COBRA
SNAKES ON THE MOON

TEAM 8

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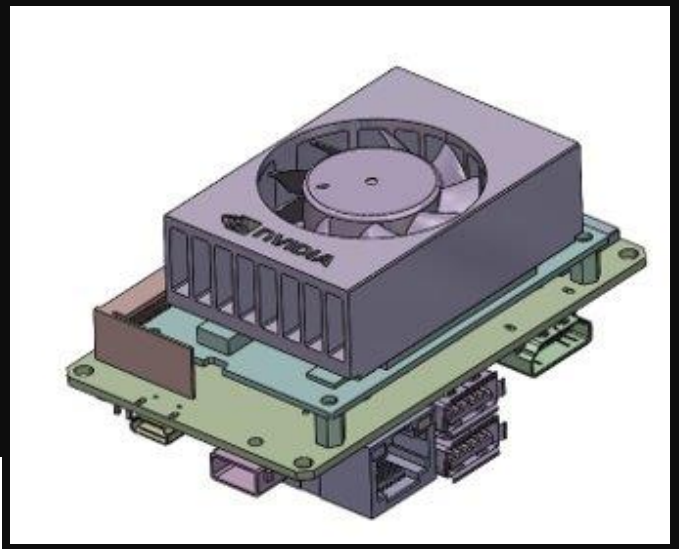
COBRA - Crater Observing Bio-inspired Rolling Articulator

- Crater Observing device to study, analyze, and gather data from impact craters on the moon
- Bio-inspired design based on principles found in snake
- Rolling is used to roll on any uneven terrain
- Articulator allows it to move and change shape with joints or segments

Components:

1. Pi camera
2. Nvidia Jetson Orin
3. Intel RealSense camera



Perception Module

Addition of a completely new domain – **Computer** Vision

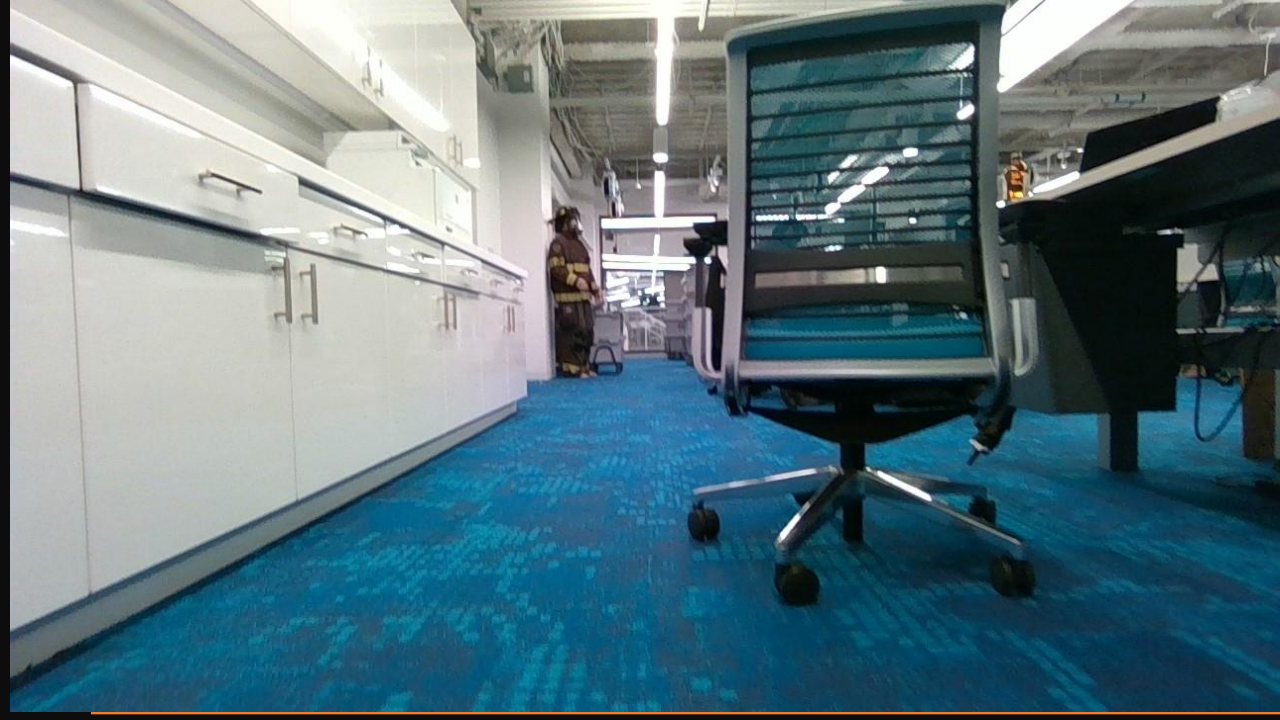
Perform tasks – scene segmentation to better understand the environment

