Automated Stockpile Moving: Experimental Validation of a Vision-Based Front Loader

Senior Design Project

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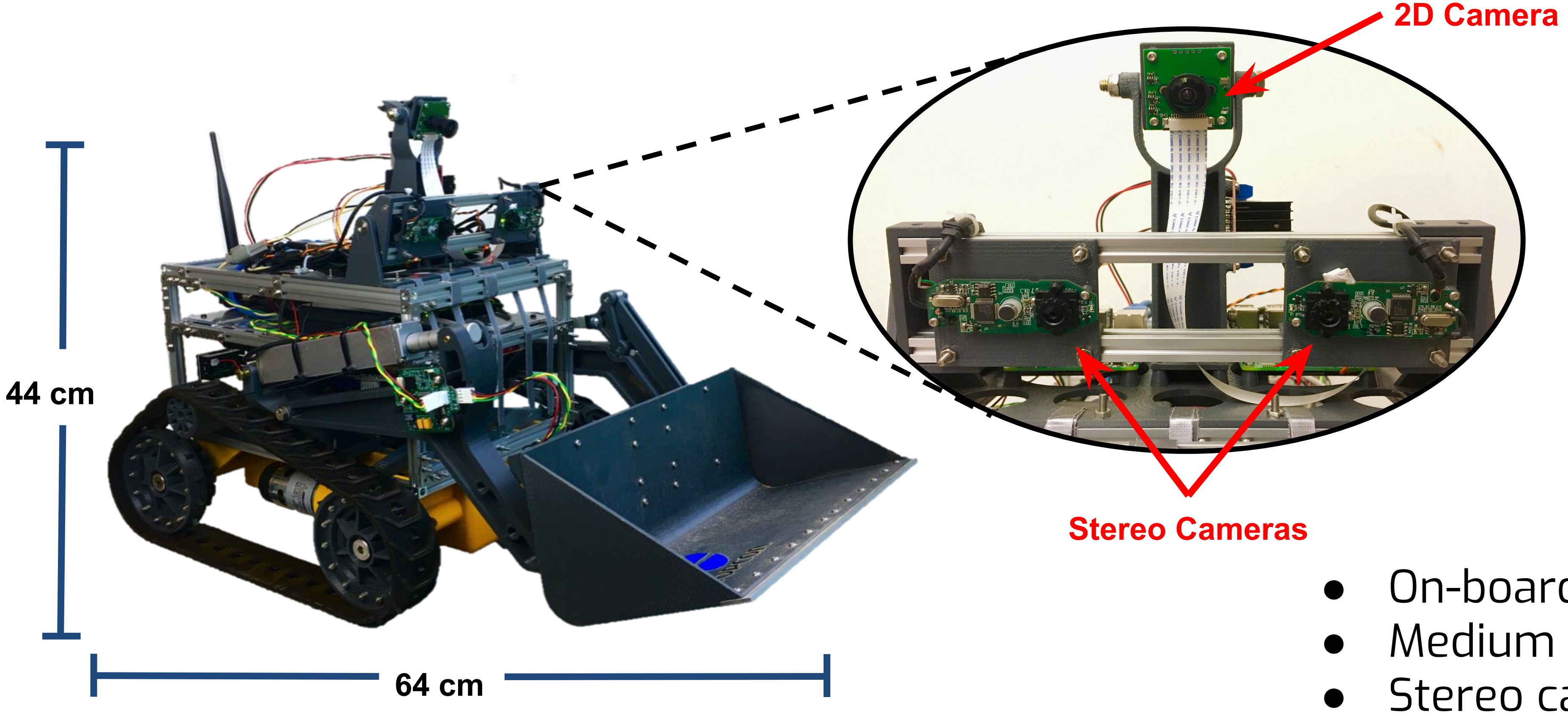
Problem Statement

Research and develop technology to enable a Bulldozer's autonomous approach and dig operation

Primarily rely on Computer Vision for:

- Pile identification and alignment
- Optimal approach calculation
- Dig verification

