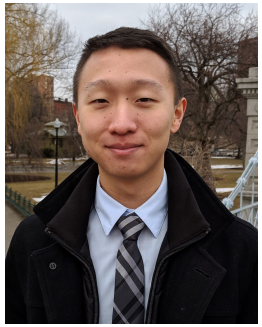
Comprehensive Design Review

IntelliSAR
March 5, 2020

IntelliSAR



Derek Sun

Arthur Zhu

Background and Motivation

- Safety and information of the environment are very important aspects of rescue missions
- Not fully understanding the environment and situation can lead to unnecessary risks and dangers

Examples:

Cave/mine rescue

Explorers trapped or lost

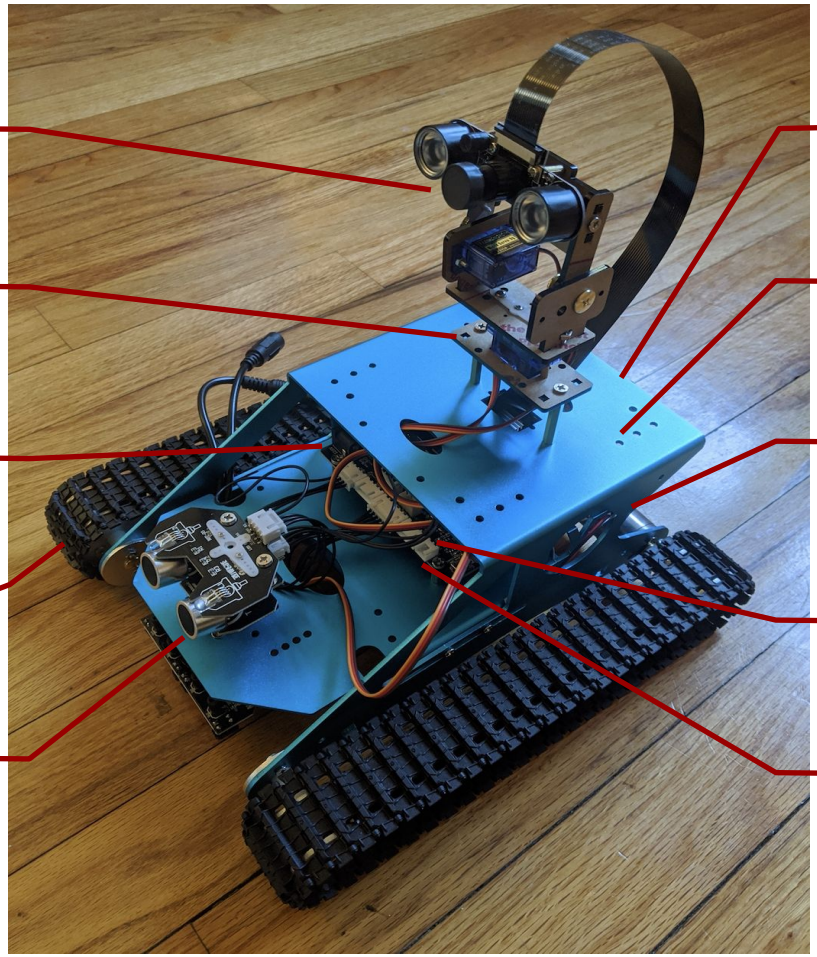
Urban search and rescue

Victims trapped in collapsed buildings

Goal

- Provide ability to remotely examine the situation and environment
- Reduce possible risks or dangers
- Improve efficiency of rescue teams in unknown environments

