



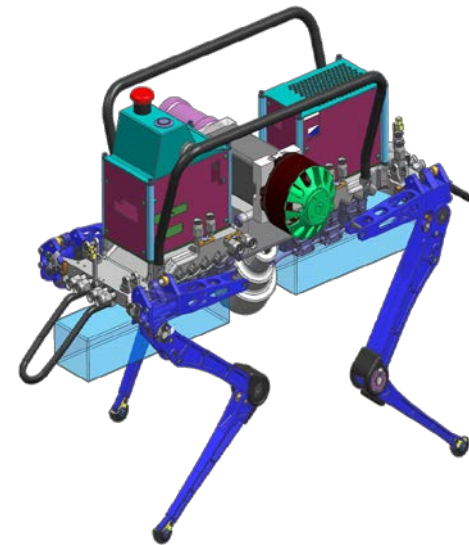
Neuromorphic Robot Perception for Autonomous Control

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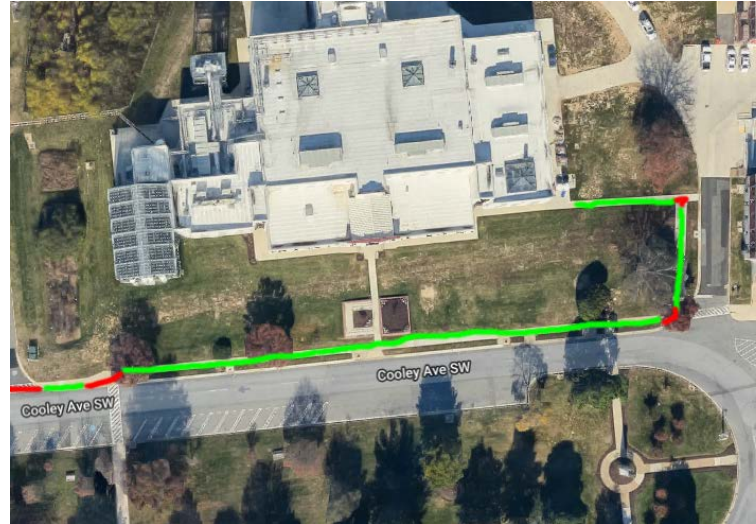
Naval Research Laboratory, Washington, DC

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

Small, lightweight, backpackable robot



MeRLIn

Meso-scale Robotic Locomotion Initiative

Research

Investigate quadruped locomotion on the 5-10 kg (meso) scale

Study high power density hydraulic drivetrains

Develop the controls to perform highly dynamic maneuvers

Objective

Provide new capabilities to the warfighter

What is the Meso-scale?



NRL Scout

Unique Capabilities

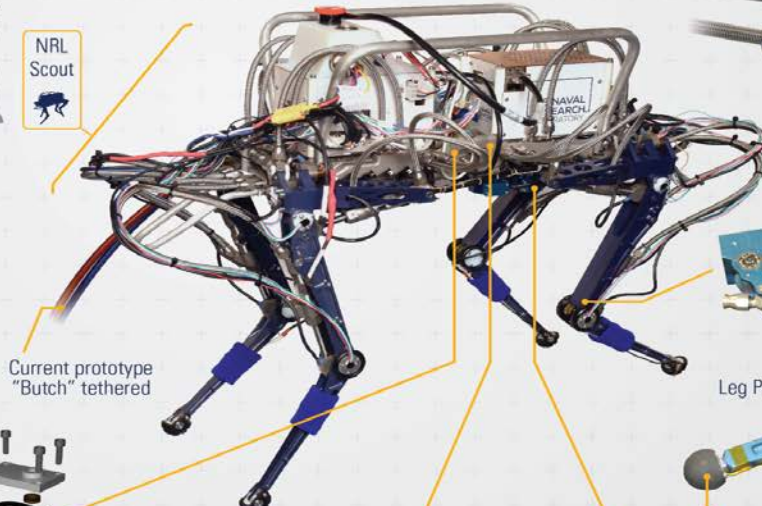
Equip squad with prototype robotic capabilities to perform covert or hazardous operations: Intelligence, Surveillance, and Reconnaissance (ISR), walk point, EOD/ counter-IED operations, share supplies, or project power

Increased Performance

Quadrupeds are capable of navigating terrain too challenging for wheeled or tracked platforms, and can perform future dynamic running, jumping, and climbing operations

Lighter

Robots easily carried and deployed from a soldier's backpack



Current prototype "Butch" tethered



Custom developed high power hydraulic cylinders



Subminiature magnetic joint encoders



Leg Prototype

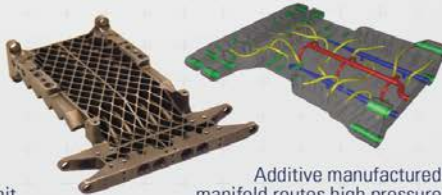
Custom integral load sensing



Custom contact sensor with force-sensitive resistor



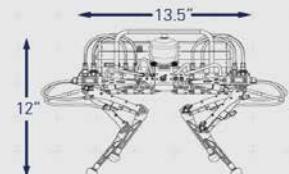
Hydraulic power unit with custom integral gear pump



Additive manufactured manifold routes high pressure hydraulic fluid and structurally supports all robot systems