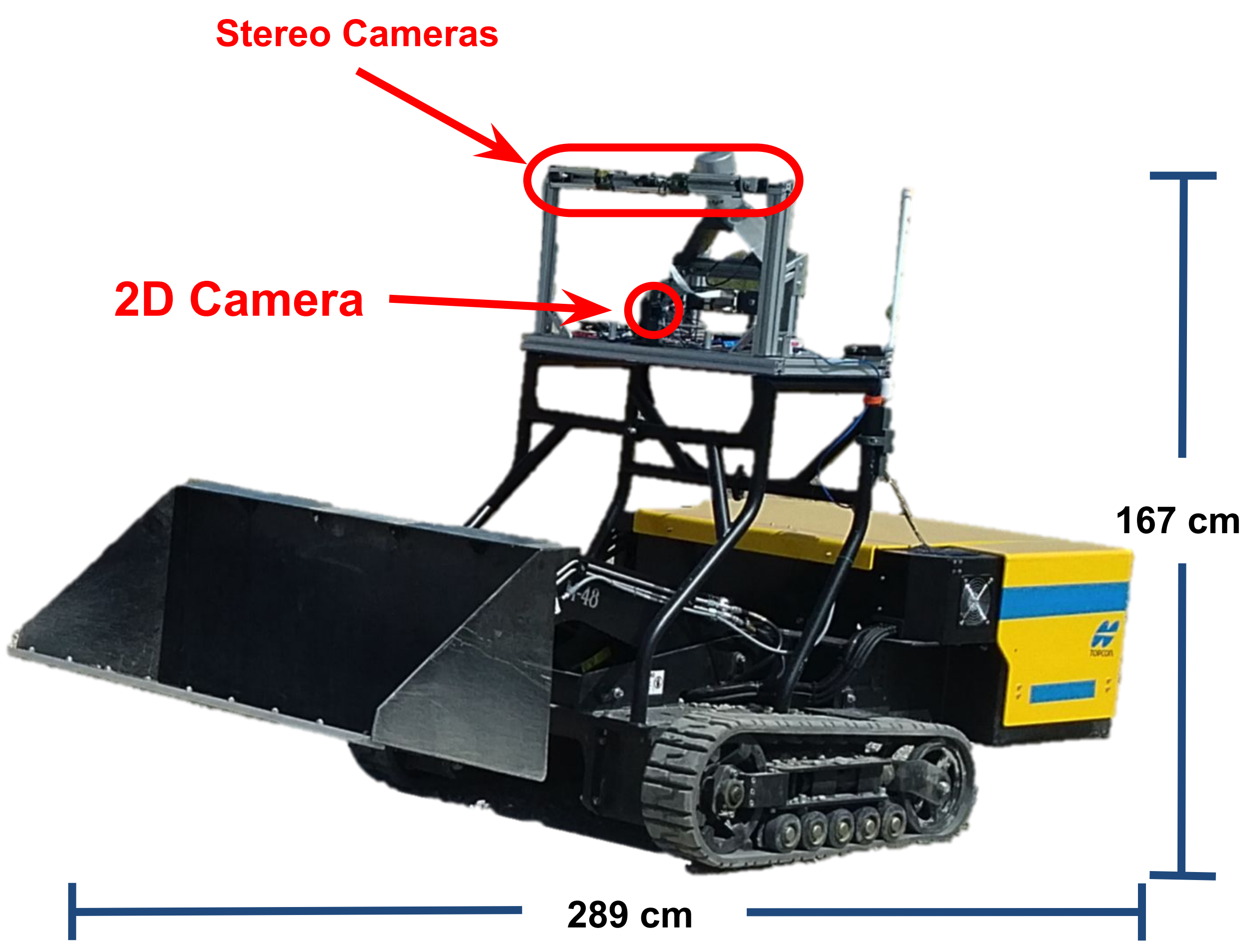
Bulldozer & Hardware



HouseCat mkII

(Load Capacity: 18kg)

- On-board Wifi Router
- Medium Resolution 2D camera
- Stereo cameras
- Linear actuators for bucket control
- IMUs for closed loop feedback
- Developed with ROS



Movex M-48

(Load Capacity: 531kg)

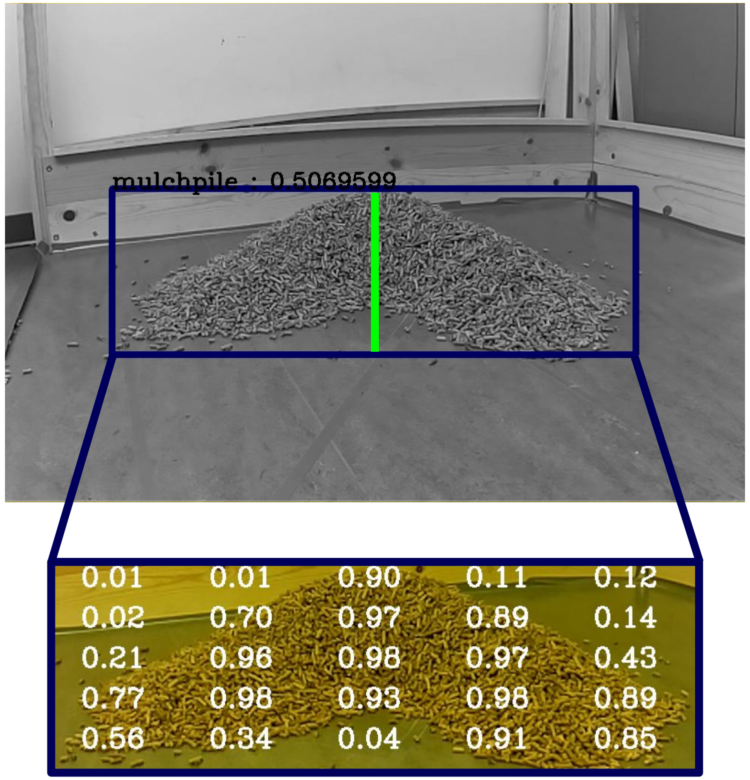
Identification and Alignment

Neural Network for object detection

- Uses YOLO (You Only Look Once) algorithm
- Trained with public domain construction stockpile images
- Outputs a bounding box and confidence of identified object

Alignment and Verification

- Bounding box segmented and run through texture network
- Computed center of confidence based on texture segments
- Discarded “false-positive” object detections with invalid texture



*Networks trained on:

