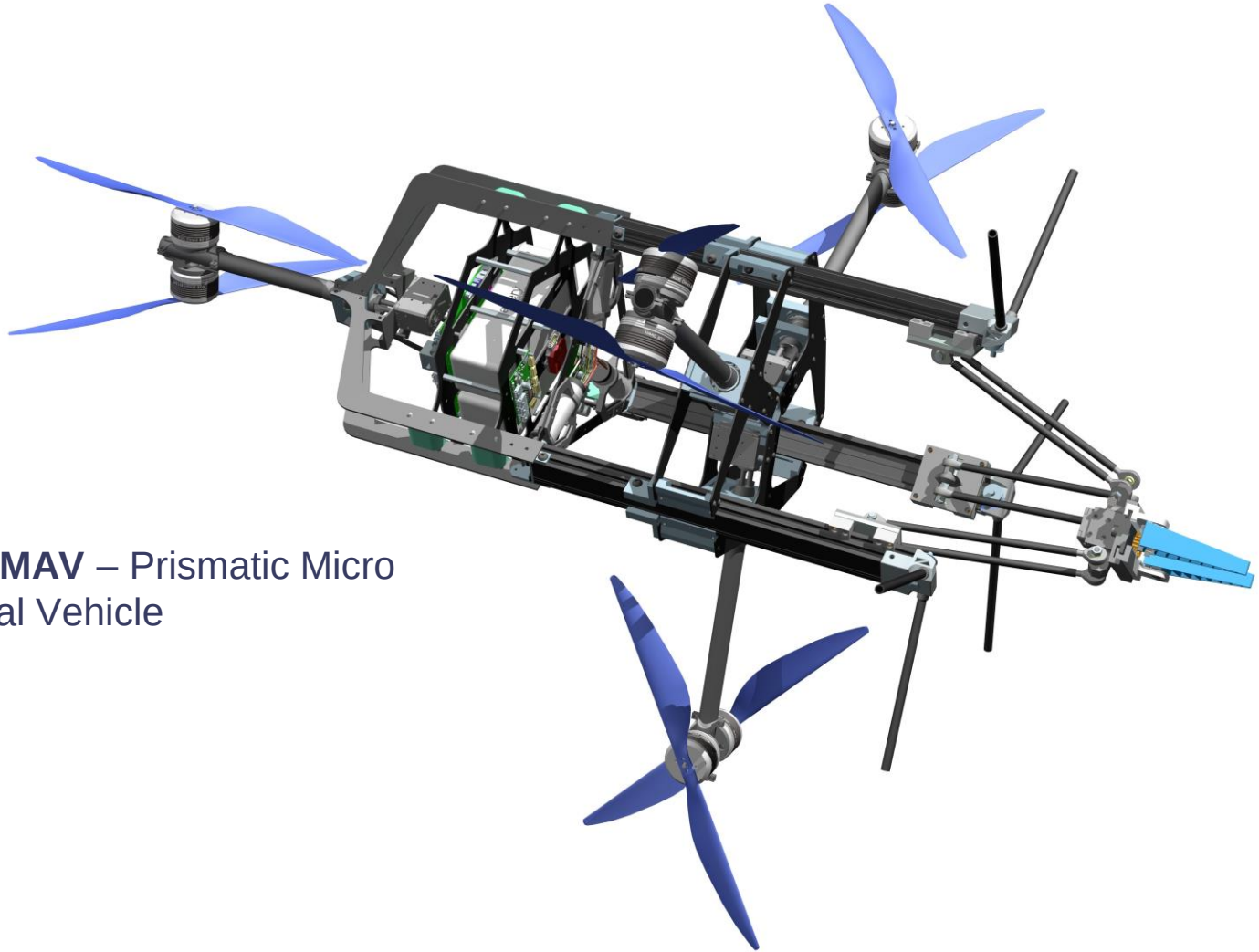
Object Detection & Grasp Planning with an Omnidirectional Aerial Manipulator