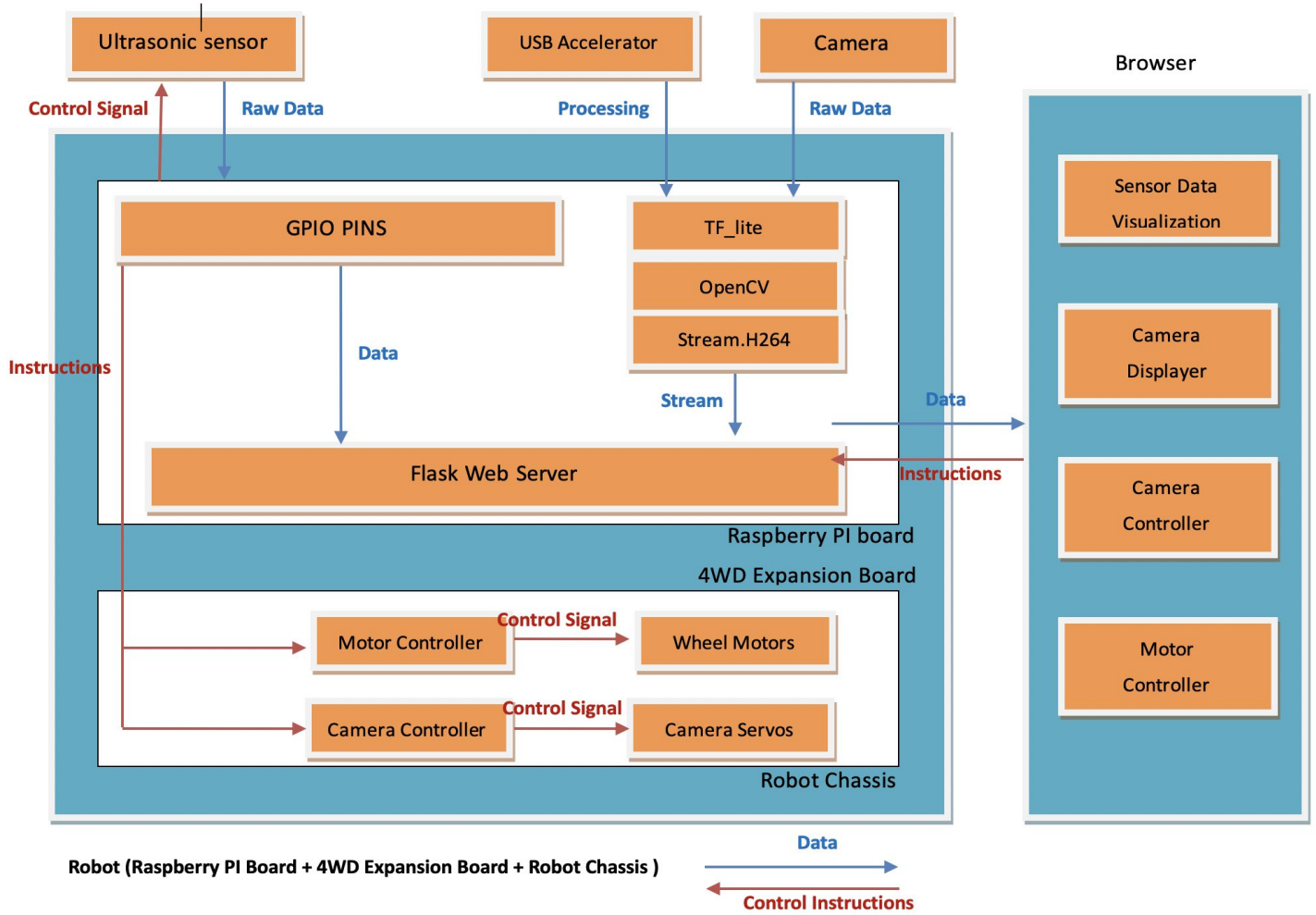
Our Product


Night Vision Camera
180 Degree Gimbal
Temperature/Humidity Sensor
Non-Slip Tracks
Ultrasonic Sensor
USB Accelerator
Shockproof Chassis
Battery Pack
Raspberry Pi
4WD Expansion Board

Requirements Analysis

- Be able to be remotely controlled via Wi-Fi
- Be able to work in dim lighting conditions with night vision
- Gathered sensor data can be viewed remotely
- Can traverse uneven/sloped ground
- Be able to detect obstacles and navigate accordingly
- Be able to detect and classify objects