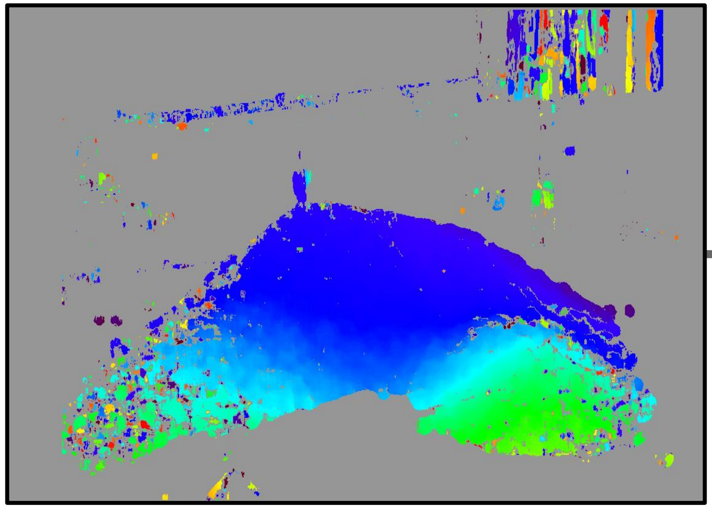
Hummingbird Computational Cluster
UC Santa Cruz Research Computing

Stereo Camera Process

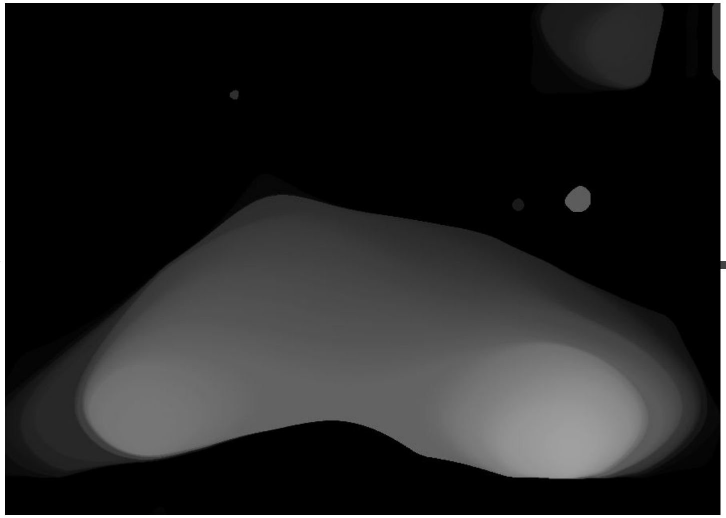
Left

Right

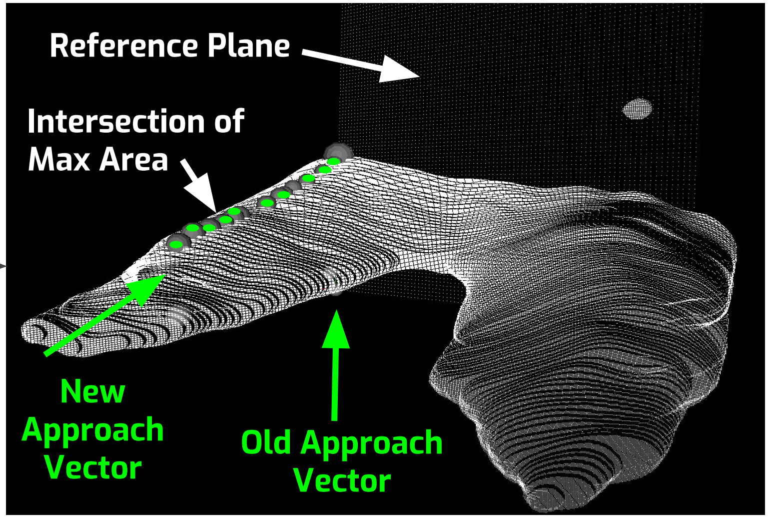
1. Rectify stereo images & generate disparity map
2. Filter disparity map for noise
3. Generate 3D point cloud
4. Run optimal approach algorithm