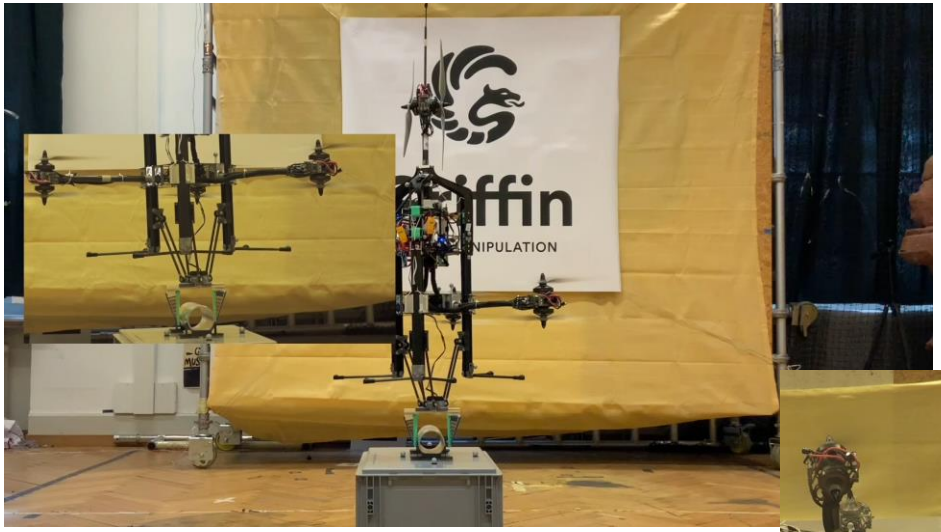
Bachelor Thesis – Final Presentation

Martin Inauen & Philippe Brigger



PrisMAV – Prismatic Micro Aerial Vehicle


Griffin
AERIAL MANIPULATION


ffin
NIPULATION


ffin

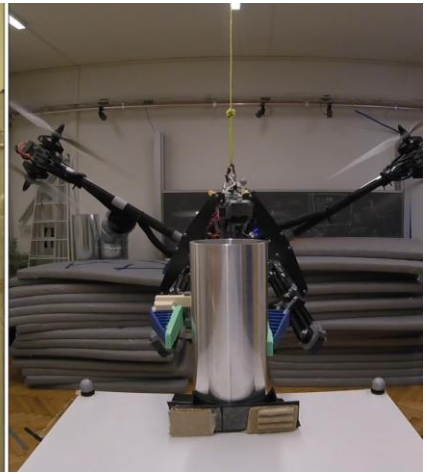


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Table of Contents

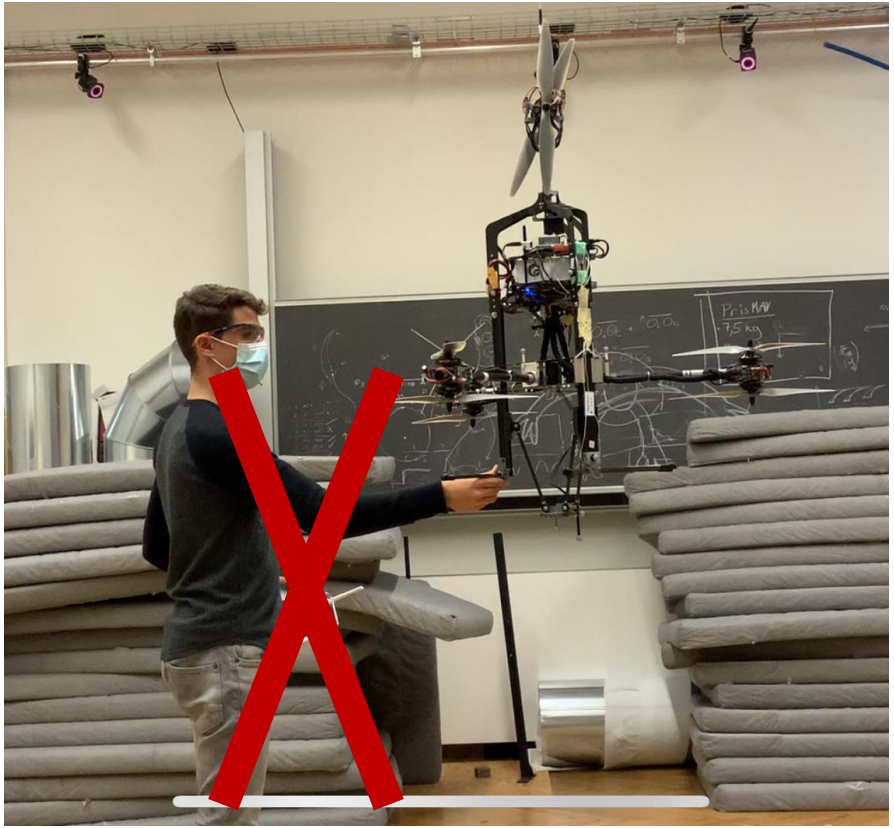
Goals

Methods

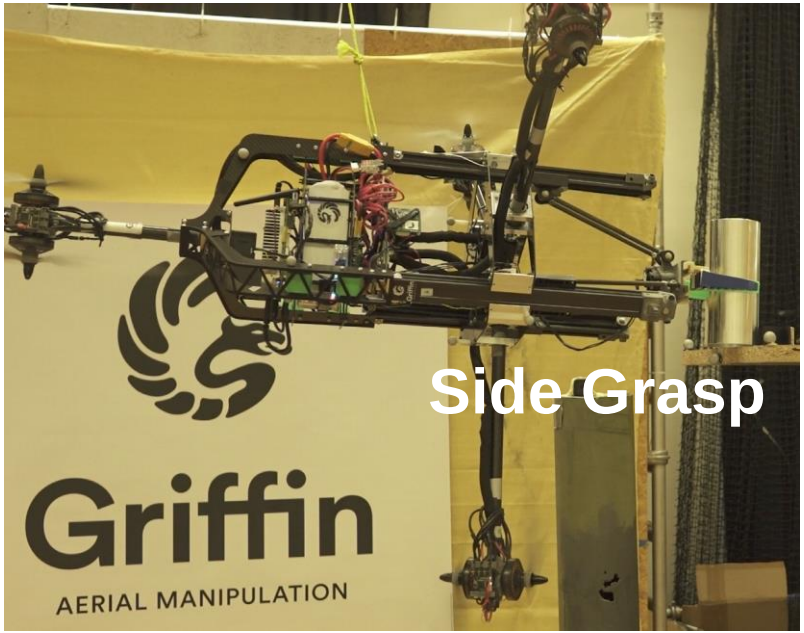
Results