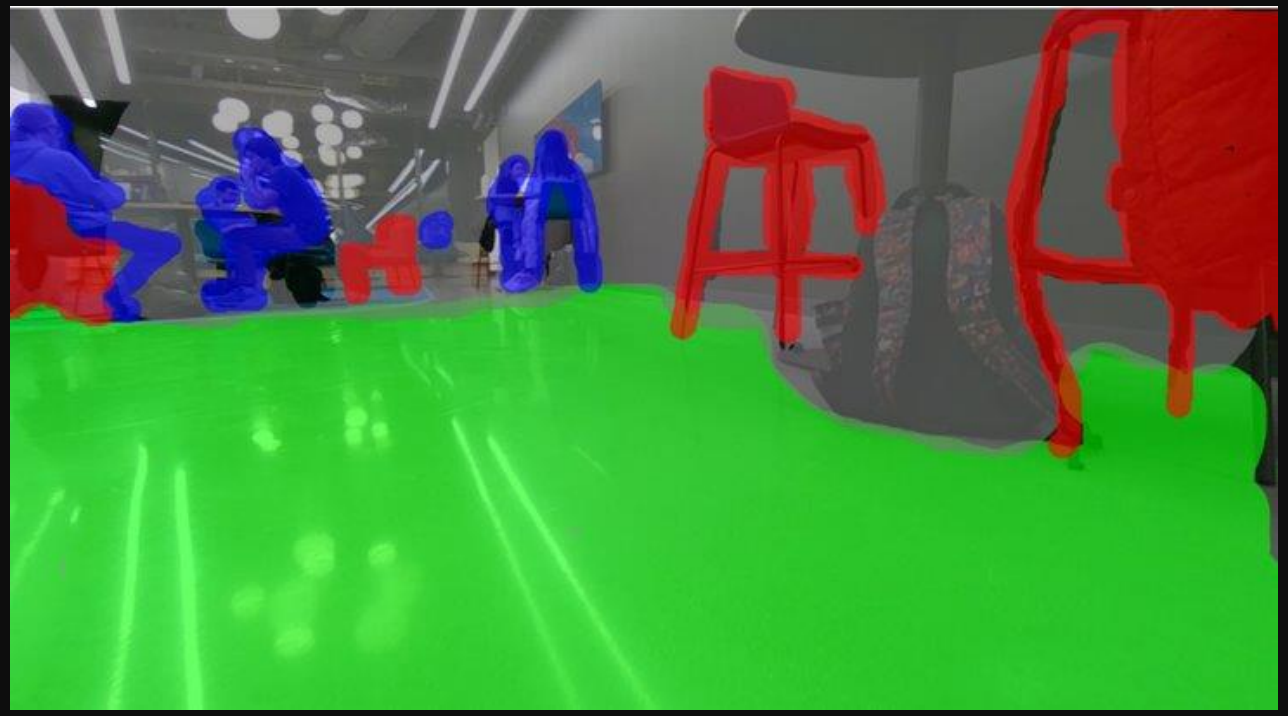
Using Deep Learning methods –

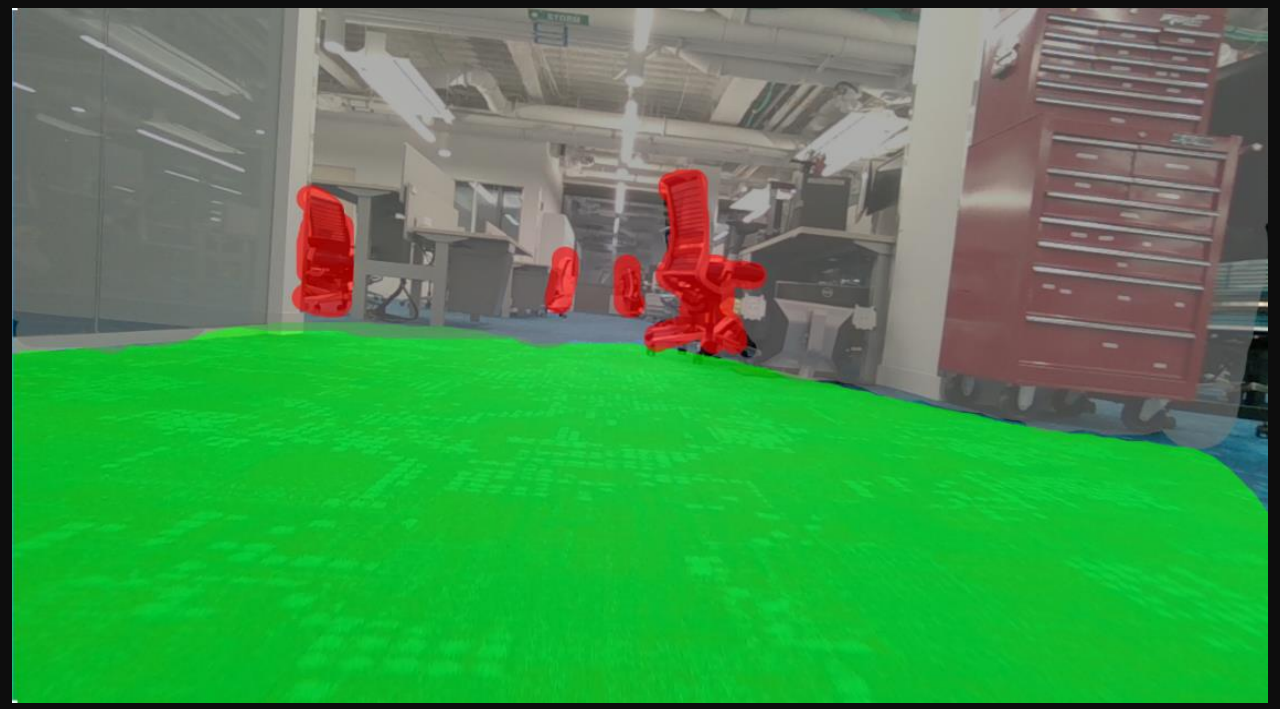
Object Detection	Semantic segmentation

Data Collection

- Place: Robotics lab (SSL)
- Using: Intel RealSense camera
- To Get: 2D RGB images
- Collected 10 videos – 5 inside lab, and 5 outside lab
- 30FPS ~ 10K frames
- 720x1280 resolution







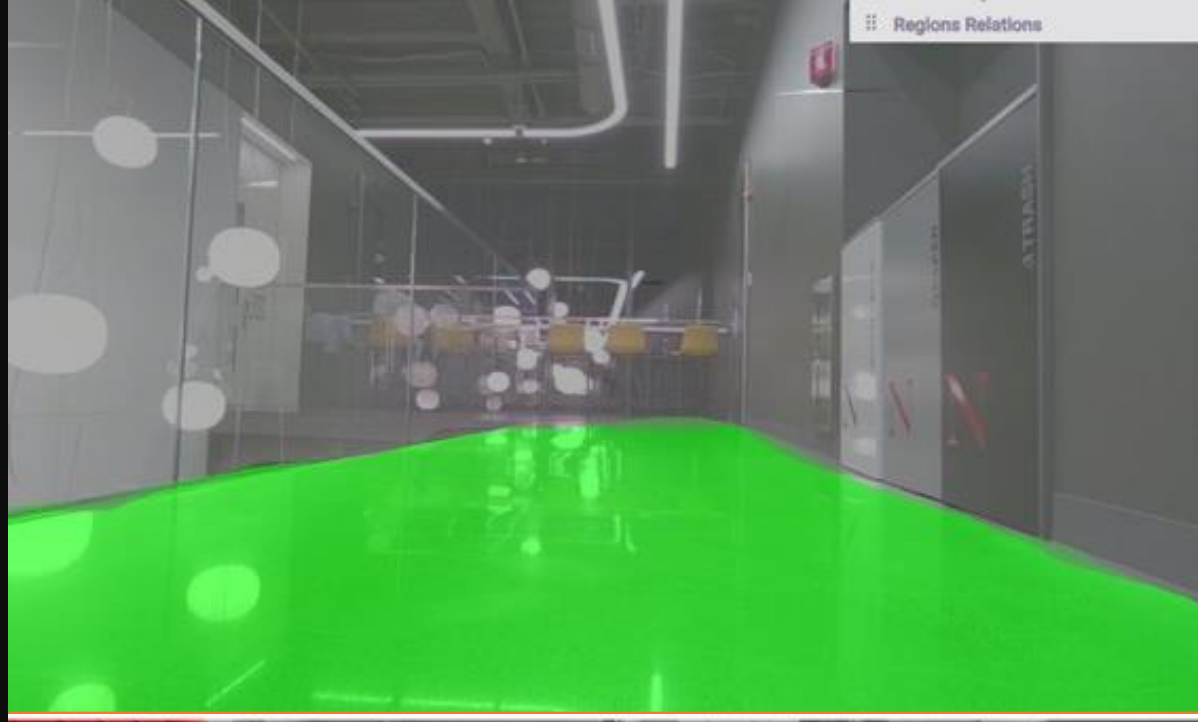
Data Labelling

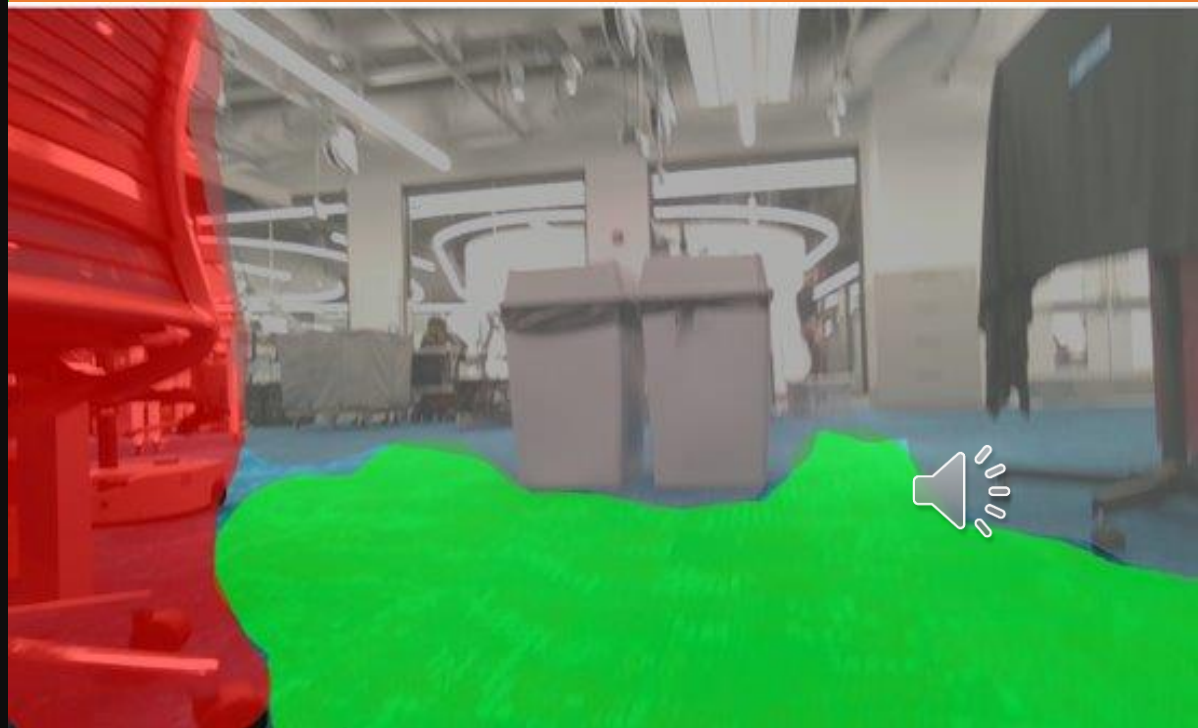
- Label Studio – open-source
- Annotations for 100 images manually
- 4 Labels –
  - Moving objects,
  - Immovable objects,
  - Ground,
  - Misc

