HALO:
High-efficiency Autonomous Low-SWaP Operations

Sloan Hatter, Blake Gisclair
Advisor: Dr. Ryan T. White

GOALS AND MOTIVATION

- Current orbital object detection uses Vision Transformer (ViT) neural networks on large computers.
  - This is ***unsustainable for satellites due to space and resource limits***.
    - Smaller devices like Raspberry Pis are better suited
- Typical downsizing method, called “pruning”, removes model layers
  - This ***reduces model size, but also accuracy.***

- Proposed solution: ***compress weights instead of removing layers.***
- Weights are stored as 32-bit floats (in C++)
- I hope to reduce them to 1-bit
  - Prior research has achieved a 1.58-bit representation for ViT.

- Objective: ***develop a true 1-bit quantization method for ViTs*** deployable on satellites to enable autonomous orbital object detection.

APPROACH

- **Accurate Object Detection**
  - The user will be able to detect and identify orbital objects, more specifically, satellite objects, within a given image space.
- **Low-SWaP Hardware Compatibility and Deployability**
  - The user will be able to send to space smaller object detection-capable computers that take up less space and resources.
- **Autonomous Operations Abilities**
  - The user will gain the ability to run these computer vision models on satellite hardware and execute autonomous operations, such as docking and repairs. Automating these operations will reduce the need to send up manned missions and increase the longevity of active missions.

NOVEL FEATURES

- One-bit representations of weights have been restricted mainly to LLM transformers and have not been explored extensively for vision transformers and vision tasks, such as classification and segmentation.

ALGORITHMS AND TOOLS

- Python
- Jupyter Lab
- Multiple data sets:
  - Hardware In the Loop (HIL)
  - Web Satellite Data (WSD)
  - Digital Twin On-Demand Data
- Neural Networks and Vision Transformers (ViTs)
- Hailo-8 NPU/HailoRT (for model inference)
- Raspberry Pi AI Hat+ (Neural Network Accelerator)
- Jetson AGX Orin Developer Kit (64GB)/Jetson Xavier NX Series (8GB) as back-up

TECHNICAL CHALLENGES

- I plan to utilize a neural network, but I do not have much experience using and training neural networks.
- I will have to do more research on ViTs to understand their functionalities better.
- I will have to determine the best hardware tool to utilize - either the Raspberry Pi or the Jetson; the Raspberry Pi may not allow for necessary low-level quantization.

MILESTONE 1

- Literature Review researching the deployment of ViTs onto Raspberry Pi’s.
- Load a Vision Transformer (ViT) onto the Raspberry Pi AI Hat+ to establish a baseline for model performance using metrics such as framerate and accuracy.
- Create Requirement Document
- Create Design Document
- Create Test Plan

MILESTONE 2

- Reduce ViT down to a 4-bit representation using model quantization.
- Tune the 4-bit model to recoup losses in accuracy.

MILESTONE 3

- Reduce model size down to 1-bit, prioritizing size reduction over accuracy retention.

TASK VECTOR

Task	Sloan
Literature Review	Research
Load ViT onto Raspberry Pi	Interface with hardware
Requirement Document	Write 100%
Design Document	Write 100%
Test Plan	Write 100%

THANK YOU!
QUESTIONS?