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Neuromorphic Robot Perception for Autonomous Control

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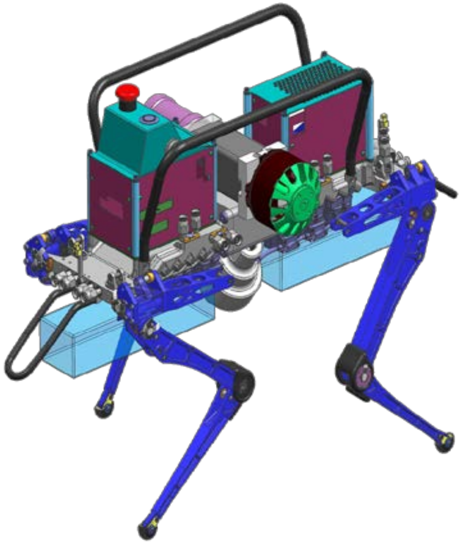
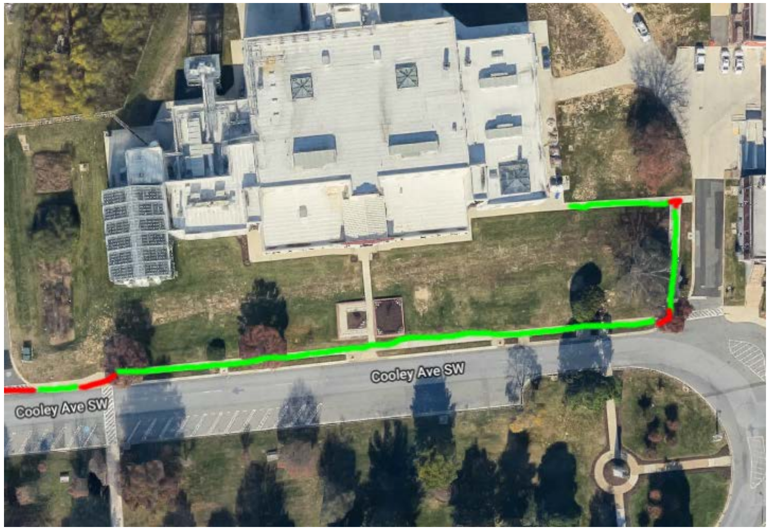
Overview: Big Picture

One of the *biggest challenges* in robot vision is how to *efficiently* make decisions from a stream of high resolution images



Navigating on SWAP constrained robots



- Consider the scenario:
  - Investigate a region: Butch is given GPS waypoints
  - How do we navigate between waypoints?

- Navigation in unstructured outdoor environments is hard!
  - Widely varying terrain, some surfaces are better than others
  - SWAP constrained platform; GPUS are too expensive