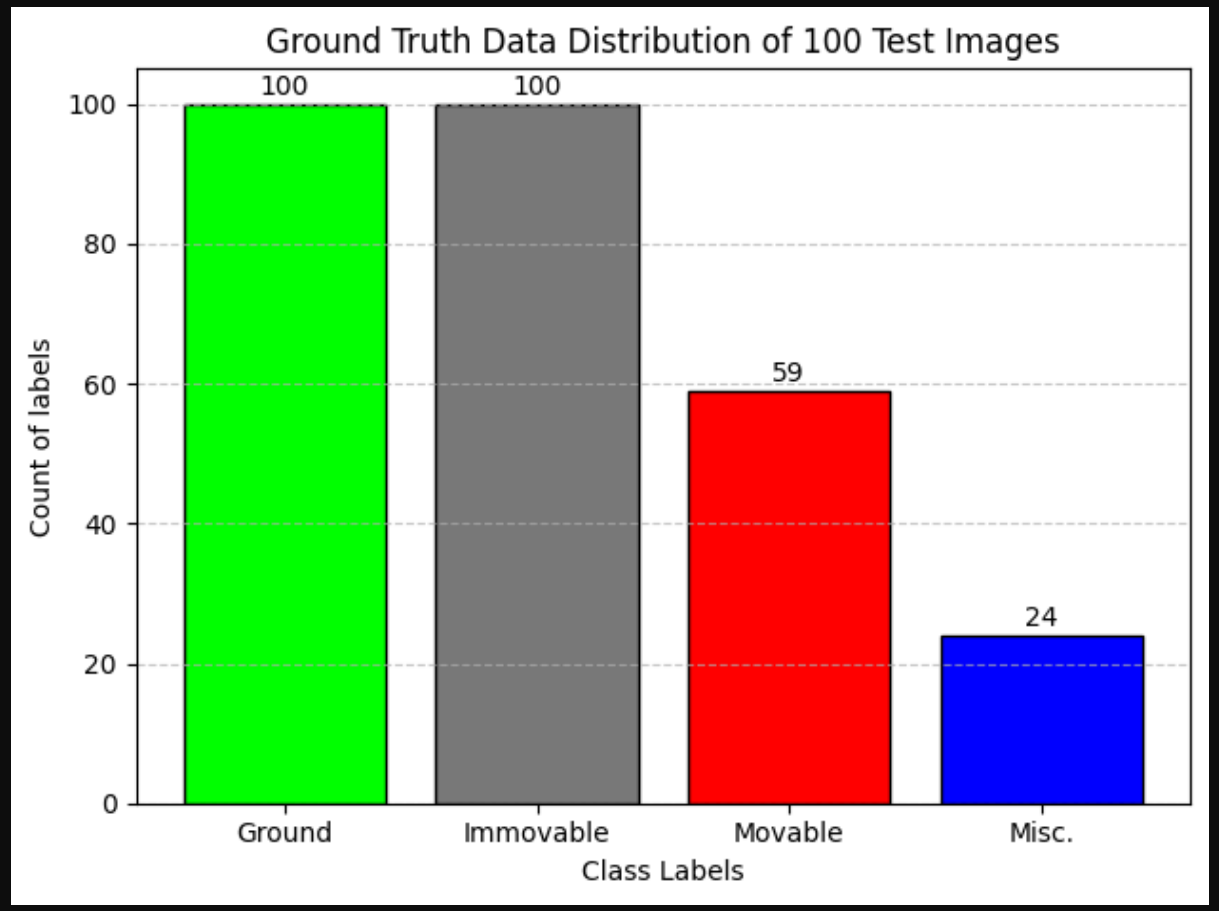
Challenges in the Dataset

Reflections of lighting on the ground and the glass

Difficult to annotate an object (chair) precisely







Data Preprocessing

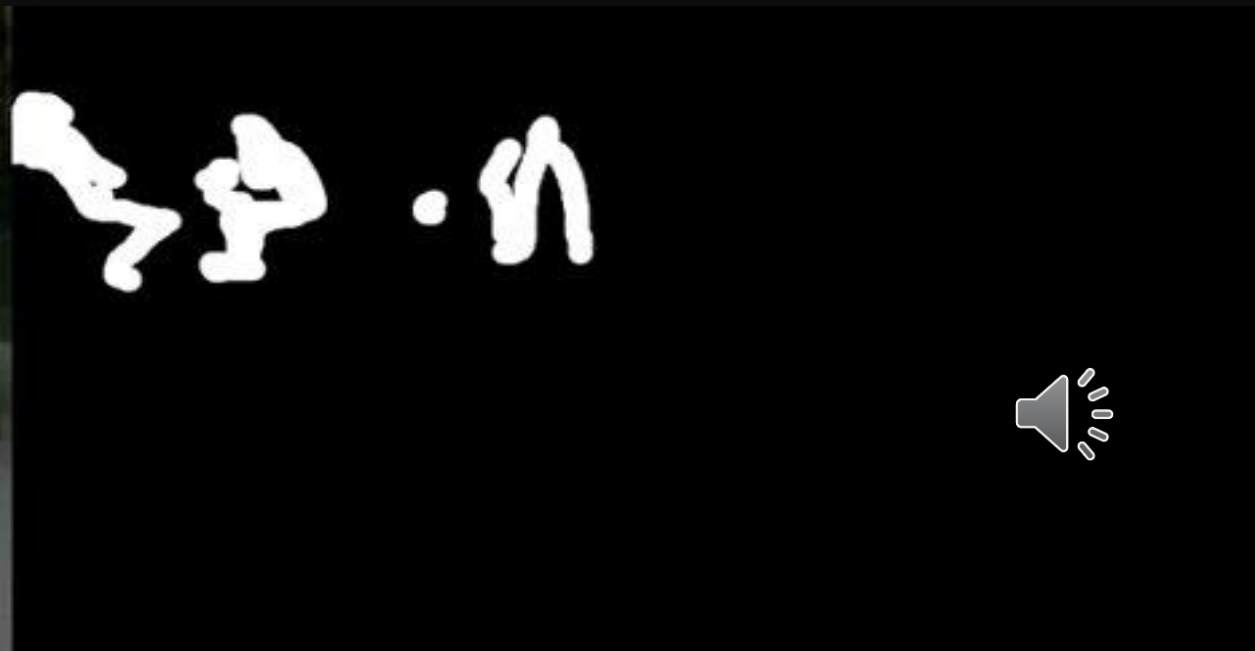
- Data distribution
- Normalizing – Standard Scaler
- Cropped labels

Immovable Object

Ground

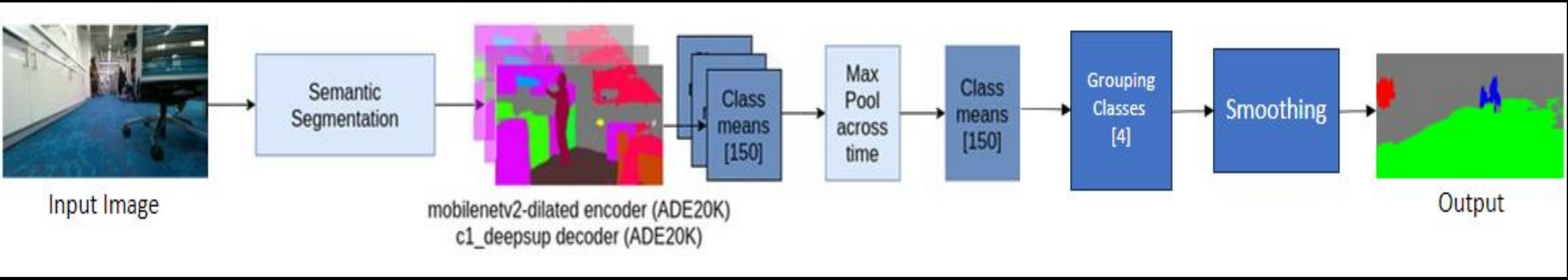
Movable Object

Misc.