Original Disparity



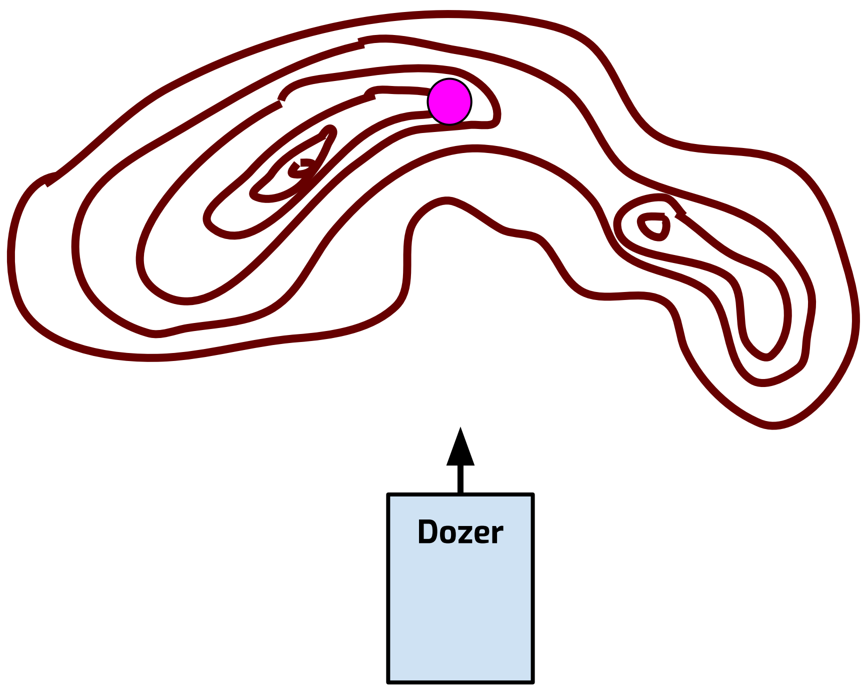
Filtered Disparity



3D Point Cloud

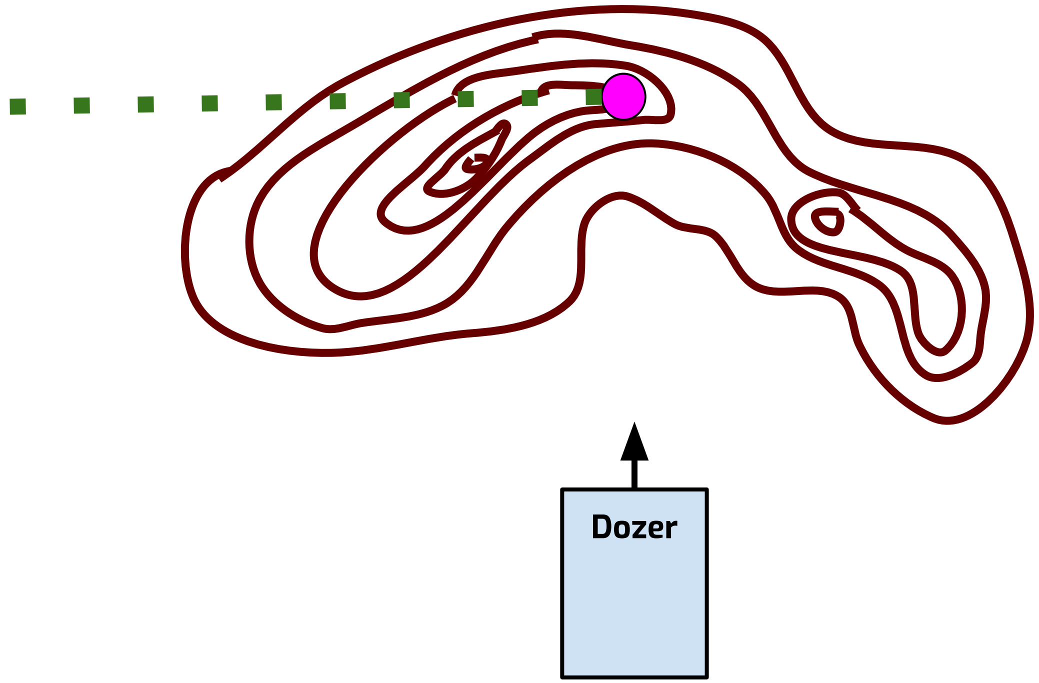
Optimal Approach Calculation

1 *Find the peak straight ahead*



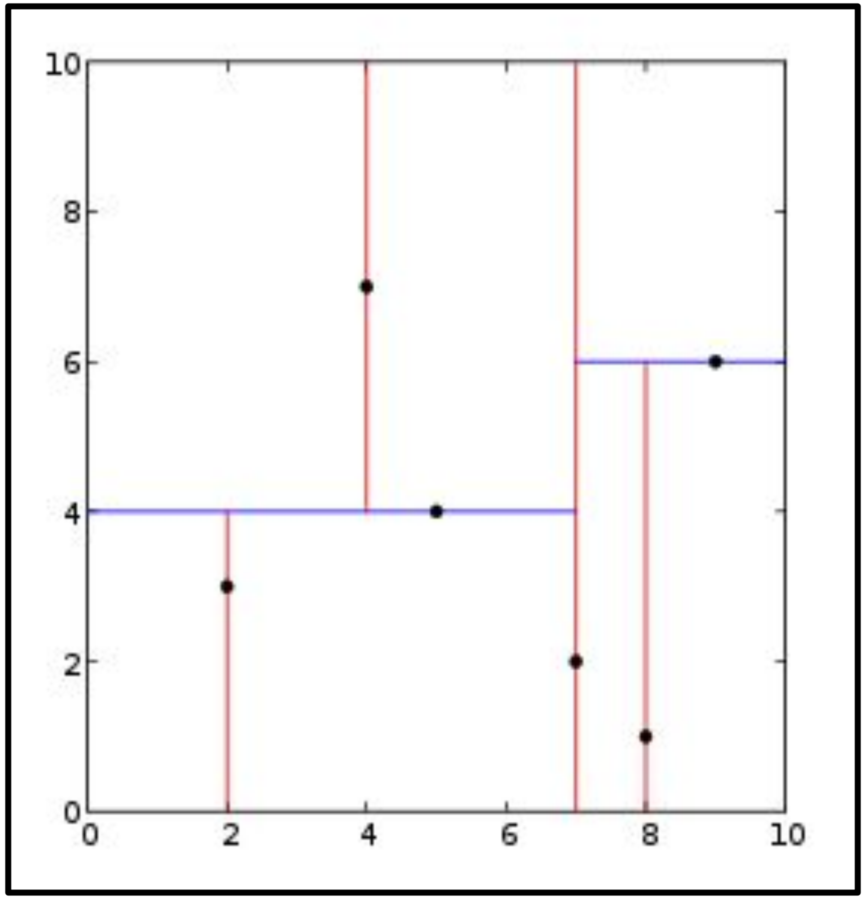
Optimal Approach Calculation

2 ***Create a reference plane with origin at the peak.***