Block Diagram



Requirements Analysis: Specifications

Specification	Value
Weight	6 lb
Dimensions	256*183*213 mm
Battery Life	Board 5.8 hours
Camera	Night Vision 5MP
Speed Range	0.7 ~ 6.5 km/h
Obstacle Detection Range	3 ~ 450 cm
Video Stream w/ Object Detection Frame Rate	H.264 640x480 @ 30FPS
Object Detection Range	6 meters (best case scenario)

Battery Life Analysis

- Current peripherals consumes 800 mA in total
- Raspberry Pi 4 requires 3.7V, 3A* to operate stably
- Very few battery banks in market provide 3.7V, 3A output

Main Board Power Consumption				
Components	Q'ty	Current (A)	Voltage (V)	Power (W)
Raspberry Pi	1	1.1	3.7	4.1
Camera	1	0.16	3.7	0.59
UltraSonic	3	0.015	3.7	0.06
Camera Motors	2	0.3	3.7	1.1
USB Accelerator	1	0.5	3.7	1.85
Sum	8	**2.375**	3.7	8.9

Battery Life Analysis				
Components	Q'ty	Capacity (Ah)	Current (A)	Battery Life(h)
Battery	1	11.1	**1.9**	**5.84**

Driving Board Power Consumption				
Components	Q'ty	Current (A)	Voltage (V)	Power (W)
Drive Board	1	0.1	12	1.2
Wheel Motors	6	0.35	12	12.6
Sum	7	**2.2**	12	13.8

*https://www.raspberrypi.org/products/raspberry-pi-4-model-b/specifications/

CDR Deliverables

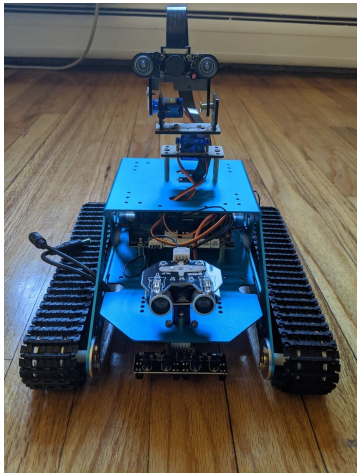
- ✓ Improve accuracy of object detection
- ✓ Improve speed of object detection
- ✓ Make semi-autonomous navigation more reliable
- ✓ Train model to be able to detect/classify certain objects

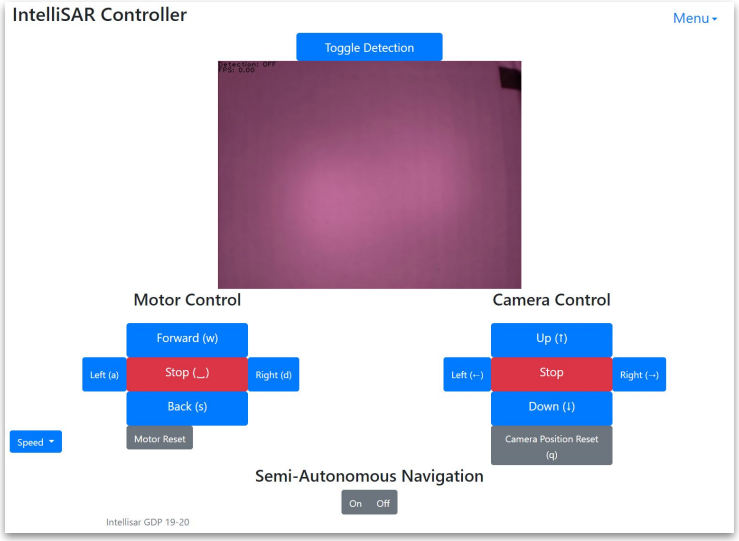
Responsibilities

- Derek Sun
  - Construct robot and restore functionality, compile training dataset, integrate USB accelerator, improve object detection, re-implement semi-autonomous navigation
- Arthur Zhu
  - Compile training dataset, improve object detection, data collection and analysis, battery analysis