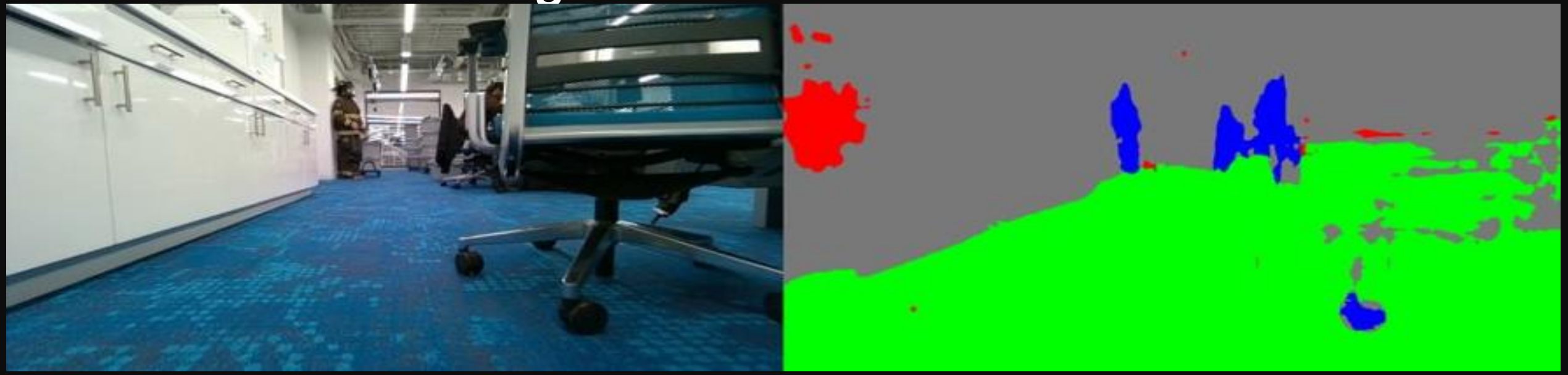


Model Architecture

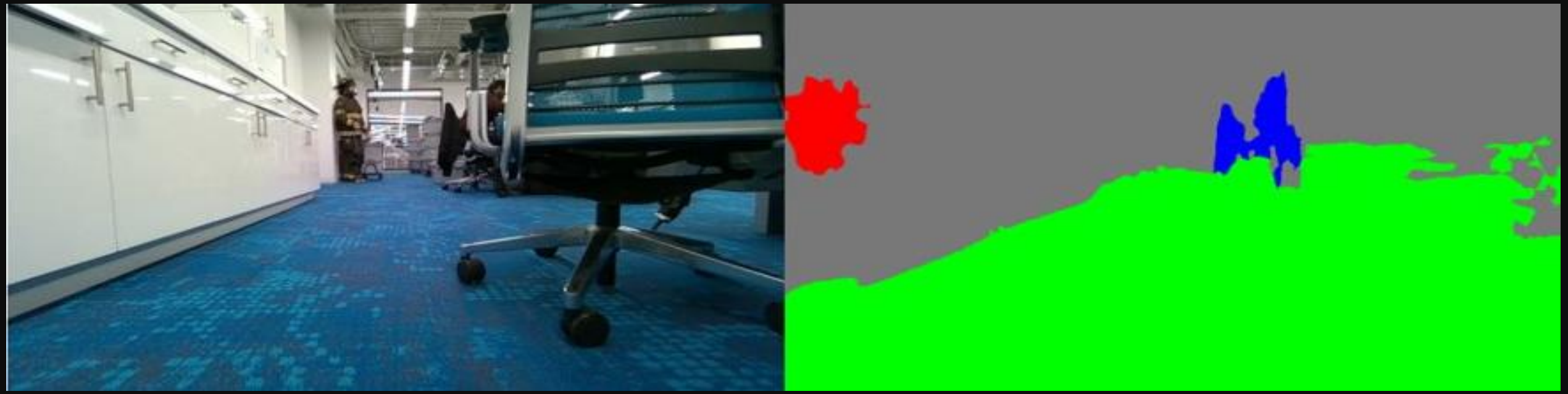
- Model – AutoEncoder architecture with Mobilenet encoder and c1DeepSup decoder
- Model Pretrained on Imagenet and finetuned on MIT – data –ADE20K is the largest open-source dataset for semantic segmentation and scene parsing, released by MIT Computer Vision team.



Without Smoothing



With Smoothing



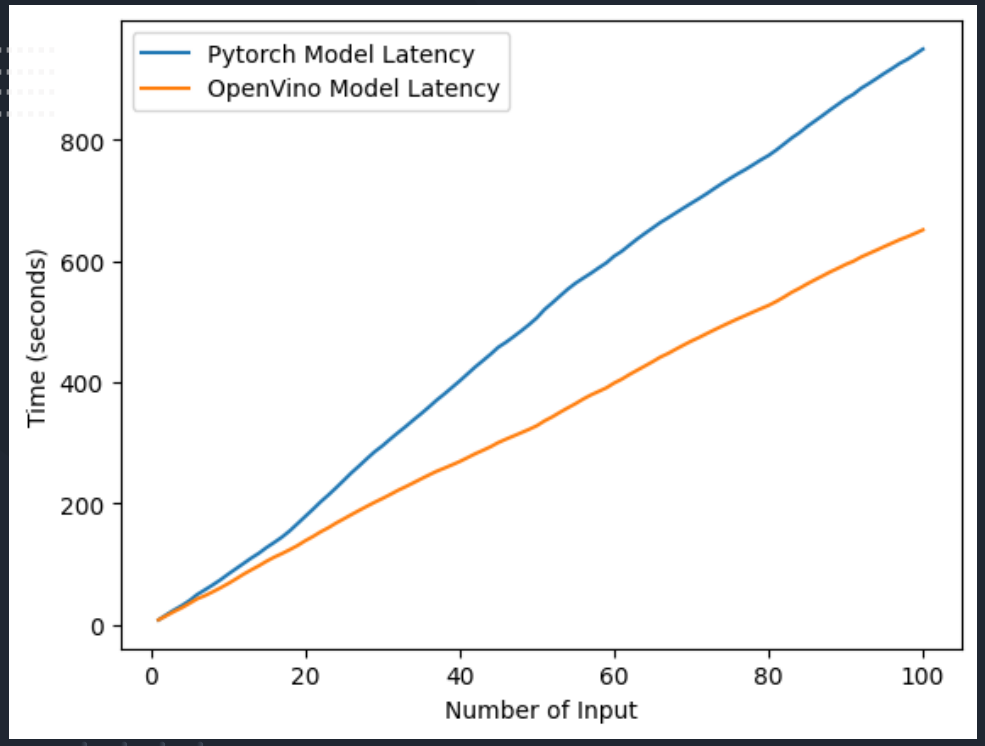
Evaluation Results

- IOU score – Intersection over Union is the ration of intersection of two region and the union of two regions.
- Ground and immovable Objects classes are better as they are more data than the other two

Label Name	IOU Score W.O. Smoothing	IOU Score W. Smoothing
Ground	0.77	0.78
Immovable Objects	0.75	0.76
Movable Objects	0.05	0.03
Misc.	0.31	0.26