Outlook

Autonomy



Flexible Grasping



Side Grasp

Top Grasp

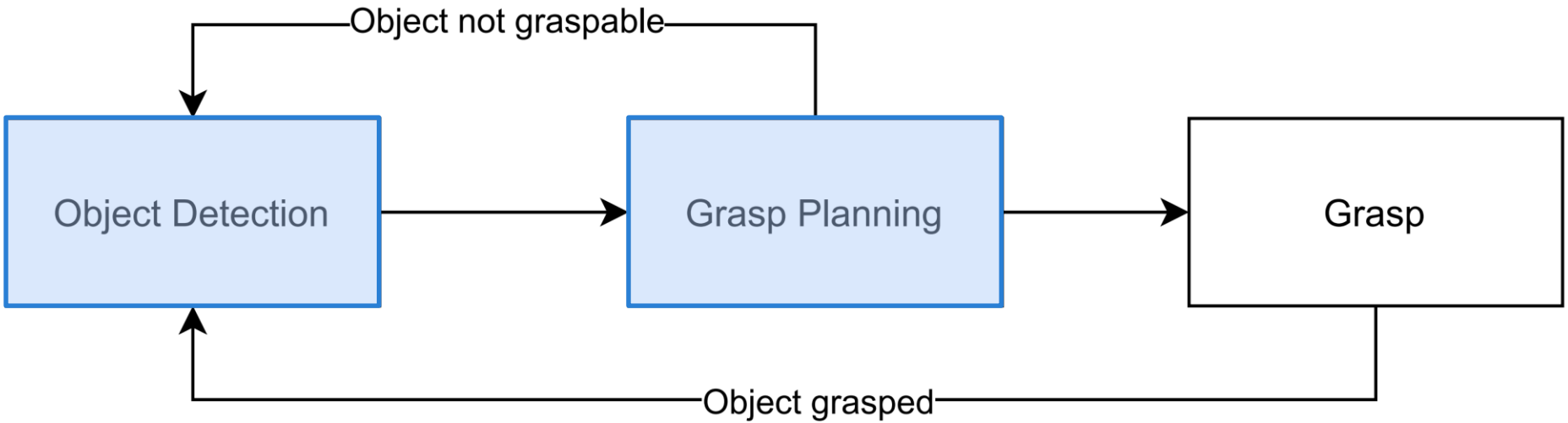
Thesis Goals

Detect & locate target objects

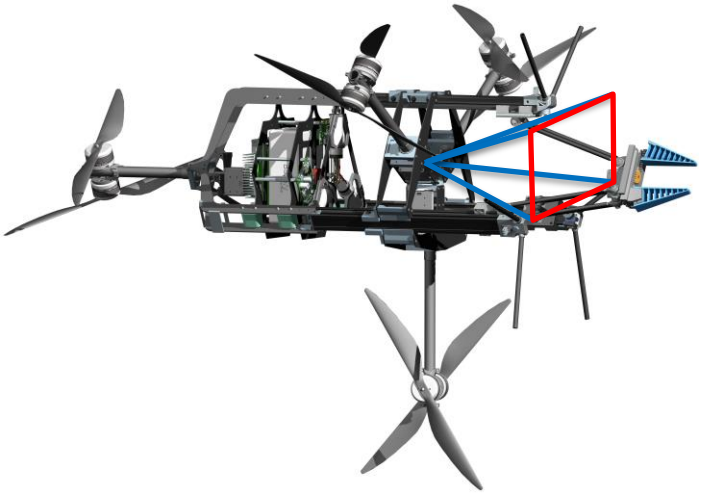
Optimal flight mode for grasp

Calculate grasp point

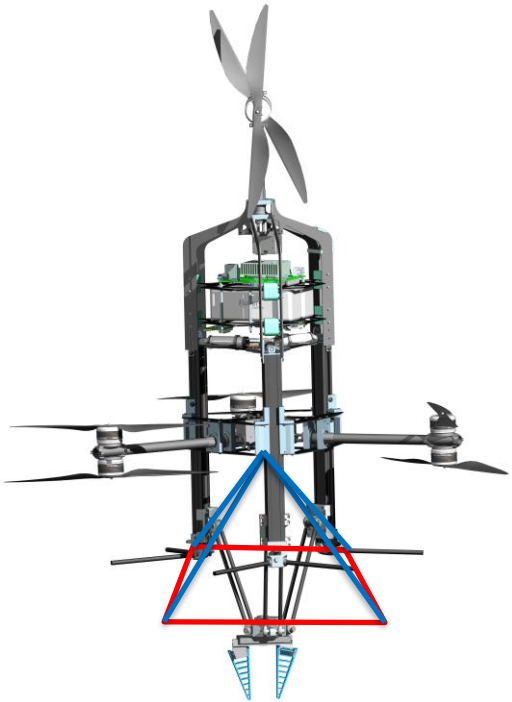
Pipeline Overview



Flight Modes

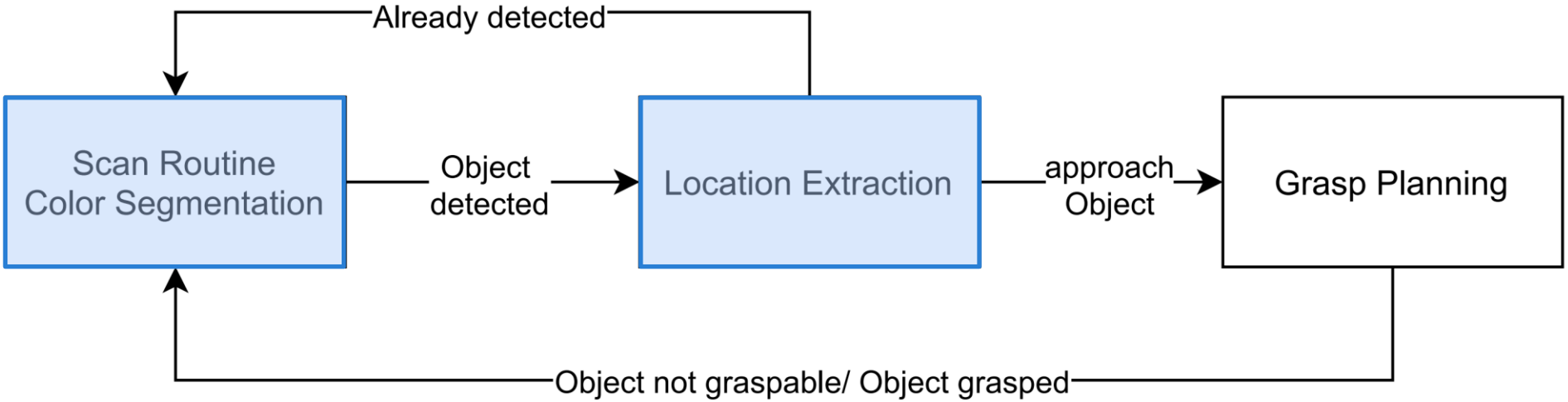


Horizontal Flight Mode

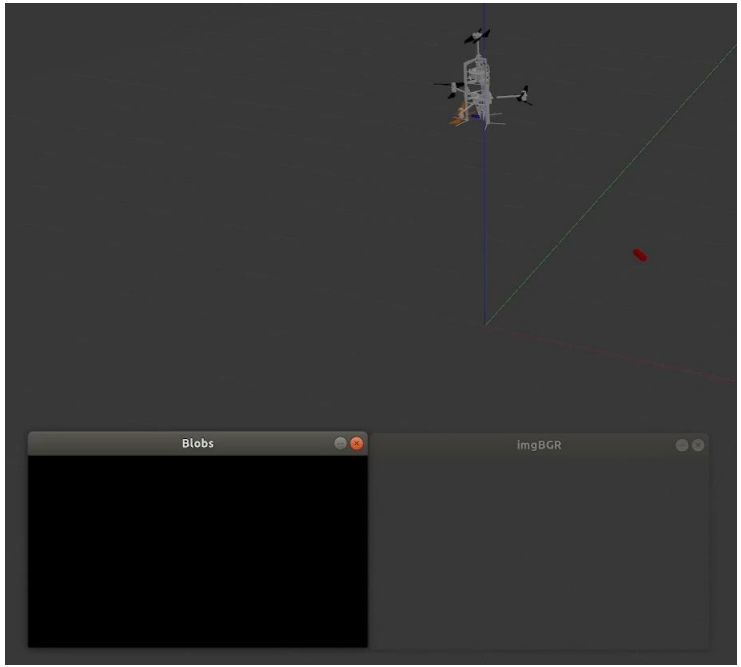