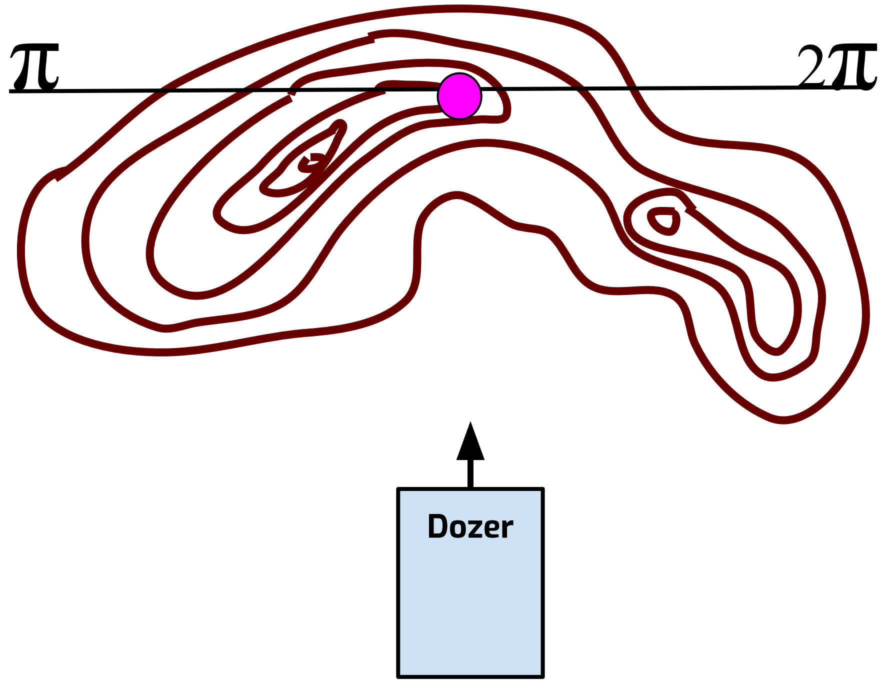
Optimal Approach Calculation

3 ***Create a K-D Tree of the point cloud***



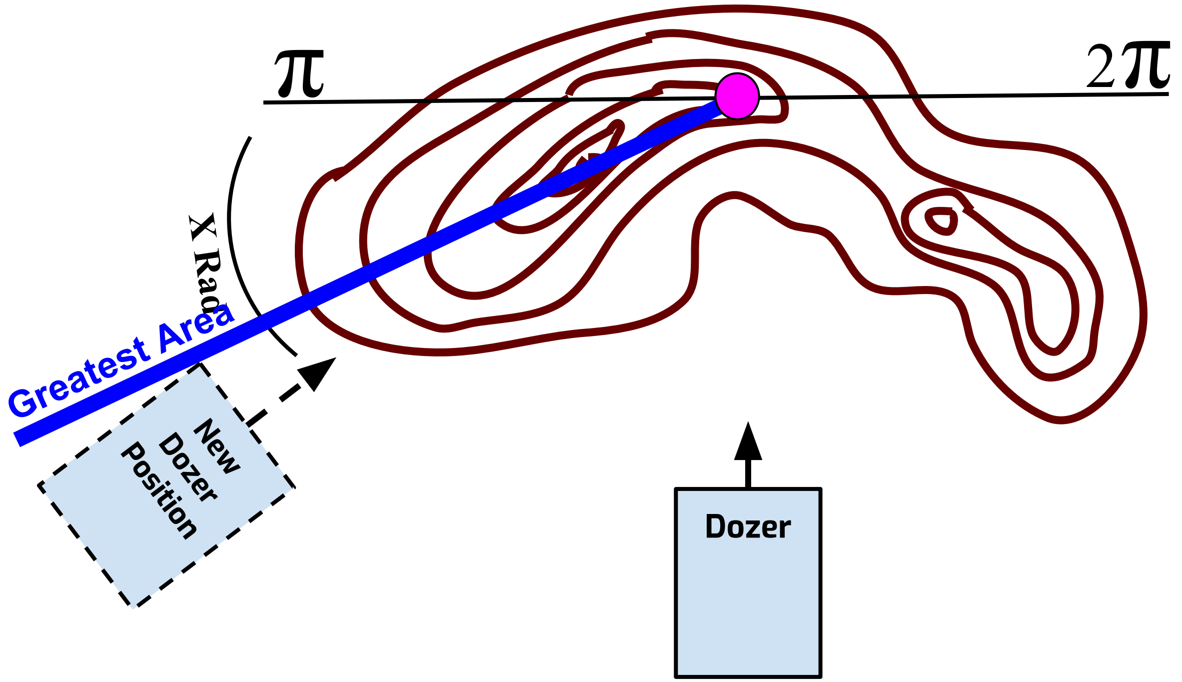
Optimal Approach Calculation

4 ***Sweep the reference plane from π to 2π and compute the area beneath each curve***