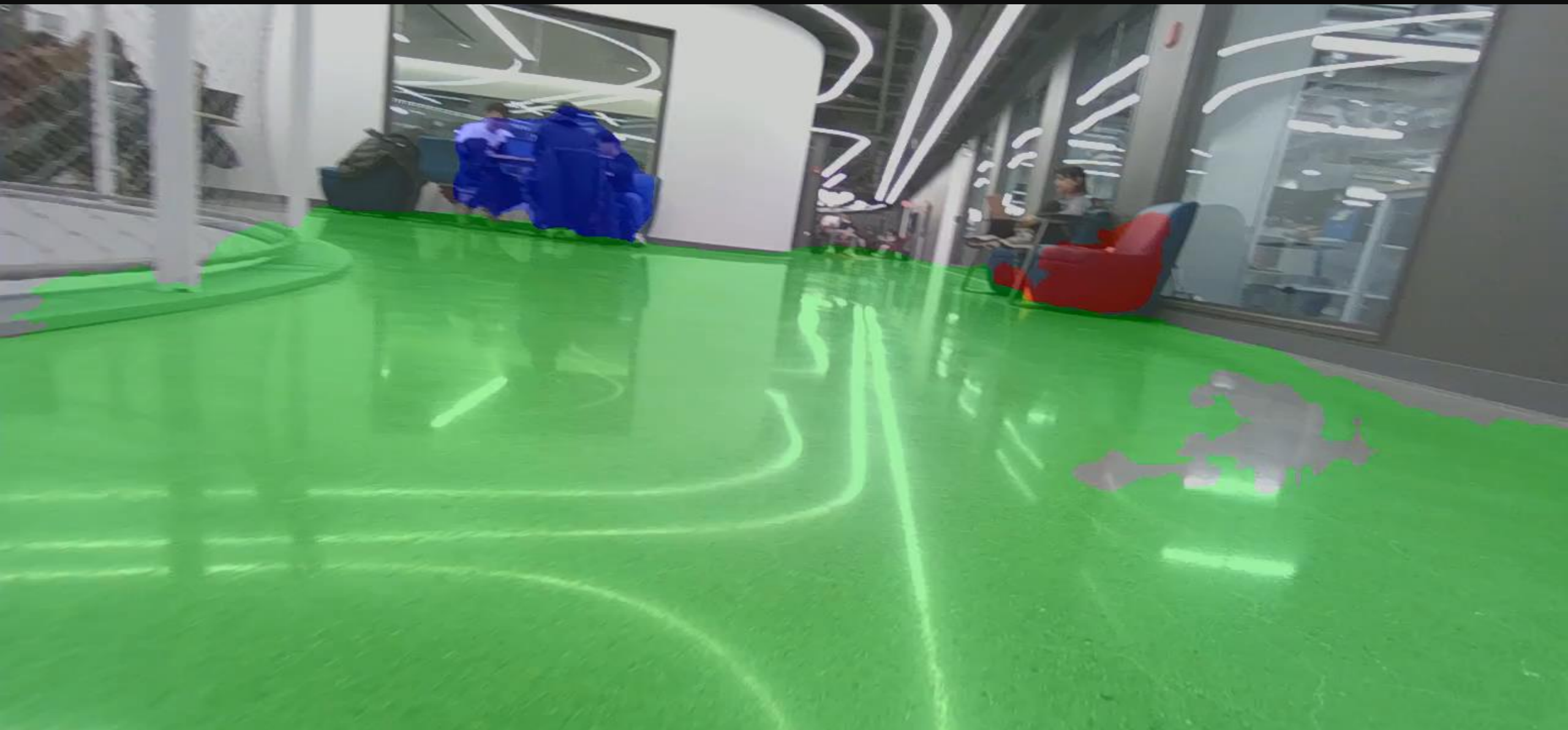
Quantization

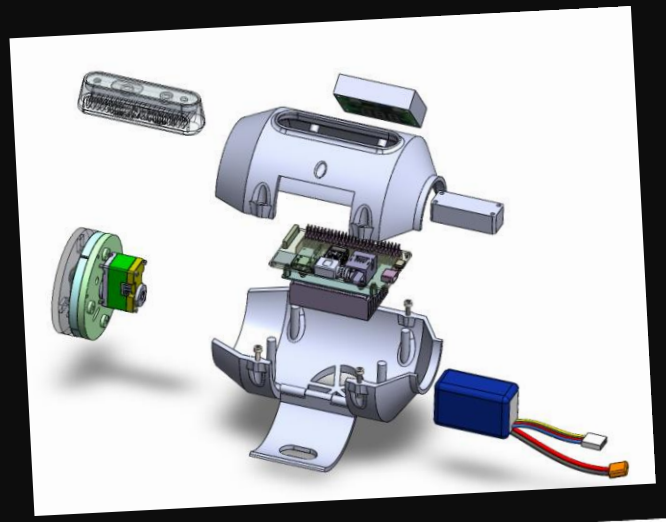
- OpenVino/TensorRT for model optimization through quantization
- Exponential decreases in inference time
- Pytorch model 8.72 mb, quantized model 3.88 mb. 2x reduction in memory
- Inference trade-off is negligible

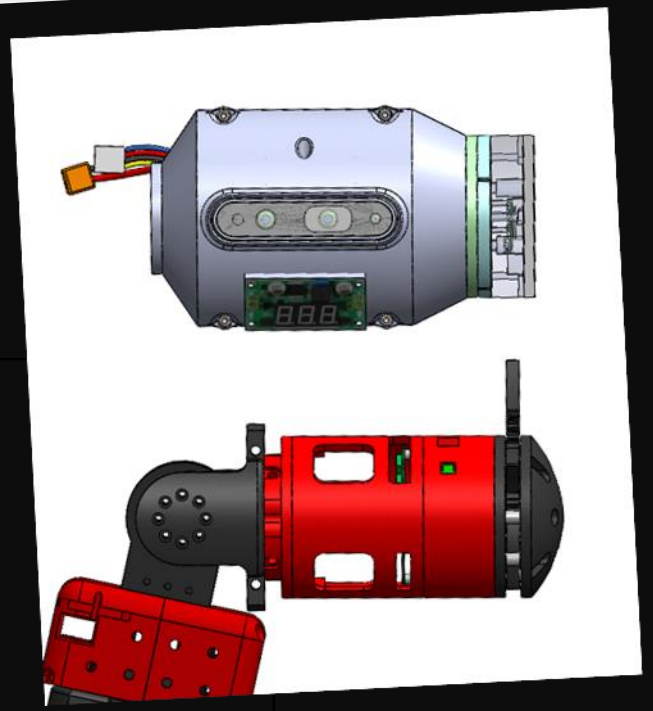


Label Name	IOU Score model + smoothen	IOU Score Quantized model + smoothen
Ground	0.78	0.78
Immovable	0.76	0.75
Movable	0.03	0.03
Misc.	0.26	0.26