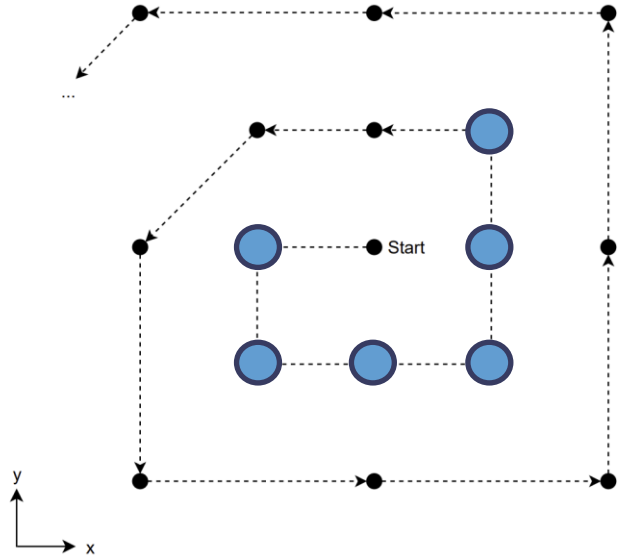
Tricopter Flight Mode

Object Detection

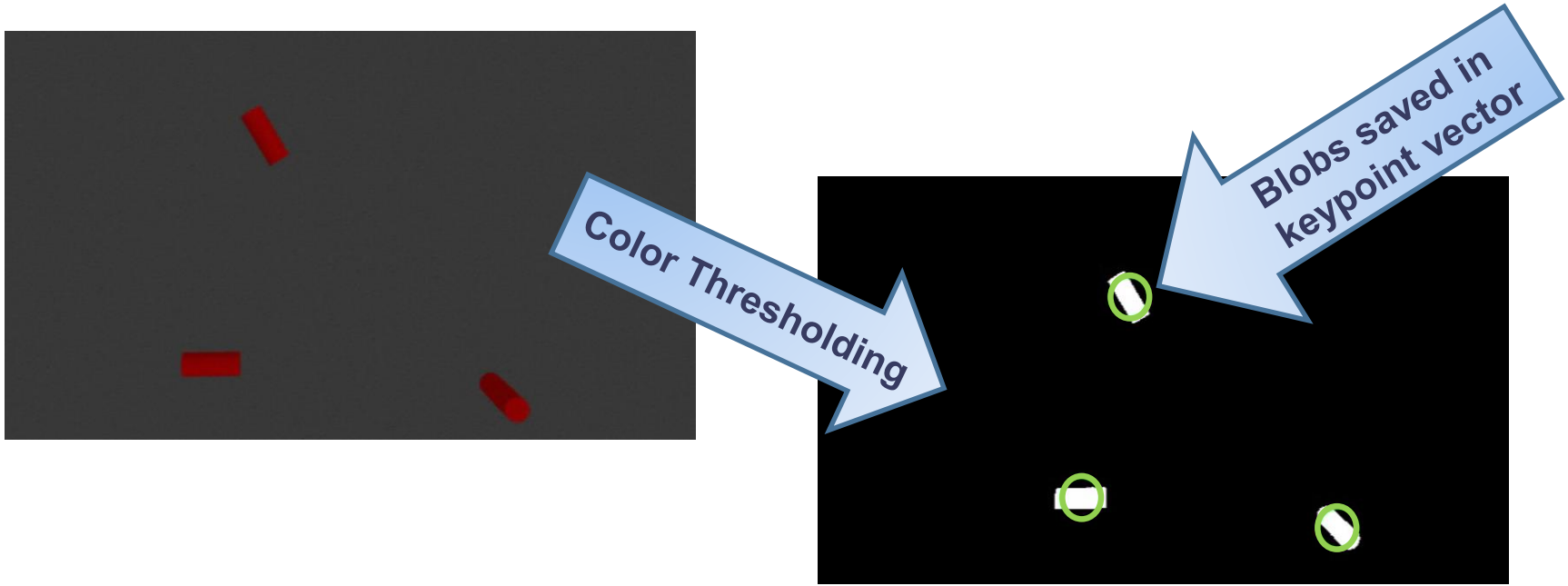


Scan Routine & Color Segmentation

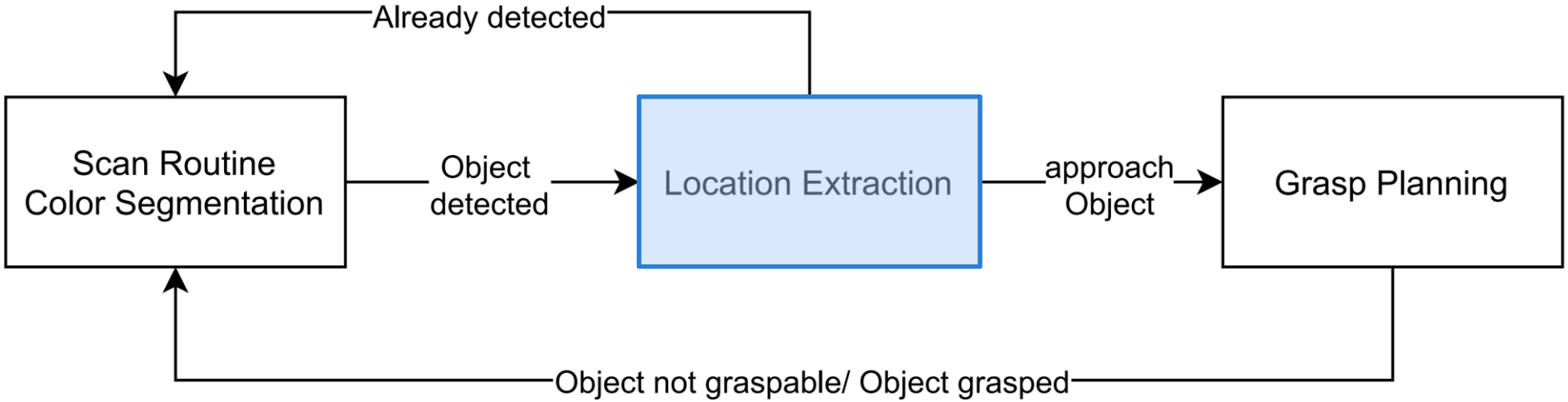




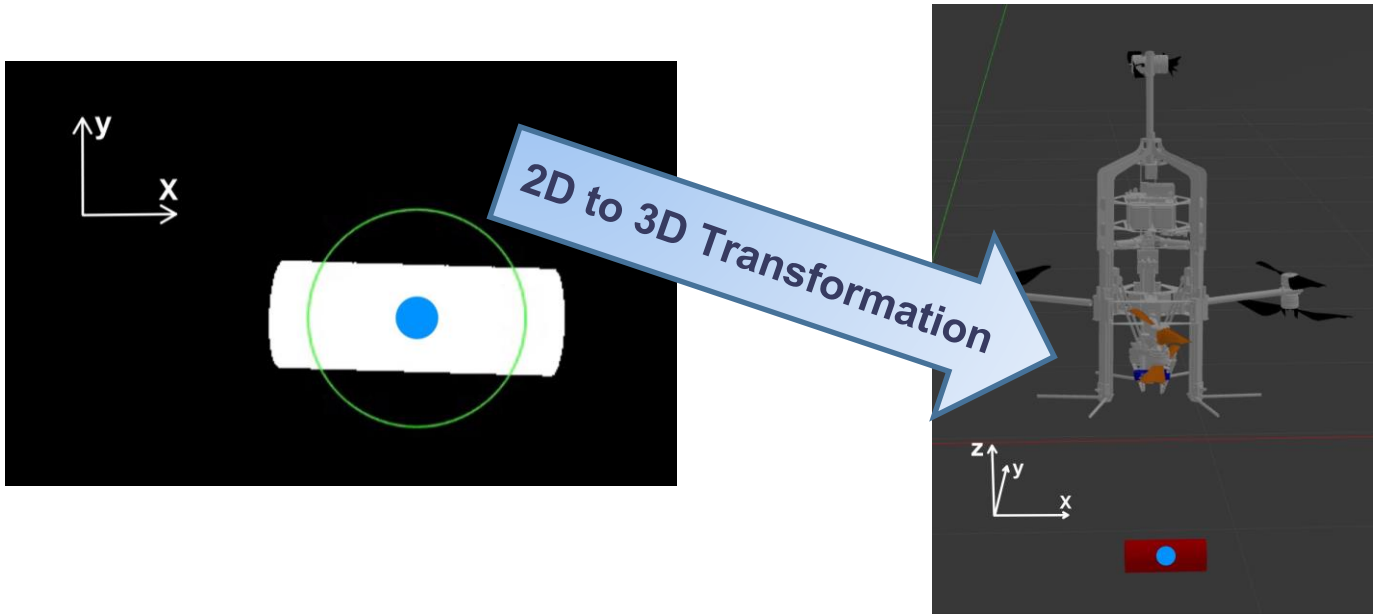
Scan Routine & Color Segmentation



Object Detection

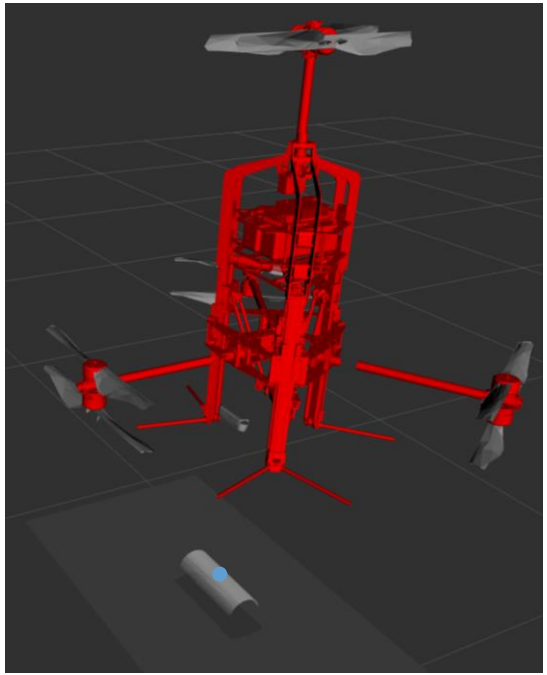


Location – Blob Center

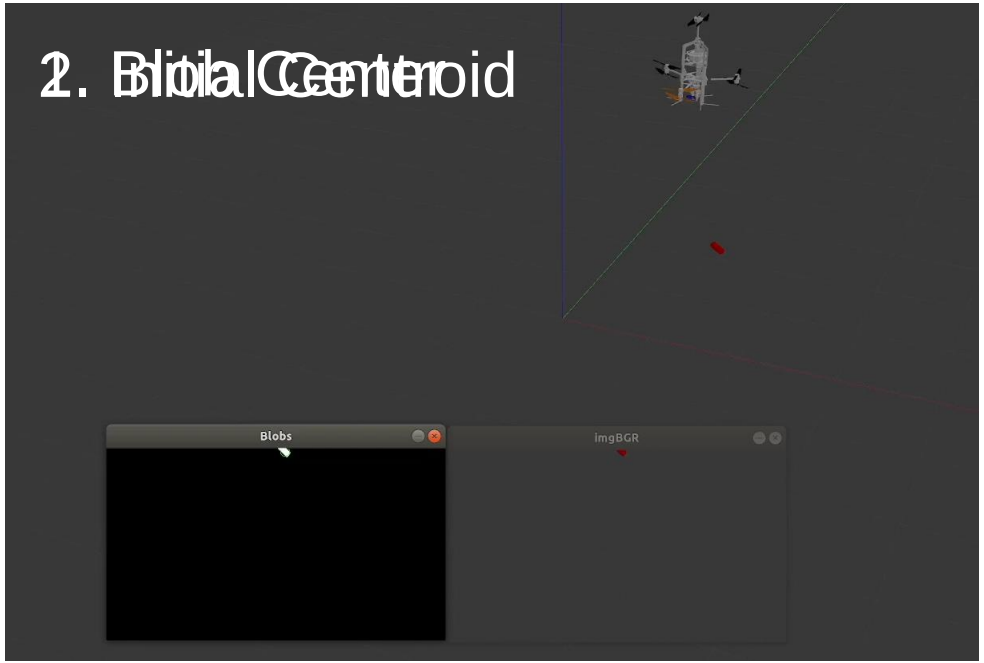


