Capstone Project

# Autonomous Bulldozer

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UC SANTA CRUZ
Baskin Engineering

TOPCON

## Objective

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

Computer vision & robotic software designed for:

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

## Target Identification & Alignment

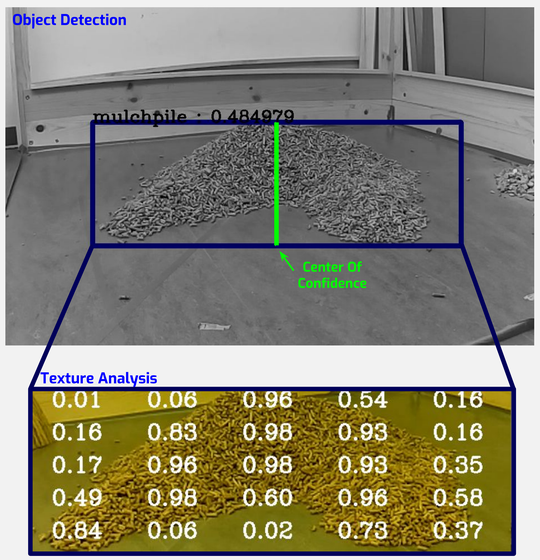
Neural Networks performe object detection & texture analysis.

**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

**Texture Analysis**
- Built on the Tensorflow framework
- Trained with specifically constructed images
- Segment bounded image and run through texture network
- Outputs target texture accuracy for each segment

**Alignment**
- Compute center of confidence based on texture segments
- Center of confidence demarcated by green line

**Verification**
- Discard "false-positive" object detections with invalid texture
- Retry dig operation if bucket has low texture score



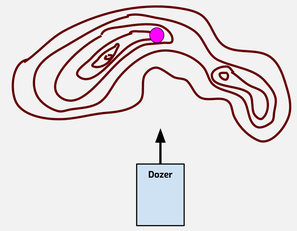

*Networks trained on:

Hummingbird Computational Cluster
UC Santa Cruz Research Computing

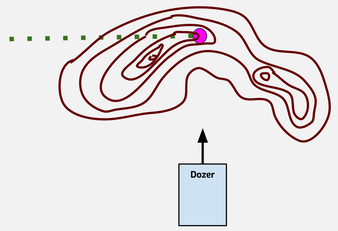
## Optimal Approach Calculation

How do we determine the best entry point when filling a bulldozer's bucket?

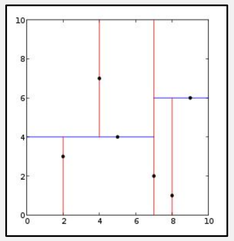
**1** *Find the peak straight ahead*



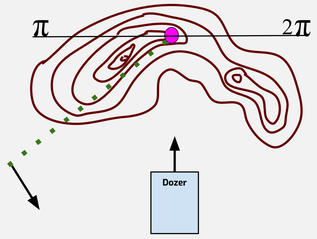

**2** *Create a reference plane with its origin at the peak*



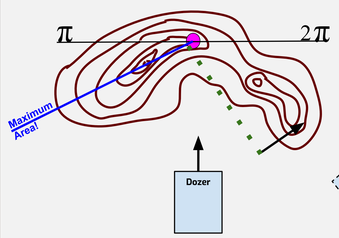

**3** *Create a K-D Tree of the point cloud*



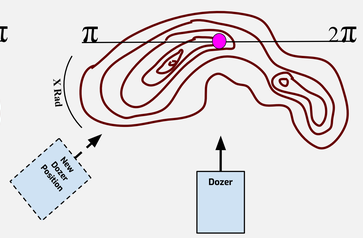

**4** *Sweep the reference plane from π to 2π and use the KD-Tree to get the intersections between the point cloud and the reference plane.*