Real time prediction

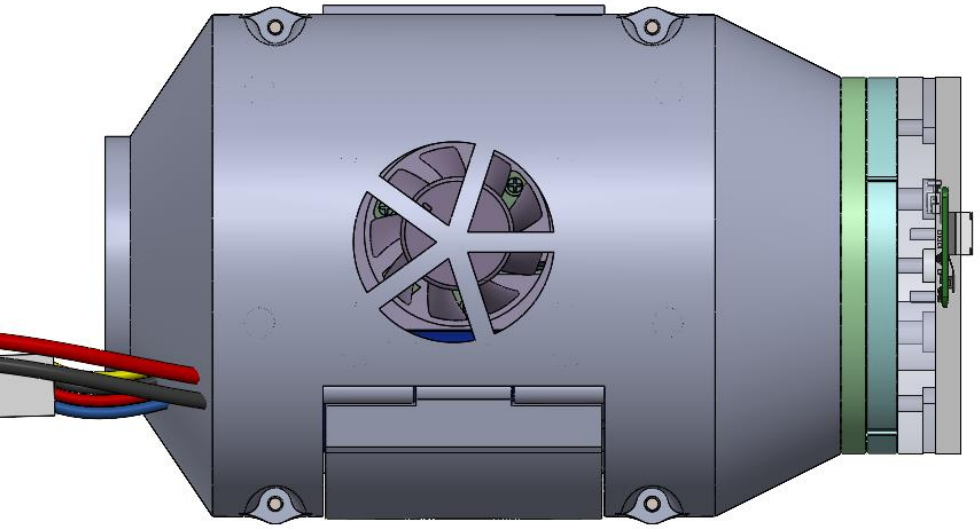


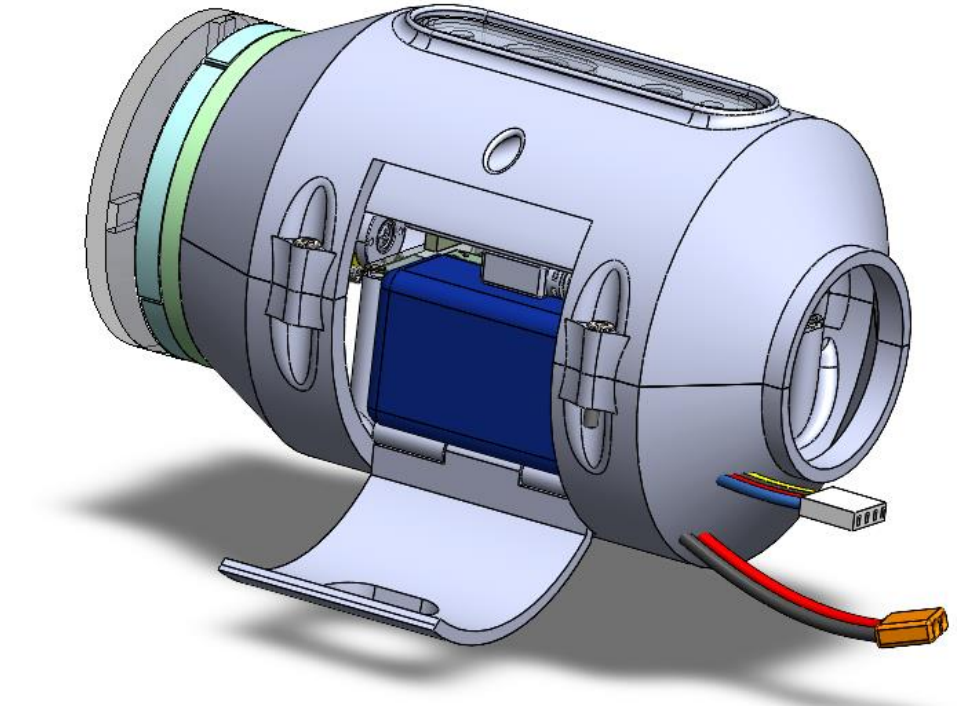




Problem with Old Cobra Head:

- The old Cobra head does not support a vision camera to track or detect object.
- No proper way to replace battery.
- The cables stood out from the head.
- No proper mesh provided for the Jetson Orin fan



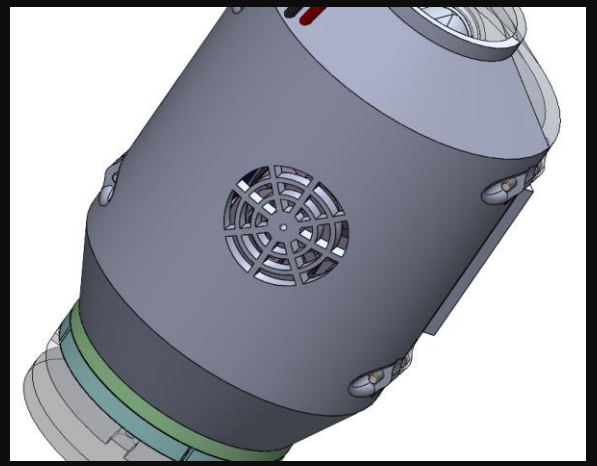


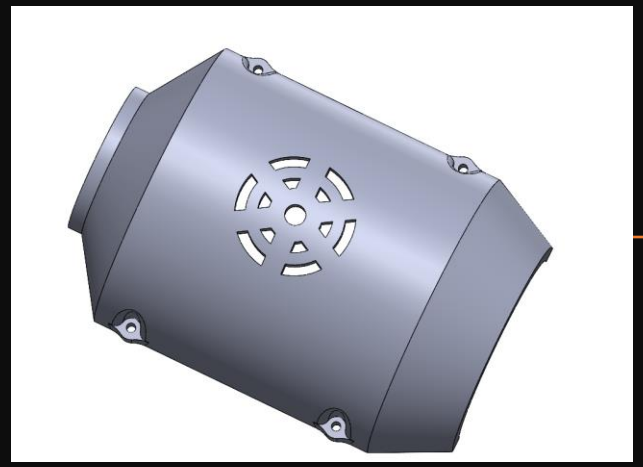
COBRA Head Re-design

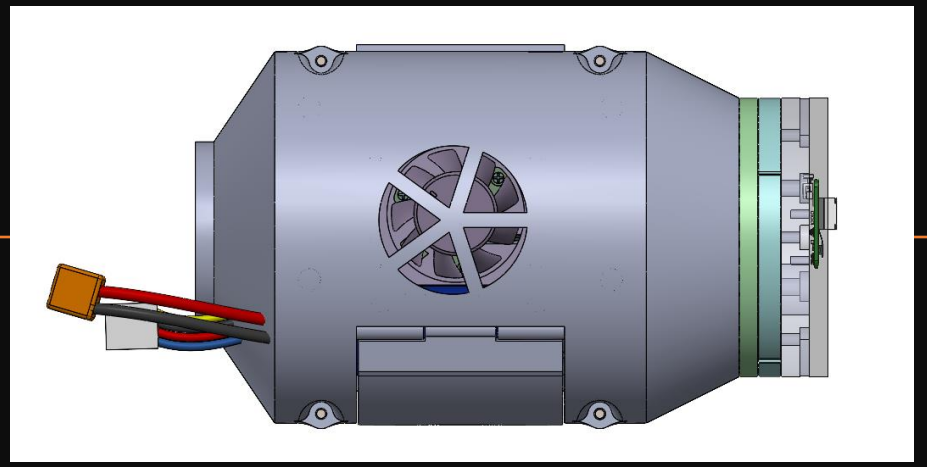
- The New head incorporates number of features to improve its functionality and performance.
- Created a proper window for battery to slid in and out.
- Mesh is created for the Jetson Orin.

Design Challenge: Iterative Refinement for Optimal Functionality

To get the best result, we repeatedly attempted to modify the Cobra head design.