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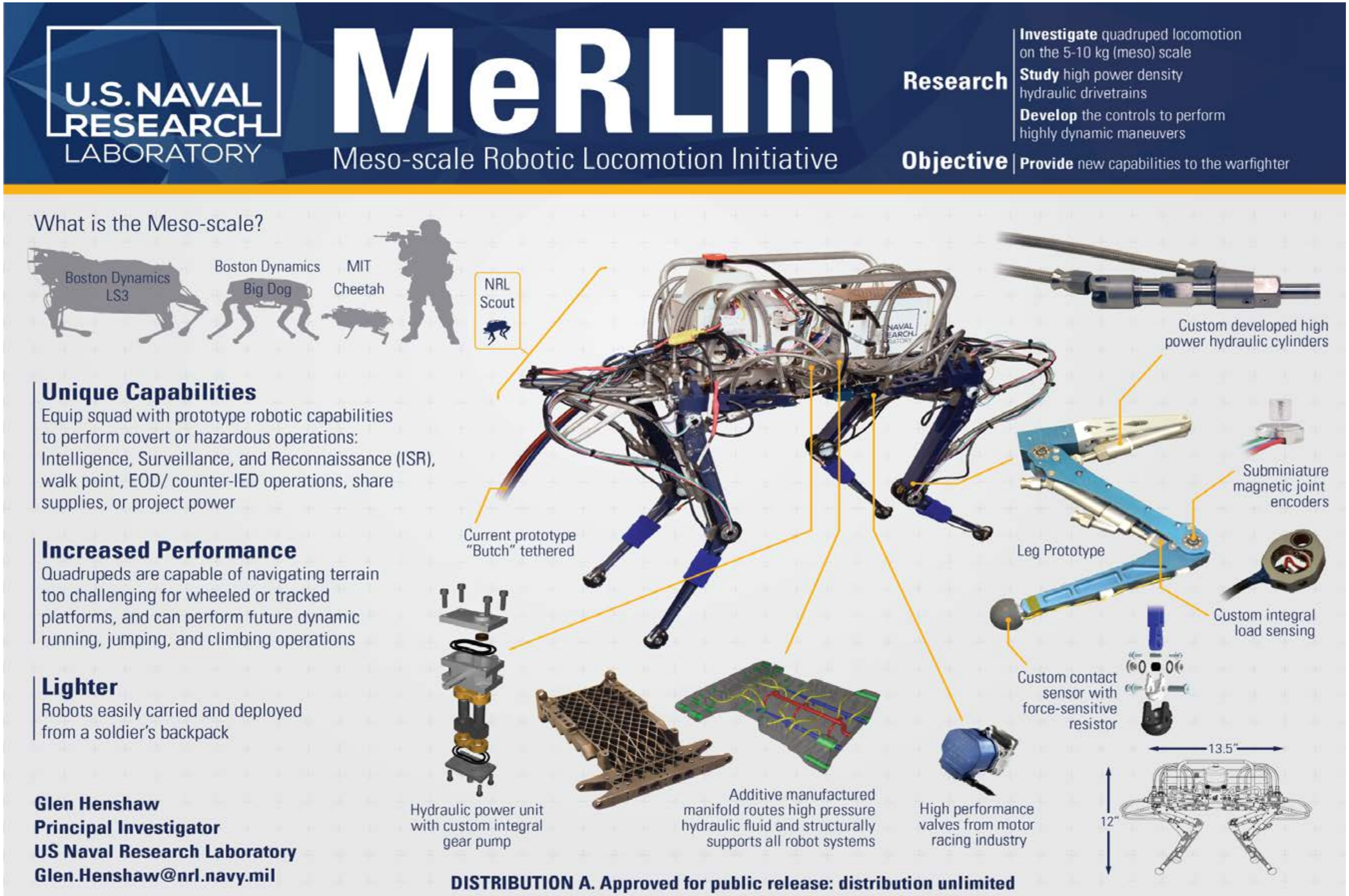
Small, lightweight, backpackable robot

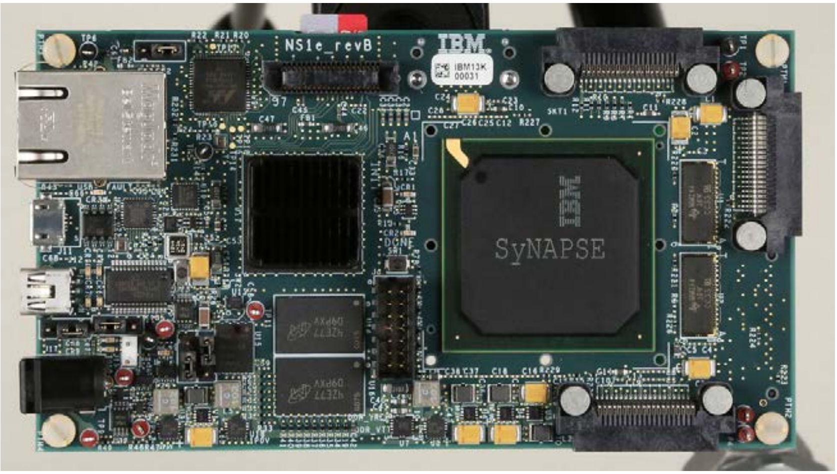


IBM TrueNorth

TrueNorth: IBM Research's neuromorphic processor

- *Ultra low power*, 70mW in full operation
- Over 1 million neurons, 256 million synapses, 4096 parallel neural cores
- Trains using a standard deep network (CNNs) with the Eedn framework

- Streaming library processes images at 1000 inferences per second



Surrogate Problem

Using neuromorphic computing, identify traversable terrain to navigate a small autonomous robot around NRL, Washington, DC