CDR Deliverables: Robot

- Flask web application running off Raspberry Pi
  - Robot controller
  - Camera controller
  - Night vision video feed w/ object detection
  - Keyboard controls for better UX
  - Mobile-friendly
- Semi-autonomous navigation enabled



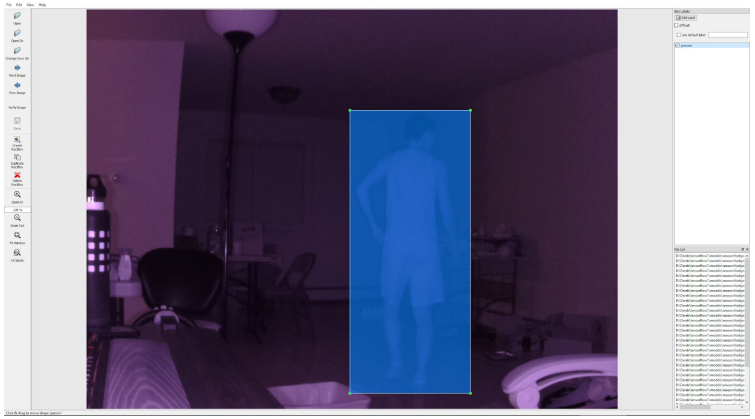


CDR Deliverables: Object Detection

- Implemented with Python, Tensorflow + TFLite, and OpenCV

Training

- Transfer learning with SSD MobileNetV2 model as basis
- Compiled our own image database (person, rock)
  - Used labelImg to label images



labelImg (person)

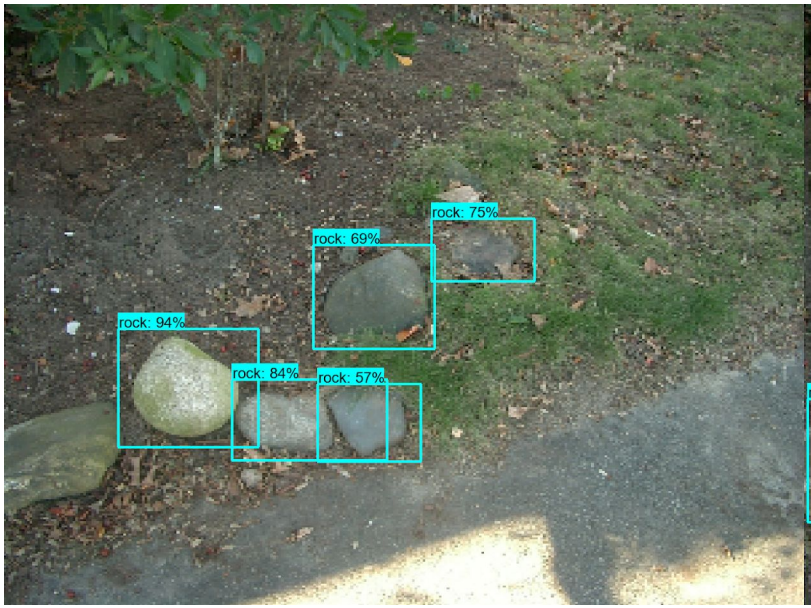
labelImg (rock)