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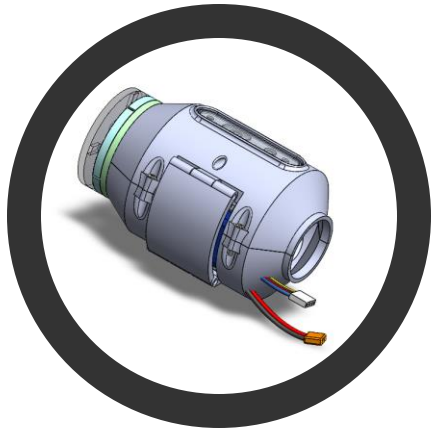
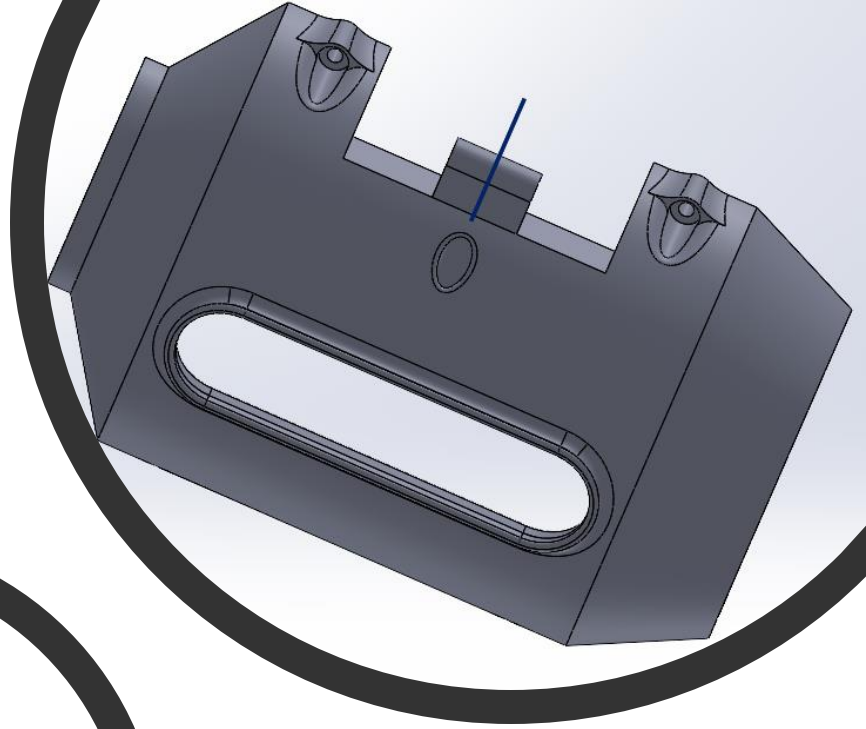
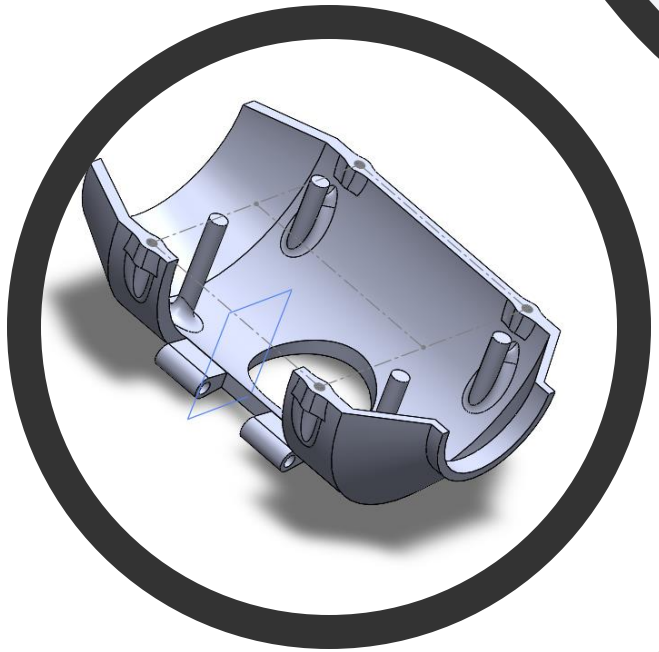
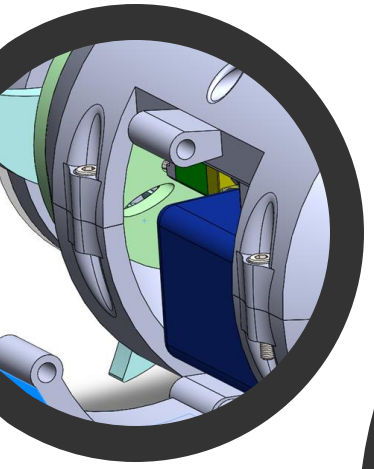
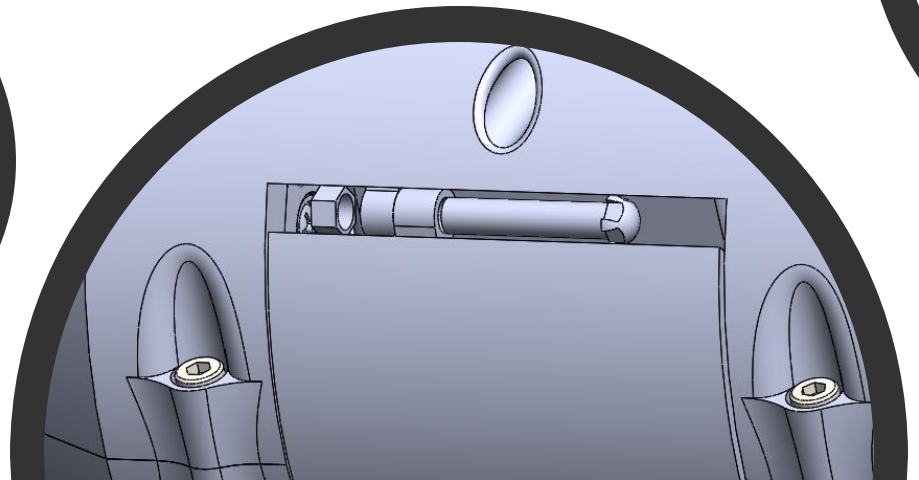
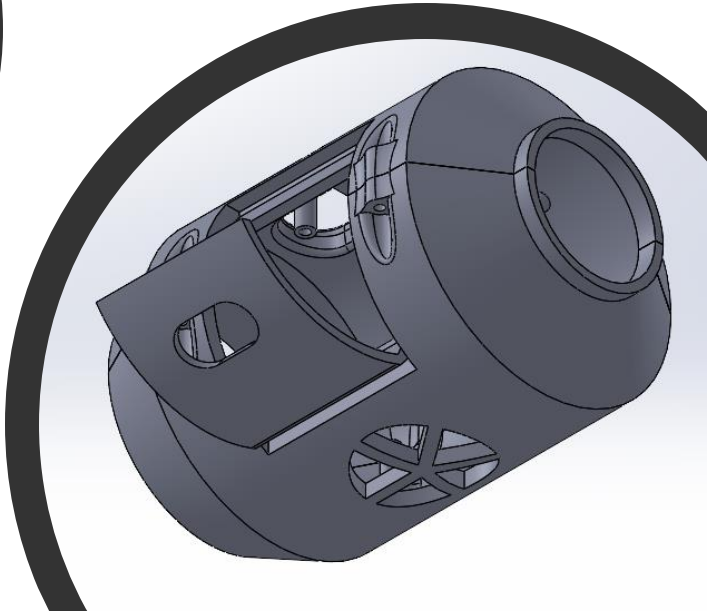