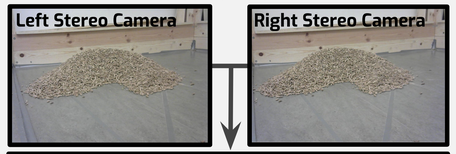

**5** *For each intersection compute the area beneath the curve*

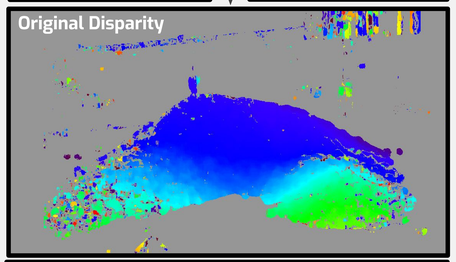


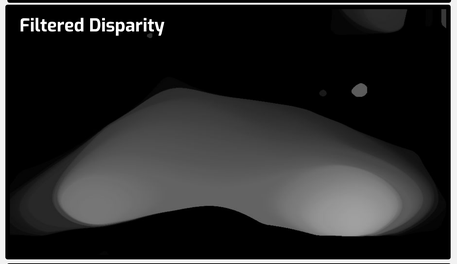

**6** *Transform Dozer to align with intersection of maximum area*

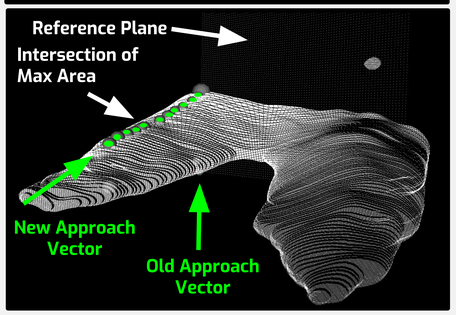



Stereo Camera Feed

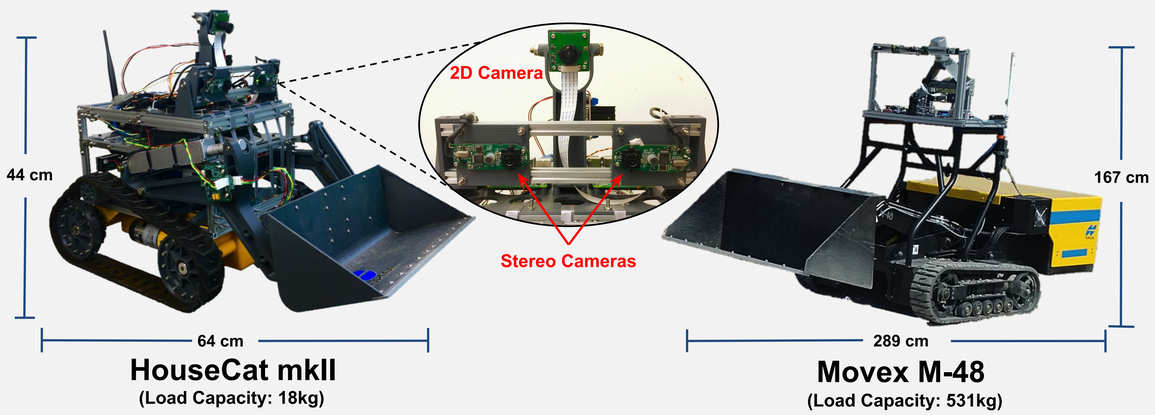



## Bulldozers

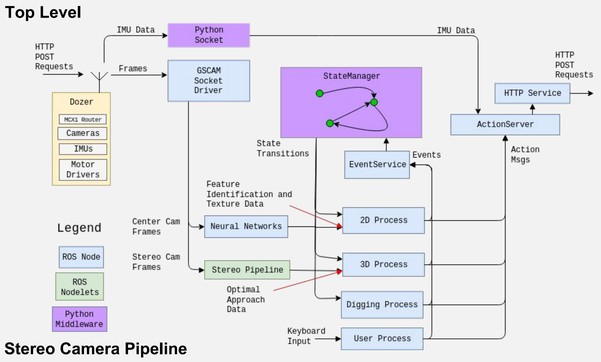



**HouseCat mkII**
(Load Capacity: 18kg)

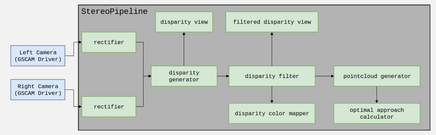
**Movex M-48**
(Load Capacity: 531kg)

## Software Architecture

**Top Level**



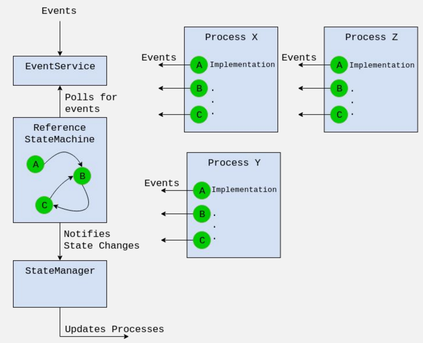

**Stereo Camera Pipeline**




## State Synchronized Processes

How to separate concerns for parallel development and modularity?

- Create N number of 'processes' to 'observe' a reference state machine
- This is based on the canonical Object-Oriented Observer design pattern




## Conclusion and Results

Several key components for an autonomous bulldozer have been developed:

- Autonomous pile approach and alignment
- Optimal approach calculation
- Movement and bucket control command sequencing
- Successful dig validation

## Acknowledgments

We would like to thank the following for their help and support:

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