Location – Initial Centroid

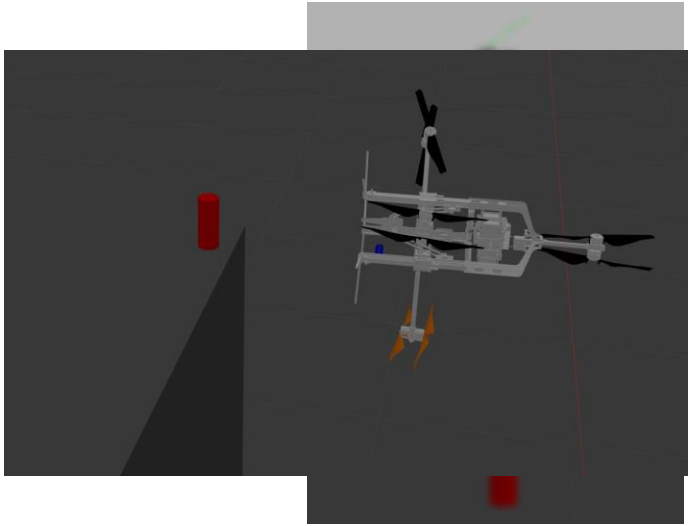
- 3D centroid from 3D point cloud

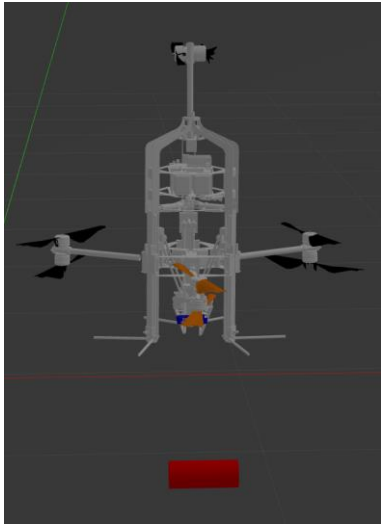


Location – Approach & Centering

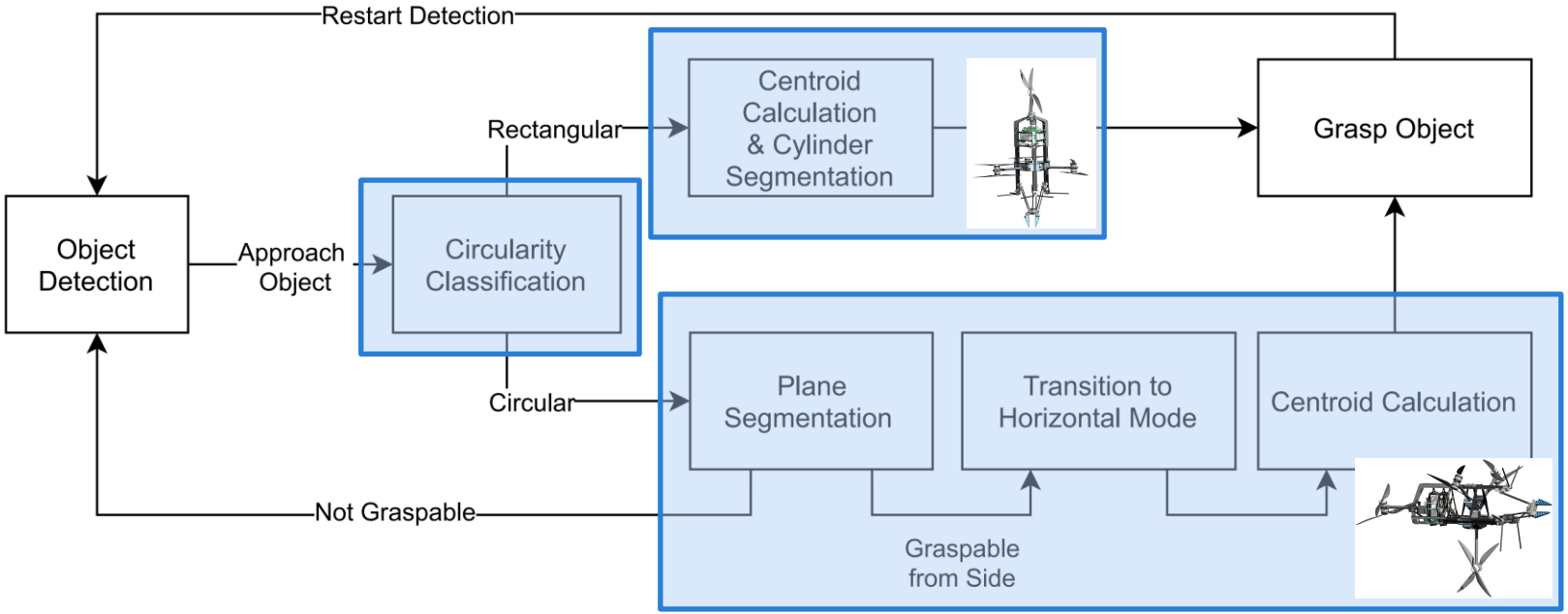


Object Grasp

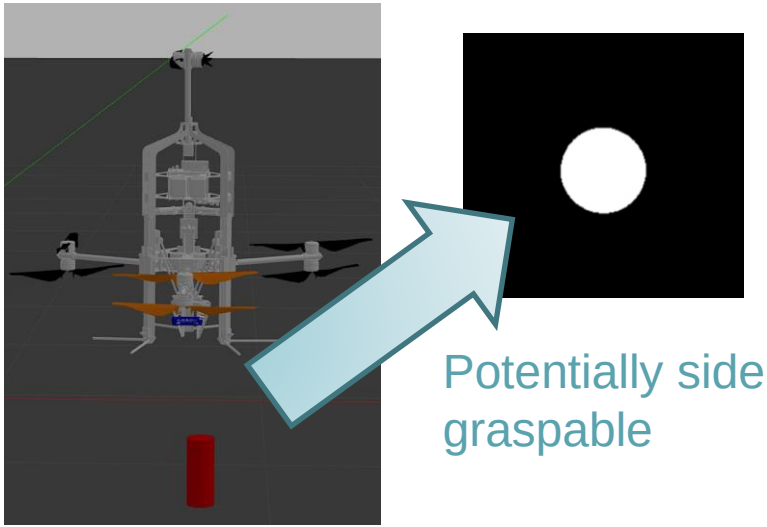




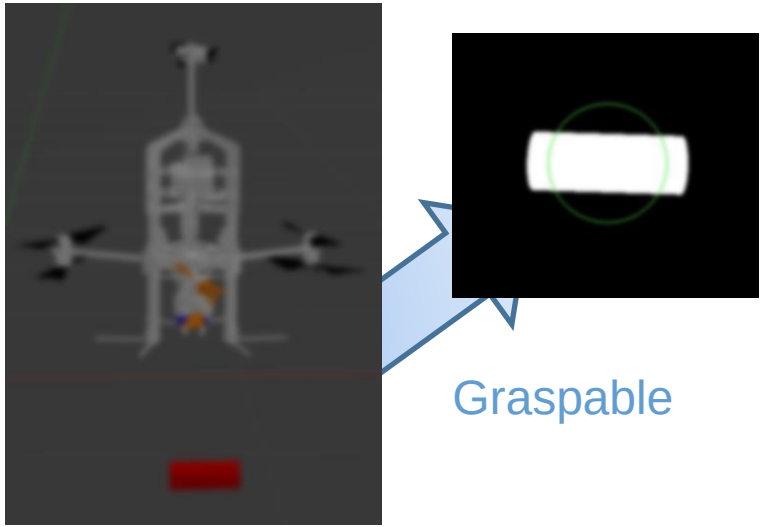
Grasp Planning



Circularity Classification

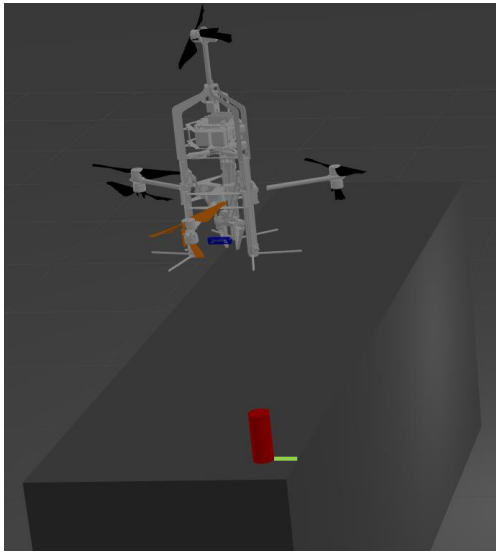


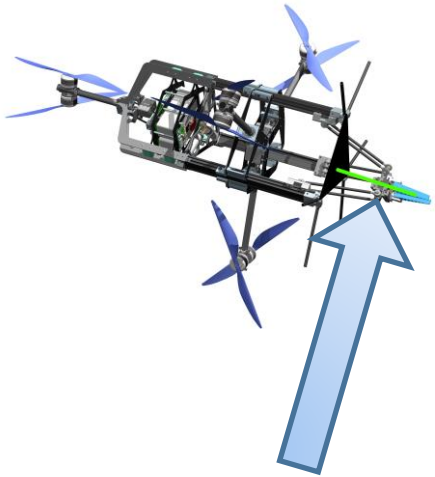