Terrain Classification

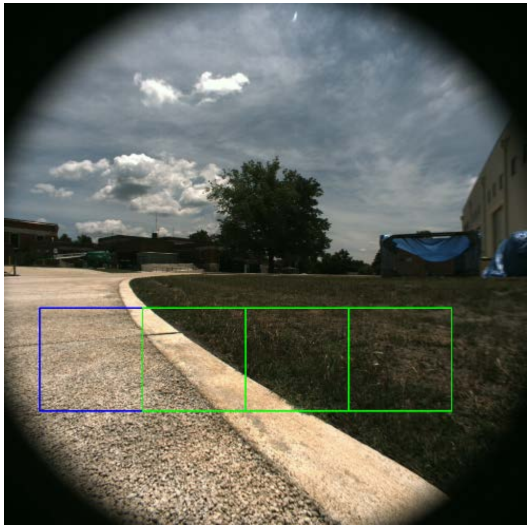
Scan the region immediately in front of the robot, making terrain classifications at 5 fixation locations

- Predict: Concrete, Grass, Asphalt
- Patch size is 350x450,
- Stay on the sidewalk!!

No concrete detected

Concrete is straight ahead

Concrete is on the left



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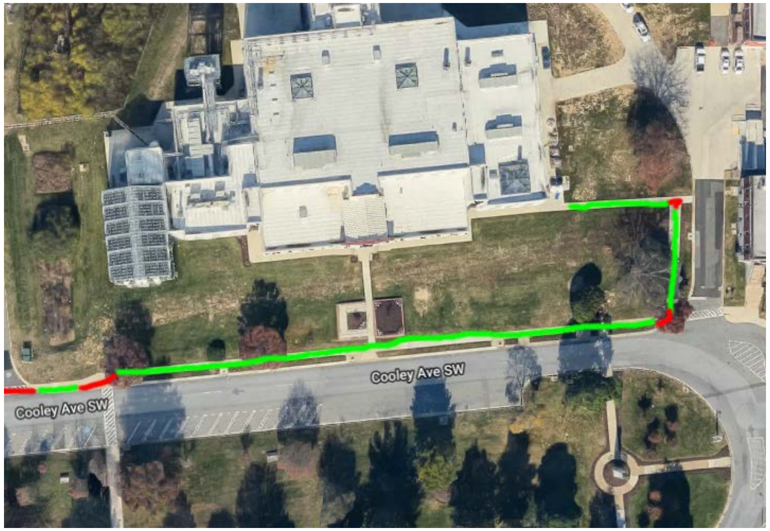
Terrain Classification

- Classification
  - Patch size (input) 350x450
  - 2 convolutional layers (128 7x7 conv.; 256 10x10 conv.)
  - Uses 2284 of the 4096 available TN cores
- Trained using images collected at NRL to learn types of terrain
  - Fully supervised training
- Endeaver Robotics PackBot equipped with carnegie robotics S7 providing images at 5 Hz
  - Found that the TN classified regions without any lag.

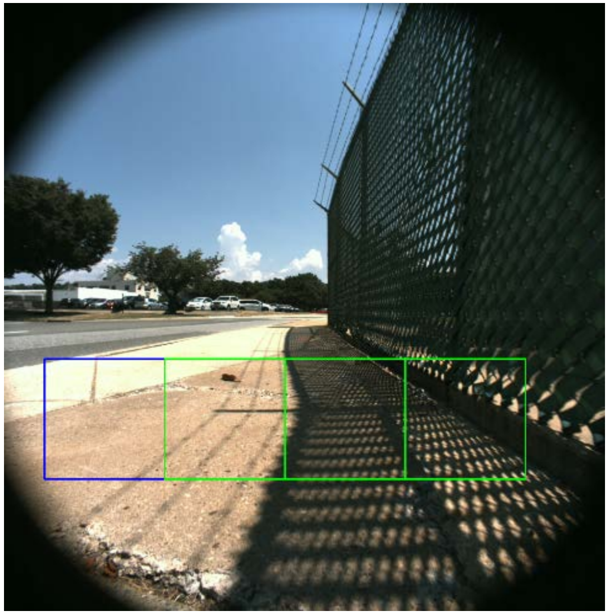
Current Status

- Effective at classifying different types of regions
- Some logic is needed to handle special cases:
  - Decision points (left vs straight)
  - Cross-walks (don't run my robot over!)



Challenges

- Unfamiliar variations that are not in the training set can be challenging – some issues are fences, hard shadow, gates, discolored concrete



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Current Status

- We currently integrating this into the ROS navigation stack
  - GPS waypoint navigation completed
- Experimentation with Loihi
- Have also explored other strategies such as foveation and fixation, which has shown to help to decrease image size and improve system accuracy