High performance valves from motor racing industry

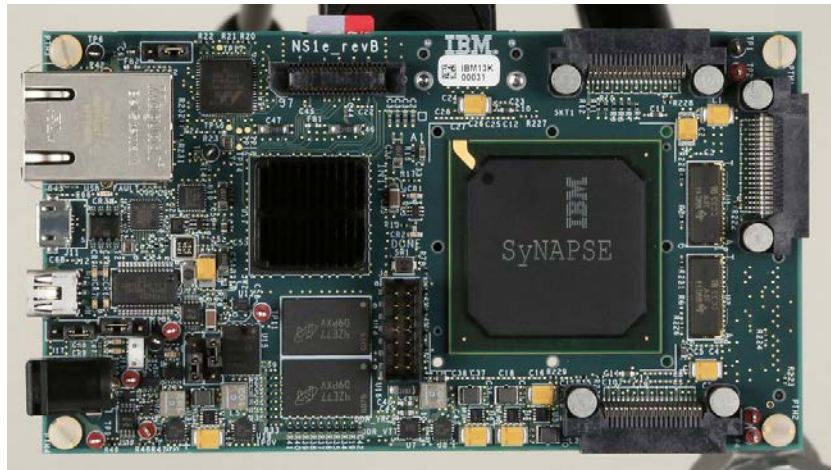


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IBM TrueNorth

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

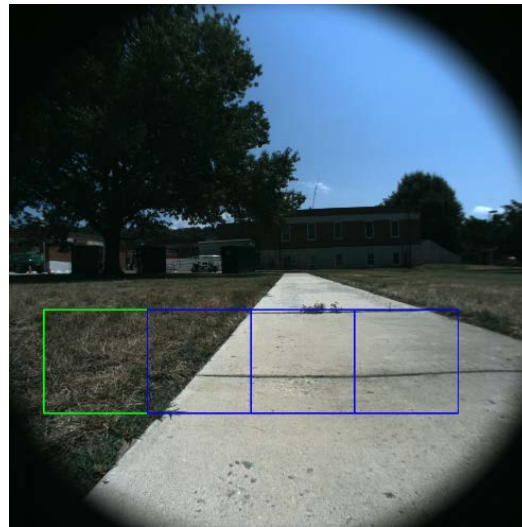
Scan the region immediately in front of the robot, making terrain classifications at 5 fixation locations

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

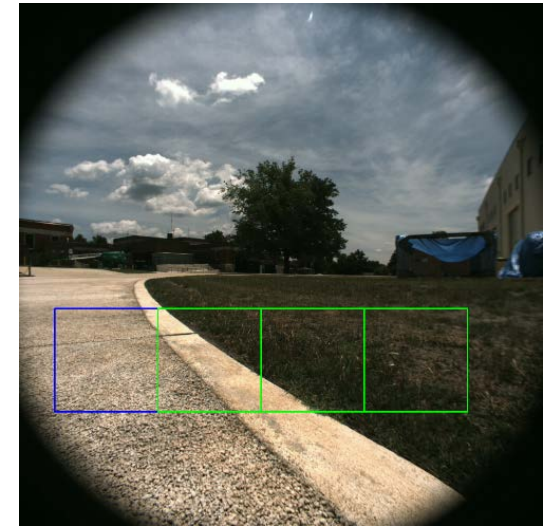
No concrete detected



Concrete is straight ahead



Concrete is on the left

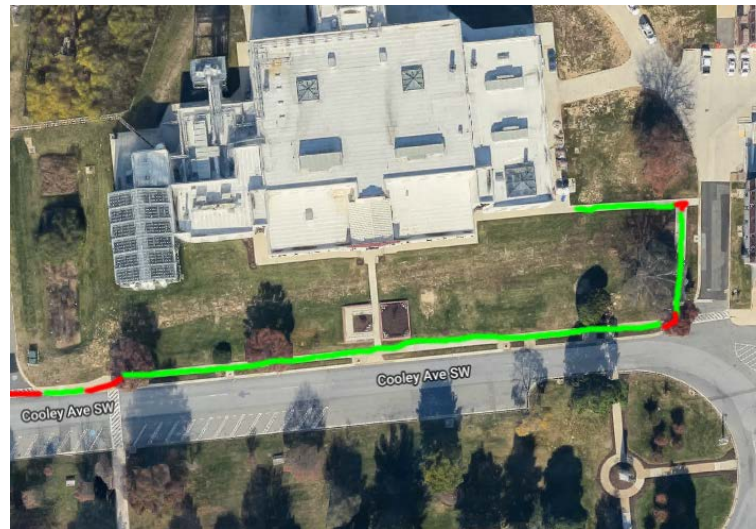


Terrain Classification

- 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
- Endeavor Robotics PackBot equipped with carnegie robotics S7 providing images at 5 Hz
 - Found that the TN classified regions without any lag.

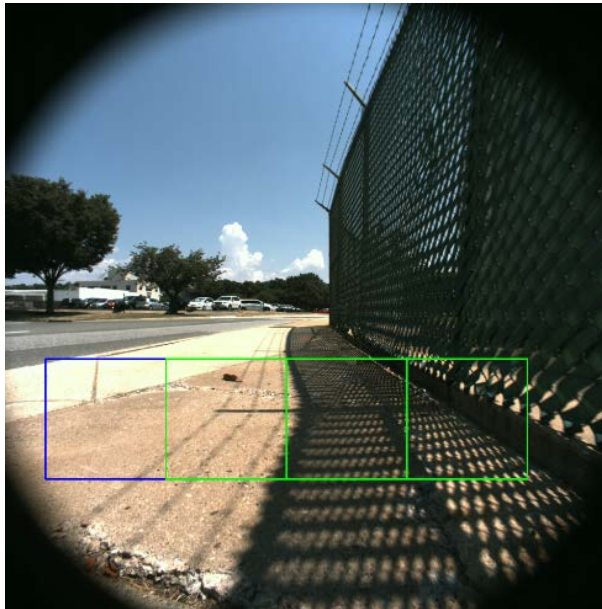
Current Status

- 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



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