CDR Deliverables: Object Detection

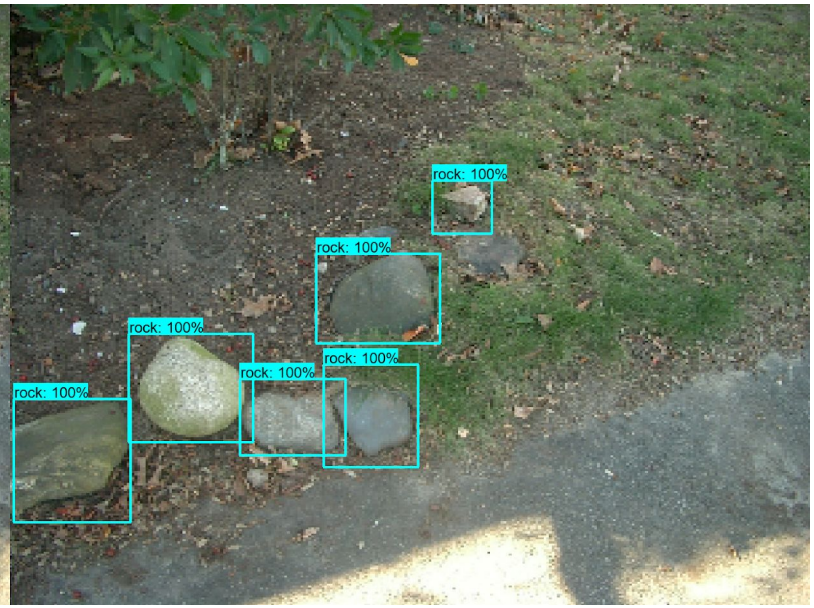
Evaluation

- Tensorboard visualization tool
  - Provides training/eval metrics
- Detect overfitting/underfitting

Detection Model Evaluation Metrics	
Metric	Value
mAP	0.4971
mAP (large)	0.5108
mAP (medium)	0.06634
mAP (small)	0.0016068
mAP@.50IOU	0.8607
mAP@.75IOU	0.5804