Optimal Approach Calculation

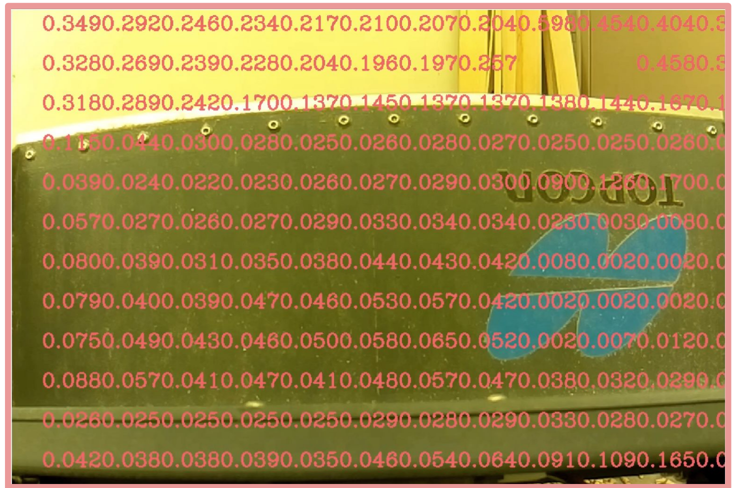
5 ***Transform Dozer to align with intersection of maximum area***



Dig Verification

Uses center camera to analyze contents of the bucket

- Bucket is tilted up in front of the center camera
- Image is segmented into a grid
- Each segment is passed through a Neural Network for texture analysis
- The score for each segment is positive if it is above a certain threshold
- Number of positive segments determines if the dig was successful



EMPTY BUCKET

FULL BUCKET

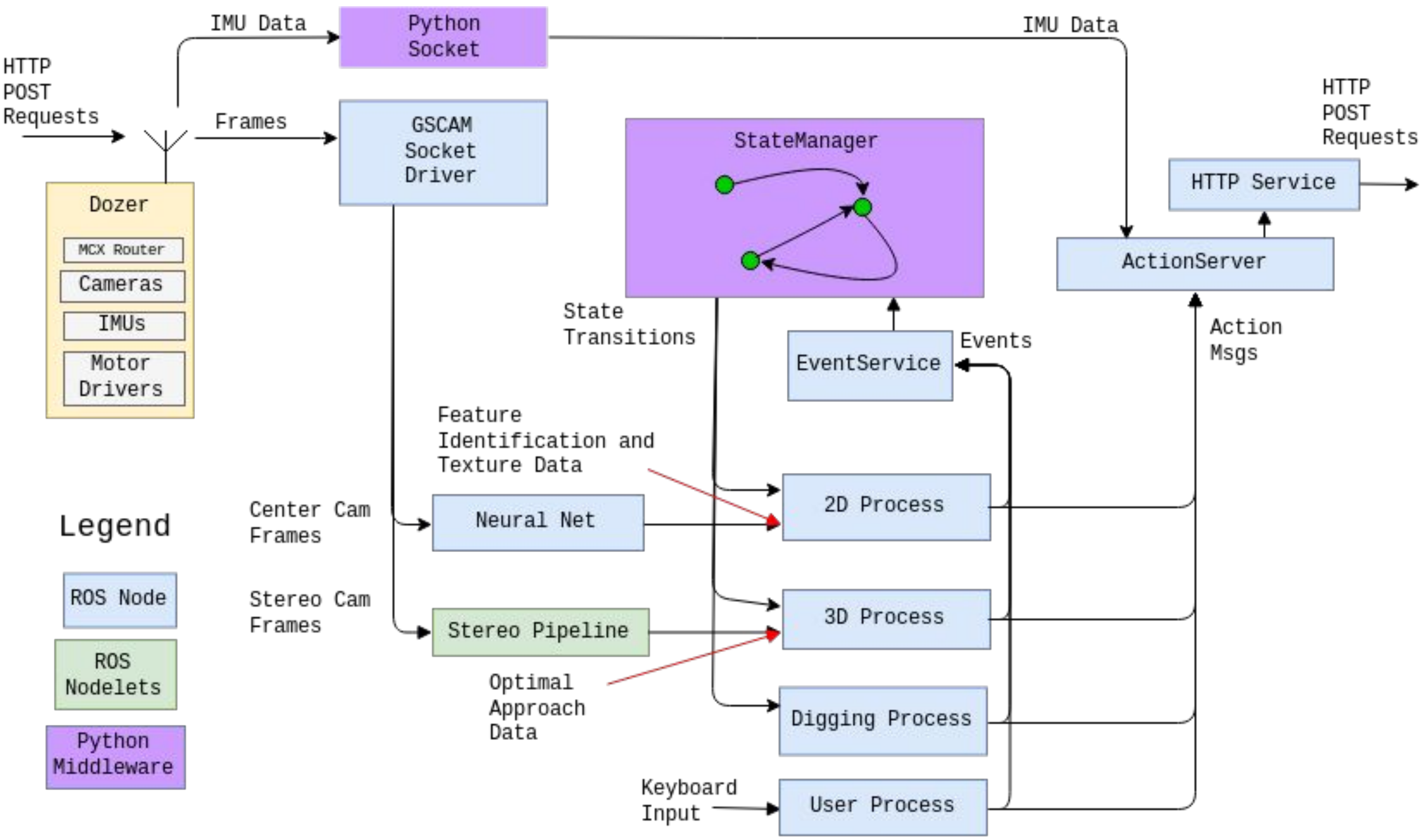
(2X SPEED)

Thank You!