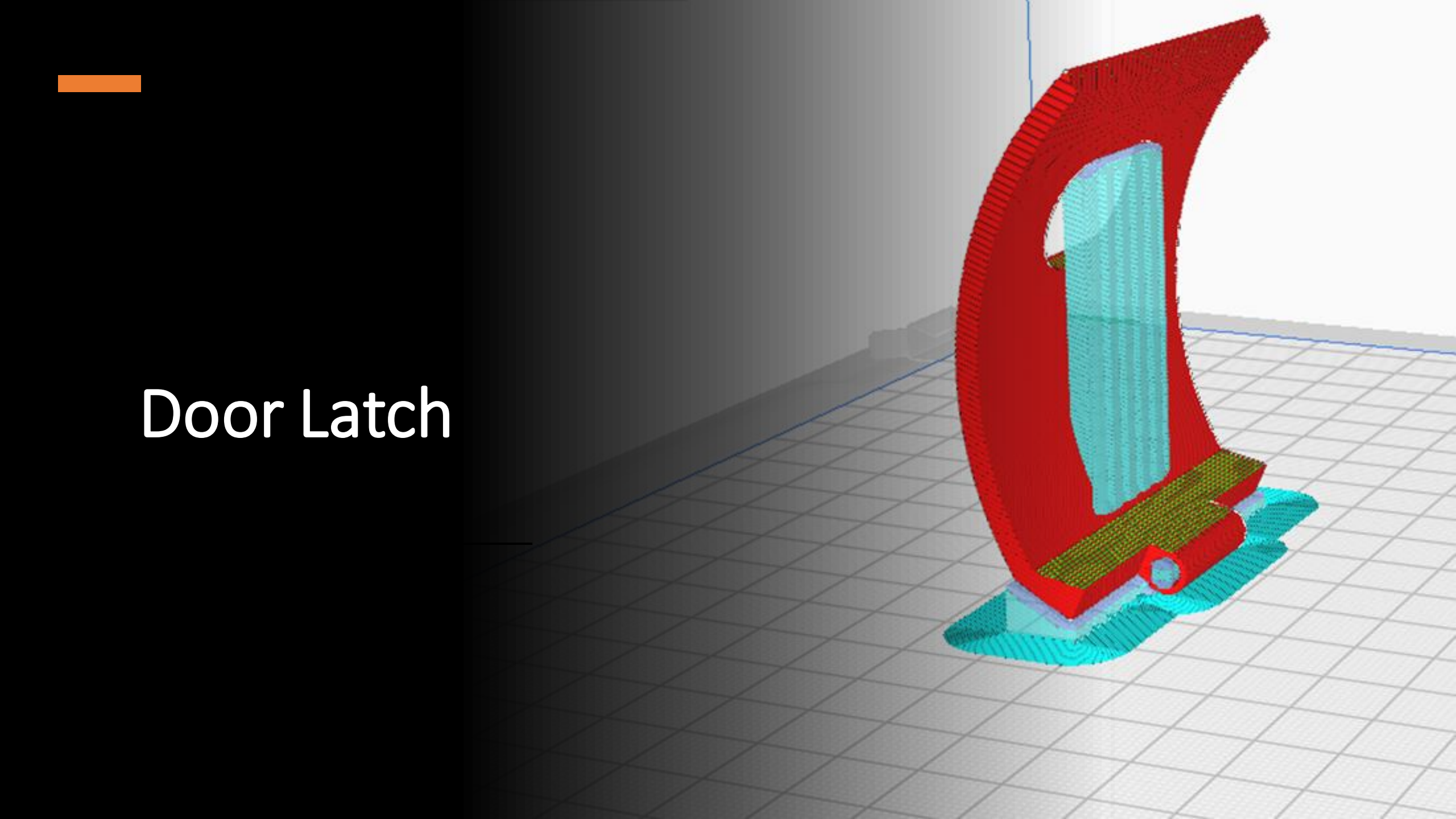




3D printing Parameters

Feature	Latching Door	Head Housing
3D Printing Process	Fused Deposition Modeling (FDM)	Fused Deposition Modeling (FDM)
Slicing Software	Ultimaker Cura	Ultimaker Cura
Material	Generic PLA (Polylactic Acid)	Generic PLA (Polylactic Acid)
Layer Resolution	0.15 mm (standard)	0.15 mm (standard)
Orientation	Straight up on the 3D printer bed	Straight up on the 3D printer bed
Infill Density	50%	60% (increased to support electronic components)
Infill Pattern	Triangular	Triangular
Shell Thickness	0.8 mm and 1 mm	0.8 mm and 1 mm
Support	Normal support	Normal support
Weight	78 grams	152 grams
Printing Time	2.5 hours	20 hours
Challenges Faced	Removing excess support material	Removing excess support material, Achieving a smooth surface finish
Future Improvements	Optimize support settings to minimize manual removal	Optimize support settings to minimize manual removal, Explore alternative materials with better surface finish properties

Door Latch



Head Housing

Post processing

- Needle nose pliers
- Flush cutters
- Putty knives, scraper knives, or pallet knives
- Xacto knives
- Pneumatic handHeld Tools

Conclusion

Novel bio-inspired mobility system combines sidewinding and tumbling to access steep crater environments

Modular mechanical design enables transformation between gaits and shapes

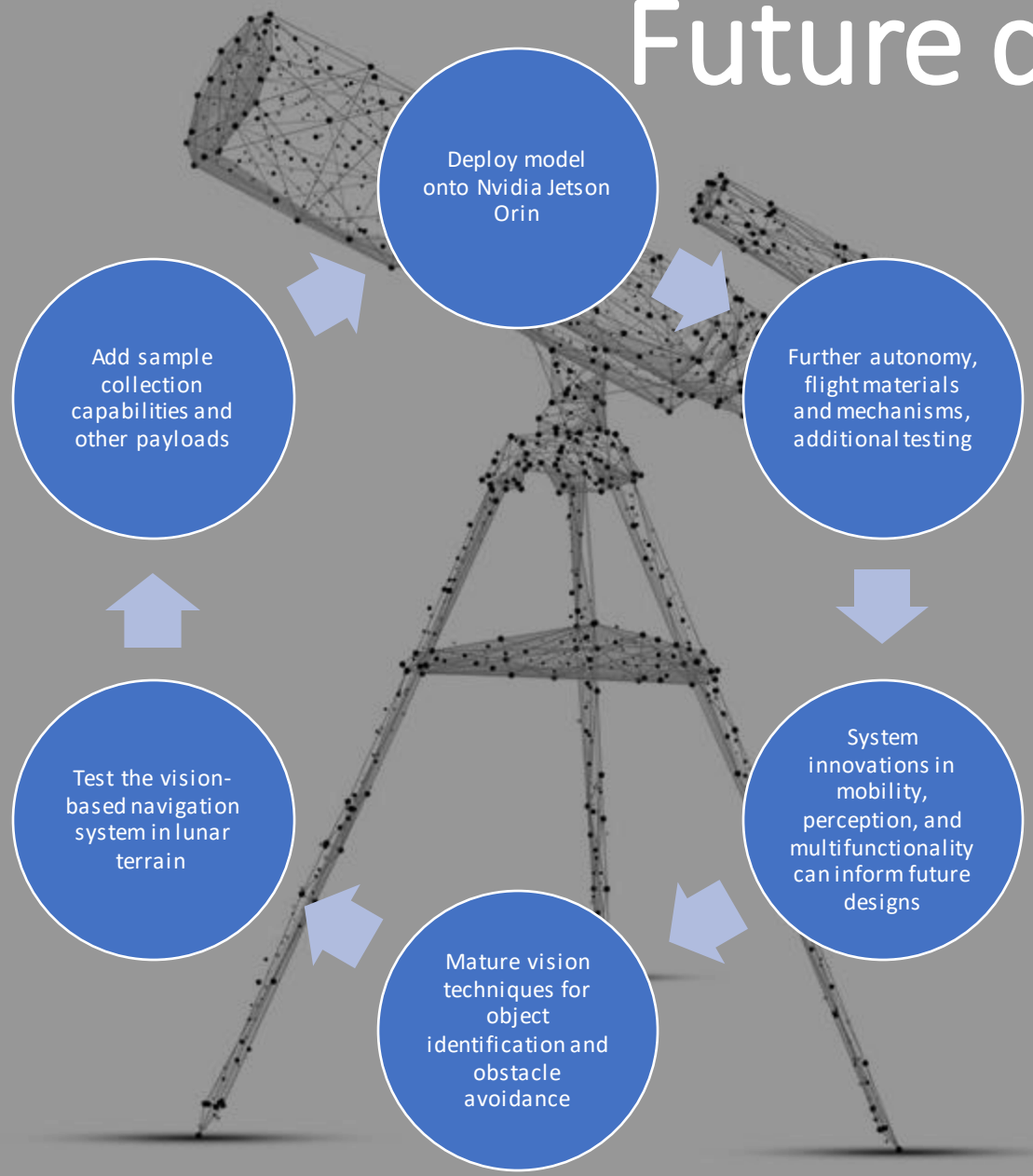
Redesigned head improves functionality with battery access, sensors, computing

Added computer vision and deep learning for terrain analysis and autonomy

3D printing process allowed iterative design optimization and fabrication

COBRA exemplifies pushing boundaries of lunar exploration through bio-inspiration and intelligence

Future development



COBRA redefines what's possible

- more innovations to come!

THANK YOU