Detections



Ground Truths

Demo

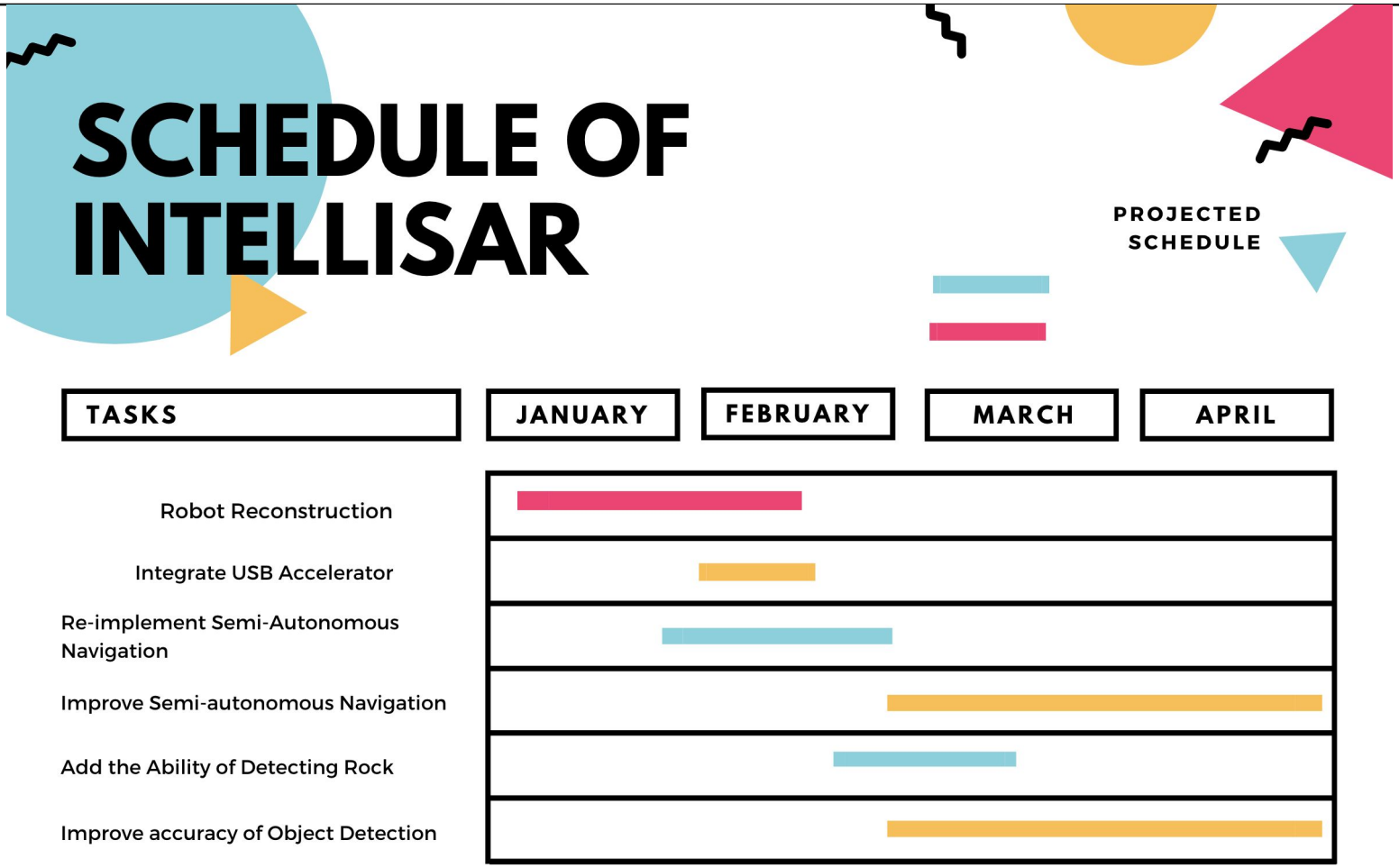
Proposed FPR Deliverables

- Further improve accuracy of object detection
- Improve robustness of robot

Responsibilities

- Derek Sun
  - Improve object detection accuracy, improve training dataset
- Arthur Zhu
  - Robustness enhancement, improve training dataset

Schedule


SCHEDULE OF INTELLISAR
PROJECTED SCHEDULE
TASKS
JANUARY
FEBRUARY
MARCH
APRIL
Robot Reconstruction
Integrate USB Accelerator
Re-implement Semi-Autonomous Navigation
Improve Semi-autonomous Navigation
Add the Ability of Detecting Rock
Improve accuracy of Object Detection

Questions?

Appendix: Object Detection Metrics

Precision

- measures how accurate the model's predictions are
- defined as: $Precision = \frac{True\ Positives}{True\ Positives + False\ Positives} = \frac{True\ Positives}{Total\ \#\ of\ Predicted\ Positives}$

Recall

- measures how well the model finds all the positives
- defined as: $Recall = \frac{True\ Positives}{True\ Positives + False\ Negatives}$

Ex) in the context of a person detector:

$$Precision = \frac{\#\ People\ correctly\ predicted}{\#\ People\ correctly\ predicted + \#\ People\ incorrectly\ predicted}$$

$$Recall = \frac{\#\ People\ correctly\ predicted}{\#\ People\ correctly\ predicted + \#\ Objects\ incorrectly\ predicted\ as\ person}$$

Appendix: Object Detection Metrics

Intersection over Union (IoU)

- measures the overlap between the bounding box generated by the model and the ground truth bounding box and is what determines whether a prediction is a true positive, false positive, or false negative

Average precision (AP)

- defined as the area under the precision-recall curve (PR curve), with the recall on the x-axis and precision on the y-axis.

Mean average precision (mAP)

- calculated by taking the average of the AP for all the classes being predicted

Appendix: TensorBoard Metrics

mAP

- obtained by averaging the mAPs calculated using IoU thresholds ranging from .5 to .95 with increments of .05

mAP (large)

- calculated mAP for large objects (96^2 pixels < area < 10000^2 pixels)

mAP (medium)

- calculated mAP for medium-sized objects (32^2 pixels < area < 96^2 pixels)

mAP (small)

- calculated mAP for small objects (area < 32^2 pixels)

Appendix: TensorBoard Metrics

mAP@.50IOU

- mAP calculated using a IoU threshold of 50%

mAP@.75IOU

- mAP calculated using a IoU threshold of 75%