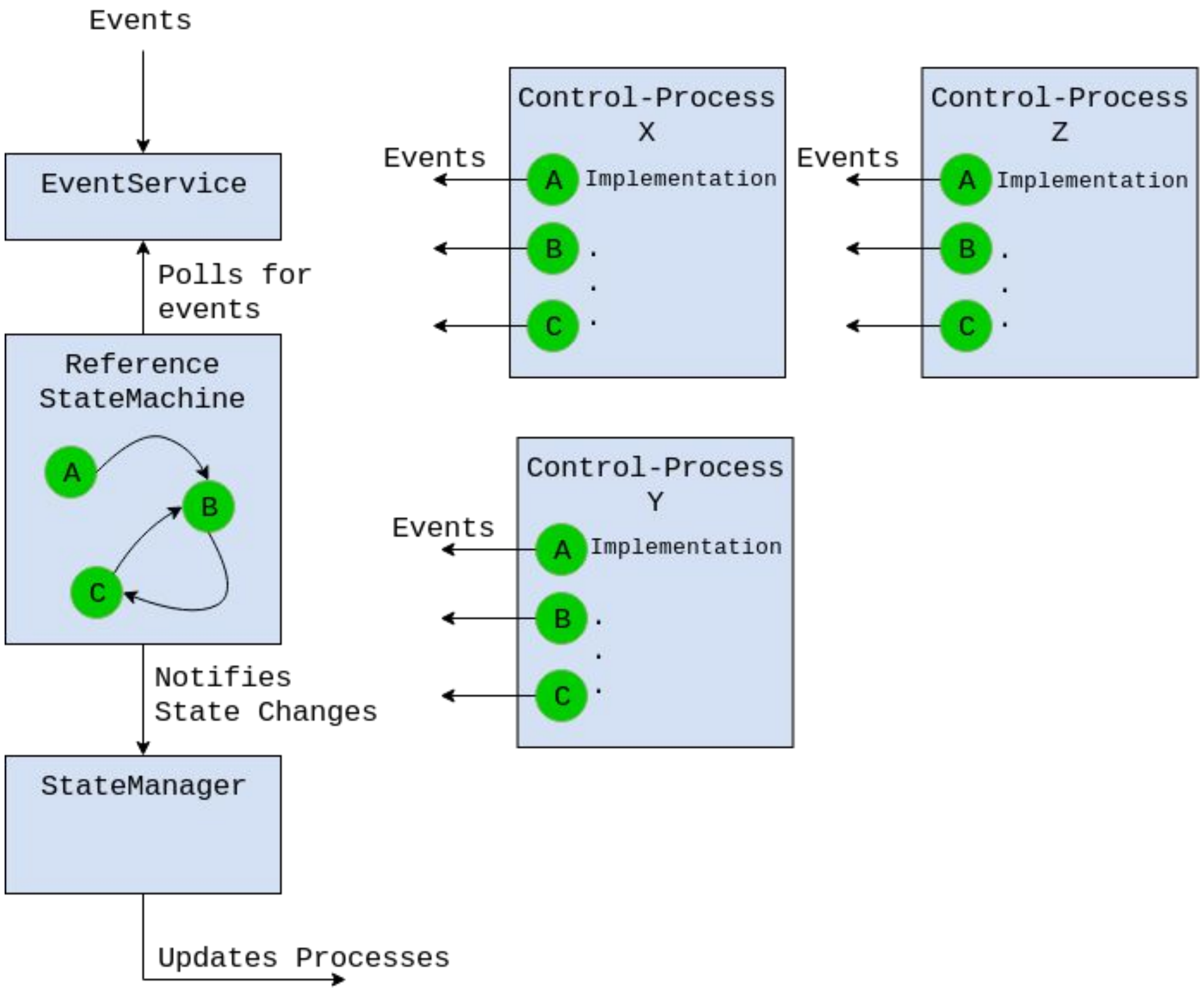
Challenges and Remarks

- Stereo Cameras can be sensitive to mounting differences / vibrations
  - Perform more precise camera calibration
  - Consider real-time rectification
  - Investigate mounting options
- High network traffic leads to slow response
  - Enable request-response for image capture (Instead of image streaming)
  - Perform on-board image processing
  - Use different network channels and hardware
- Limited in real-world recognition
  - Pre-process training images to exaggerate features
  - Perform more training