Potentially side graspable

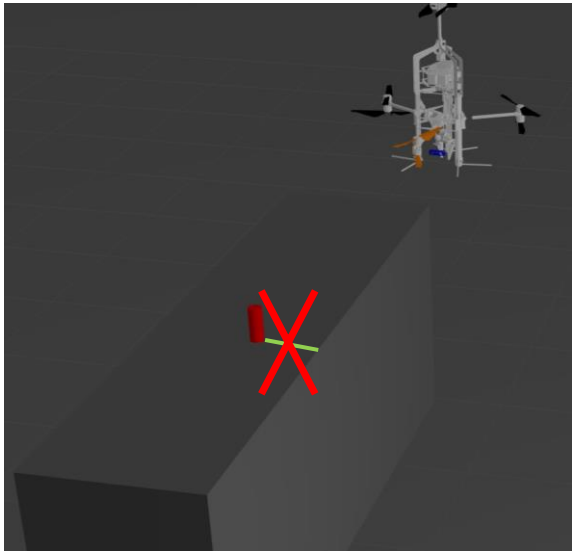


Graspable

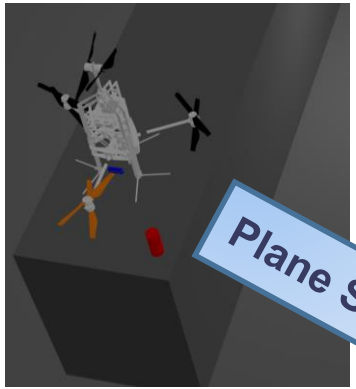
Graspable on shelf



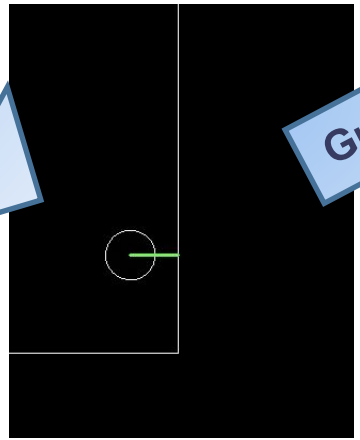




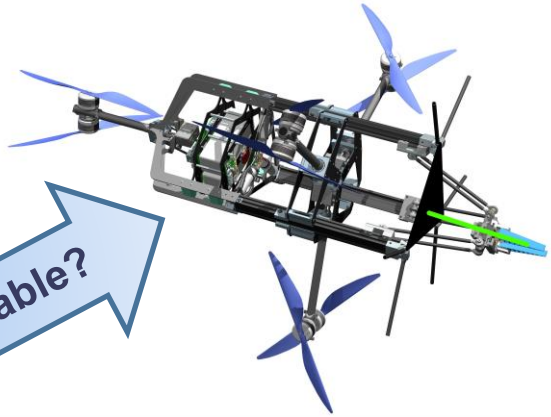
Plane Segmentation – Side Grasp

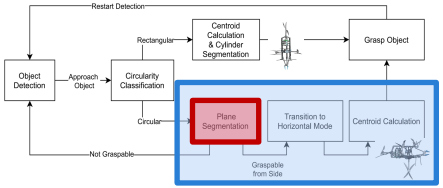


Plane Segm.

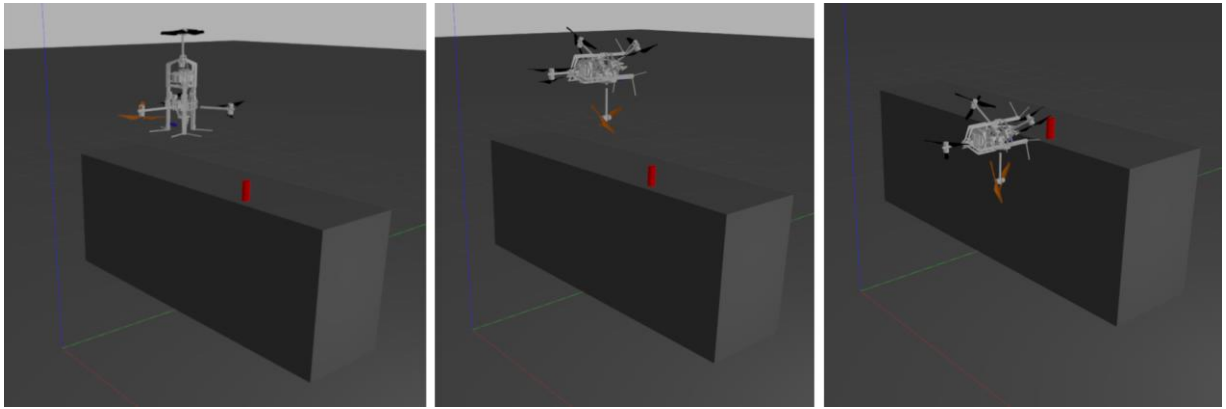


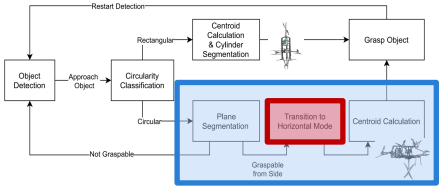
Graspable?



