

HALO: High Autonomous Low-SWaP Operations

Sloan Hatter, Blake Gisclair

Faculty Advisor: Dr. Ryan White, Dept. of Mathematics and Systems Engineering, Florida Institute of Technology

**ENGINEERING & SCIENCE
STUDENT DESIGN SHOWCASE**

FLORIDA TECH

ABSTRACT

Orbital object detection is a vital aspect of space operations, particularly when attempting to identify satellite components. Traditional space-based object detection methods such as ground-based radars, optical telescopes, and sensors fixed to satellites, while tried and true, have a latency issue that is becoming more prevalent and harder to manage, increasing the need for real-time detection. In order to achieve real-time orbital object detection, Machine Learning comes into play. Neural networks are utilized for detection by running on-board models directly on satellite systems. Convolutional Neural Networks (CNNs) are typically used due to their ability to efficiently extract spatial features and patterns from images; however, Vision Transformers (ViTs), a newer neural network architecture, have shown increased effectiveness due to their ability to capture global context.

One main issue of deploying systems with such capabilities is resource allocation. Neural network models are typically run on large computers, which take up significant space, power, and other resources. A solution is to scale down to a Low-SWaP system (low size, weight, and power); however, this results in inefficient performance due to limited memory and power.

To enable efficient operation, the model itself must be reduced through quantization. Quantization converts high-precision numerical values to lower-precision representations, reducing memory usage, increasing inference speed, and lowering energy consumption. A Vision Transformer model is typically represented in 32-bit and can be quantized to lower bit-widths. The objective of this project is to quantize a Vision Transformer model and evaluate its performance at each level, enabling real-time orbital object detection on Low-SWaP systems, known as High Autonomous Low-SWaP Operations (HALO).

MOTIVATION

- Growing need for real-time orbital object detection
- Large computing systems are impractical for satellite deployment
- Low-SWaP systems address satellite resource constraints but limits performance
- Quantization of models increases performance on Low-SWaP hardware

METHODS

- Dr. White's NEural TransmissionS (NETS) Lab GPU servers
- Python Coding Language
- NVIDIA Jetson AGX Orin
- NVIDIA TensorRT SDK
- Quantization techniques, including Post Training Quantization (PTQ), and Quantize/Dequantize (Q/DQ) Node insertion for Quantized Aware Training (QAT)

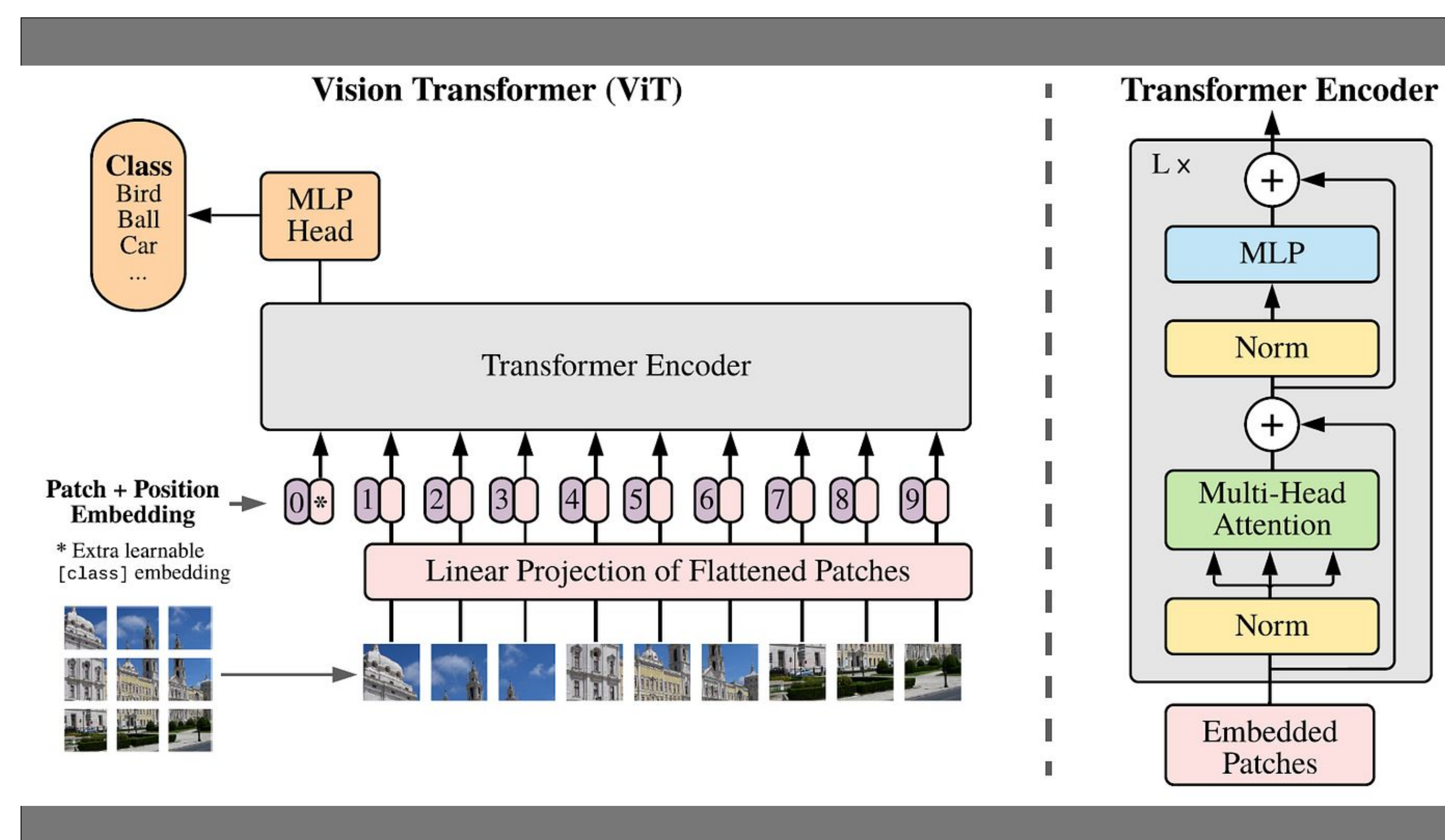


Image of mAP score comparison

Images of Detections

NOVELTY

- Vision Transformer (ViT) Neural Network Framework
- Switching from Convolutional Neural Networks (CNNs) to ViTs for orbital object detection
- Quantizing ViTs below 16-bit representation

RESULTS

FUTURE WORK

- Achieving a true 2-bit representation of a Vision Transformer for orbital object detection tasks
- Achieving a true 1-bit representation of a Vision Transformer for orbital object detection tasks
- Efficient satellite component object detection for:
 - Diagnosing broken components
 - Docking onto satellites
 - Identifying space debris

ACKNOWLEDGEMENTS

- Dr. White, for his guidance and foundational research insights.
- Arianna Issit, for her help with the Jetson computer, datasets, and initial CNN model