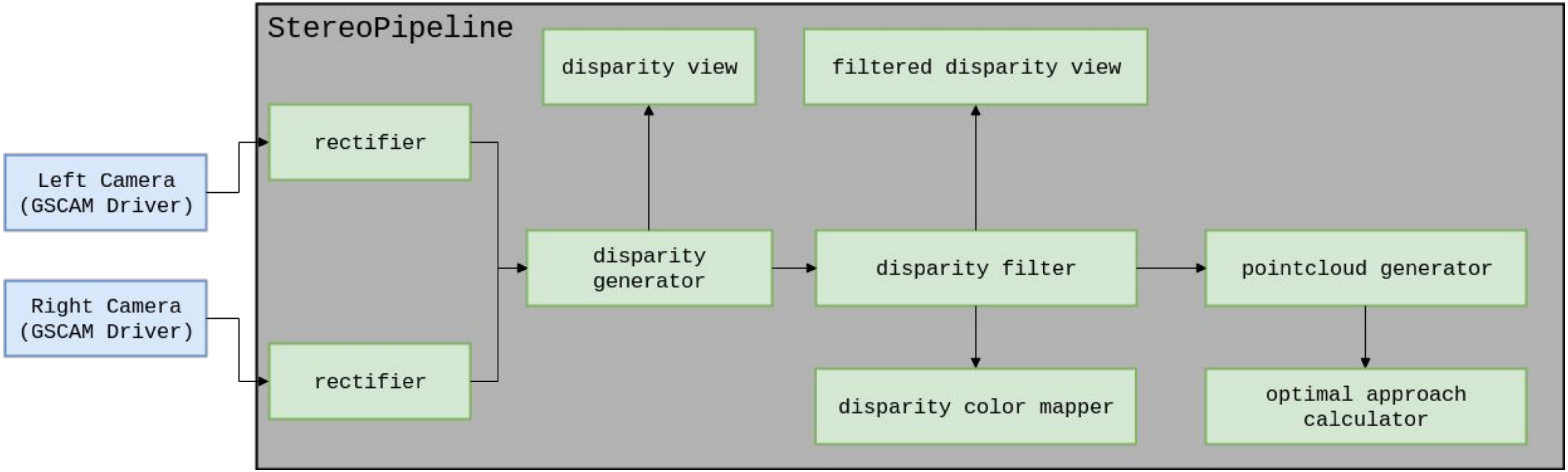
Software Architecture

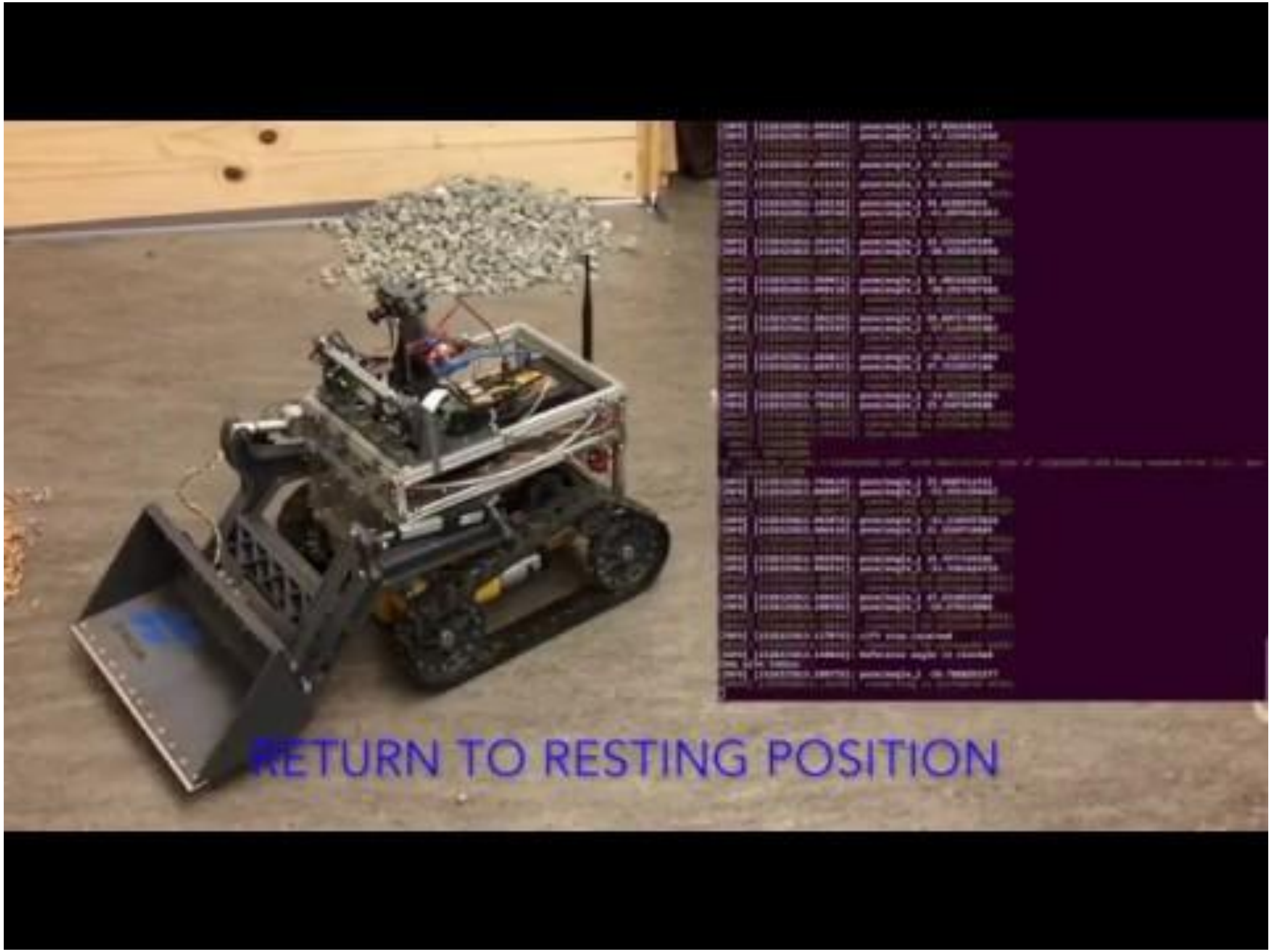


State Machine Architecture



Stereo Process




RETURN TO RESTING POSITION

Action Server

- Allows “goal” sequencing
- Enables parallel dozer commands
- Arm/Bucket may use setpoints and duration commands
- Motors may use duration commands
- Redundant commanding when no dozer response