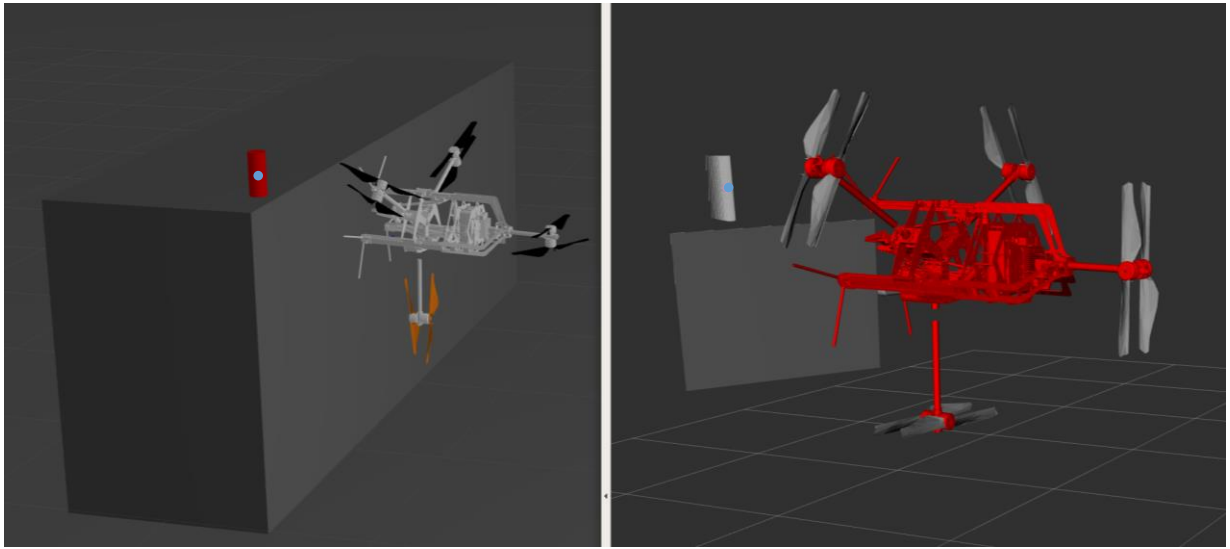


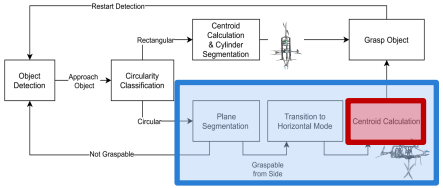
Transition – Side Grasp



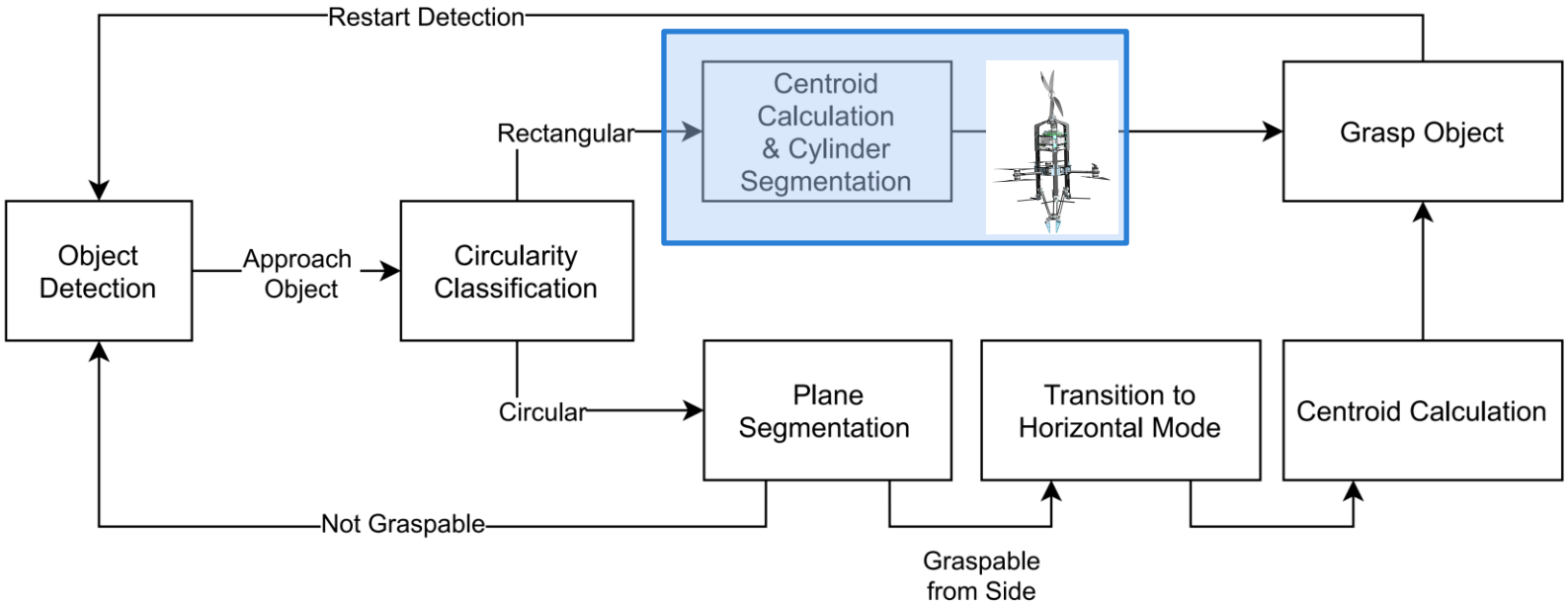


Grasp Centroid – Side Grasp

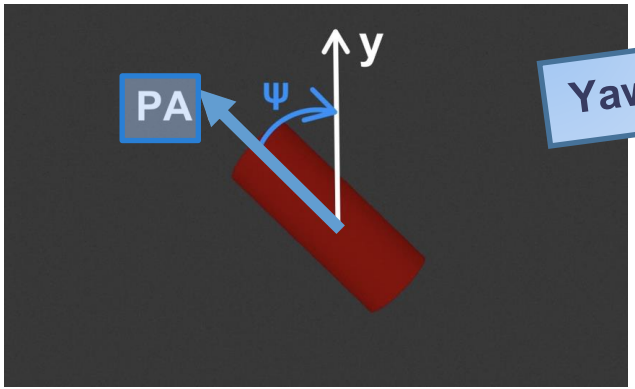


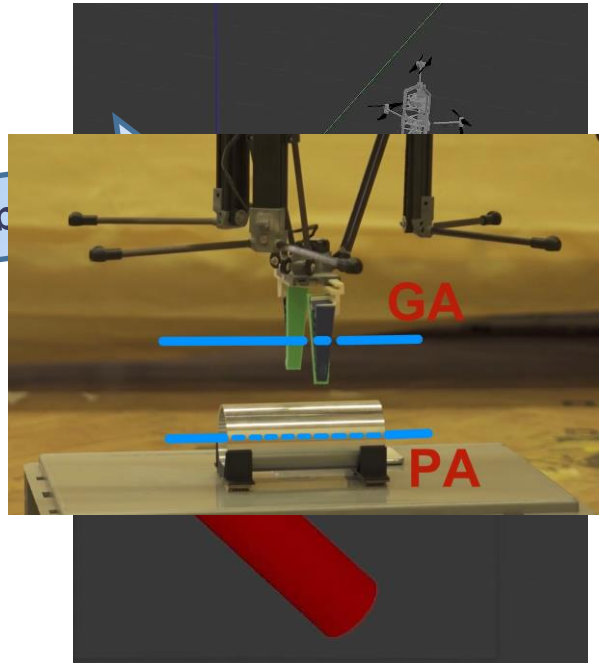


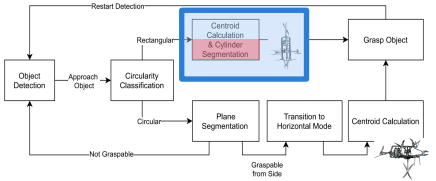
Grasp Planning Step – Top Grasp



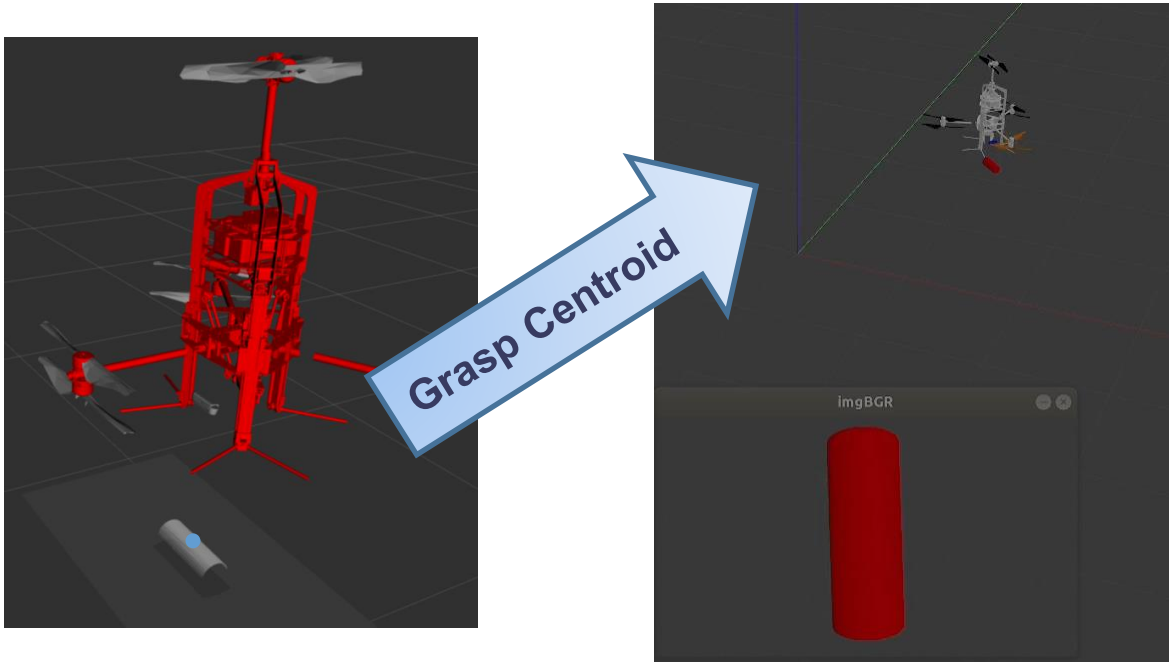
