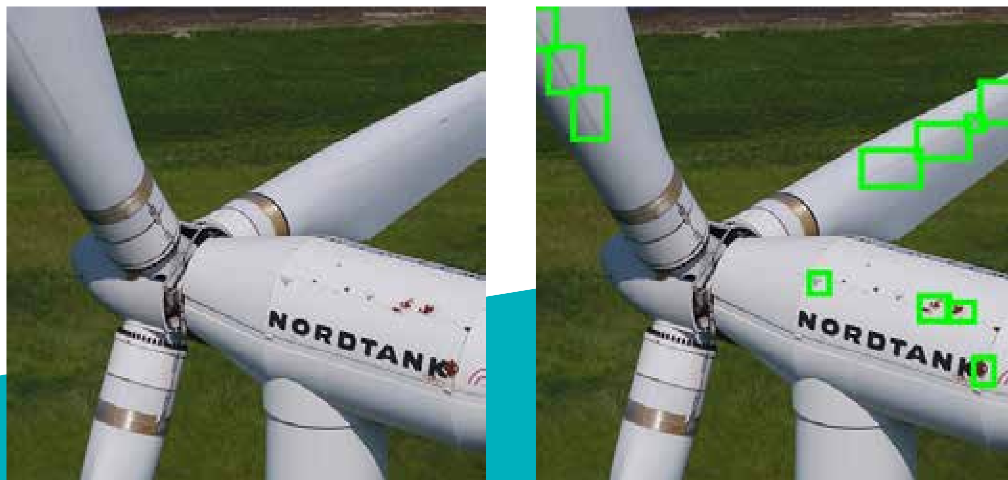

Fig 1. Identification of defects

Results and Discussions

The results show that the INT8 Precision is giving a better performance in terms of inference time on Intel® Xeon® Platinum 8256 CPU @ 3.80GHz. The same result is observed on Intel® Xeon® Platinum 8153 CPU @ 2.00GHz hardware. The model was optimized on various edge devices such as

Intel® Xeon® Processor E3-1268L v5 supports 4K at 60Hz with a maximum resolution (HDMI 1.4) of 4096x2304@24Hz, DP of 4096x2304@60Hz and eDP – integrated flat panel of 4096x2304@60Hz.

Intel® Core™ i5-6500TE CPU with IEI Mustang-F100-A10 FPGA is powered by Intel® Distribution of OpenVINO™ toolkit. It supports Ubuntu 16.04.3 LTS 64bit, CentOS 7.4 64bit, Windows 10. It has a memory of 8G on board DDR4 which consumes power of 40W.

Intel® Core™ i5-6500TE CPU WITH Intel Neural Compute Stick 2 develops, fine tunes, and deploys convolutional neural network (CNN) on low-power applications that require real-time inferencing. It supports heterogeneous execution and Raspberry Pi across computer vision accelerators using a common API. The operating systems that it supports include Ubuntu 16.04.3 LTS 64bit, CentOS 7.4 64bit and Windows 10.

Intel® Core™ i5-6500te CPU with IEI Mustang-V100-MX8 is also powered by (Intel® Distribution of OpenVINO™ toolkit. The operating systems that it supports include Ubuntu 16.04.3 LTS 64bit, CentOS 7.4 64bit and Windows 10. It consumes power of approximately less than 25W, has data plane interface PCI Express x4, and is compliant with PCI Express Specification V2.0.

Intel® Atom® x7-E3950 Processor has 4 cores and 4 threads with processor base frequency of 1.60 GHz and burst frequency of 2.0 GHz. It supports 4K at 60Hz with a maximum resolution (HDMI 1.4) of 3840x2160@30Hz, DP of 4096x2160@60Hz and eDP – integrated flat panel of 3840x2160@60Hz. It has 8 USB ports of 2.0/3.0.

Conclusion

This work aimed at saving time and costs for the unplanned maintenance of industrial equipment such as wind turbines and towers. Using drones to collect imaging data and DNNs to detect defects helps reduce operational and maintenance costs and - most importantly - improves operational safety.

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