Cylinder Segmentation – Top Grasp

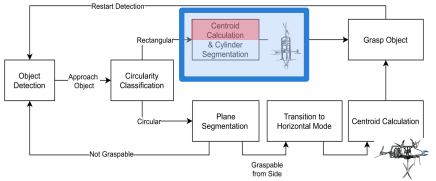






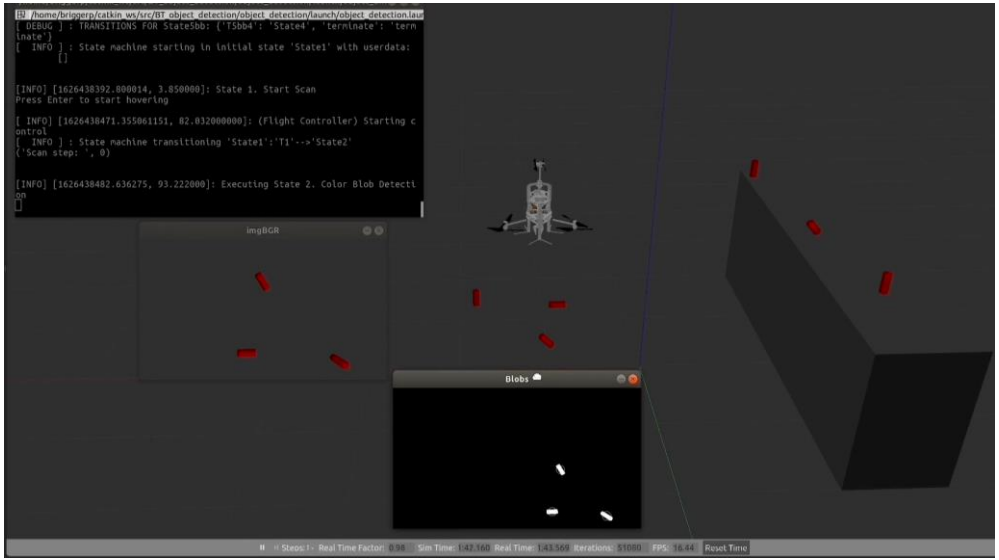
Grasp Centroid – Top Grasp



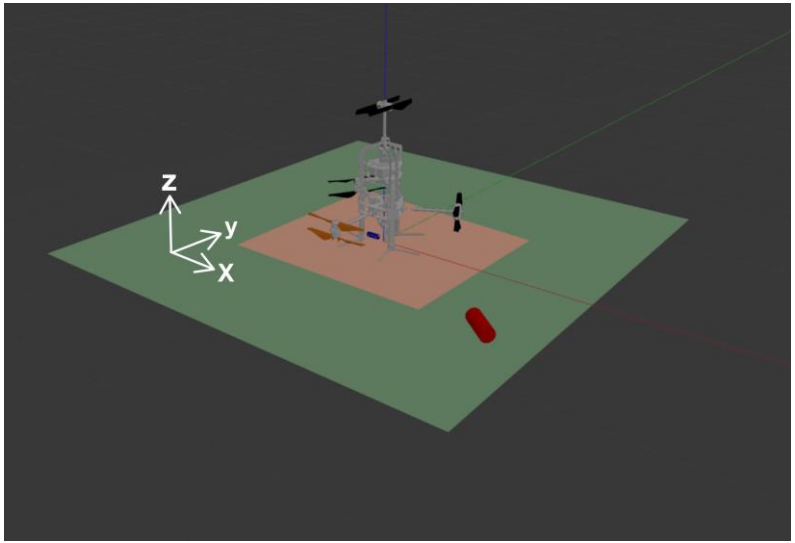


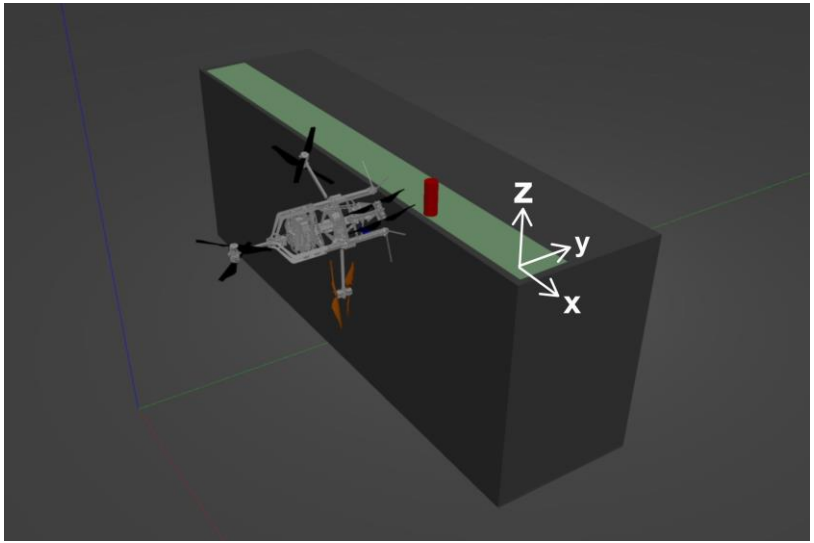
Testing & Results

- Workflow
- Precision
  - Blob Center
  - Initial Centroid
  - Grasp Centroid

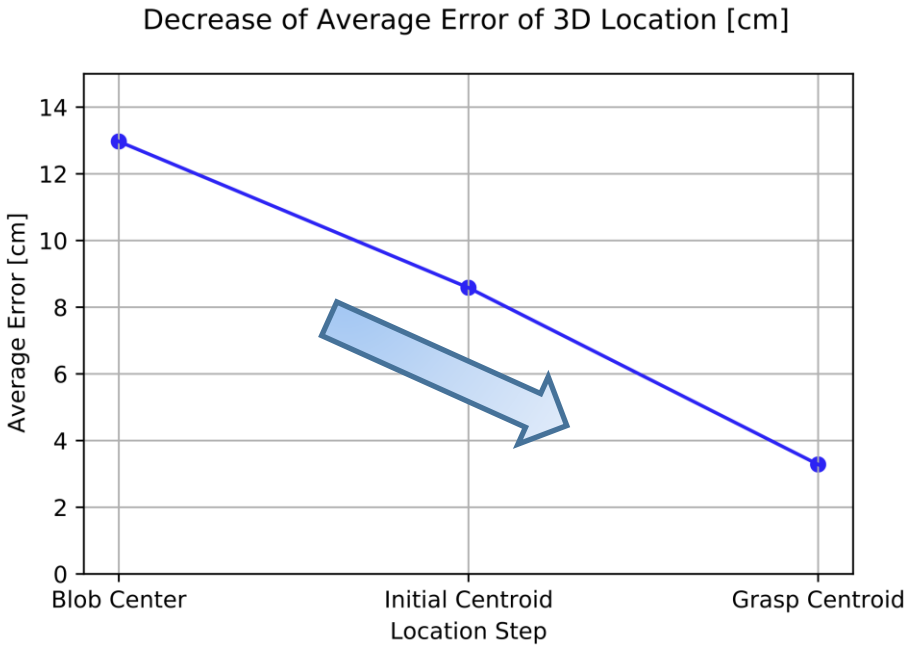


Testing & Results – Precision

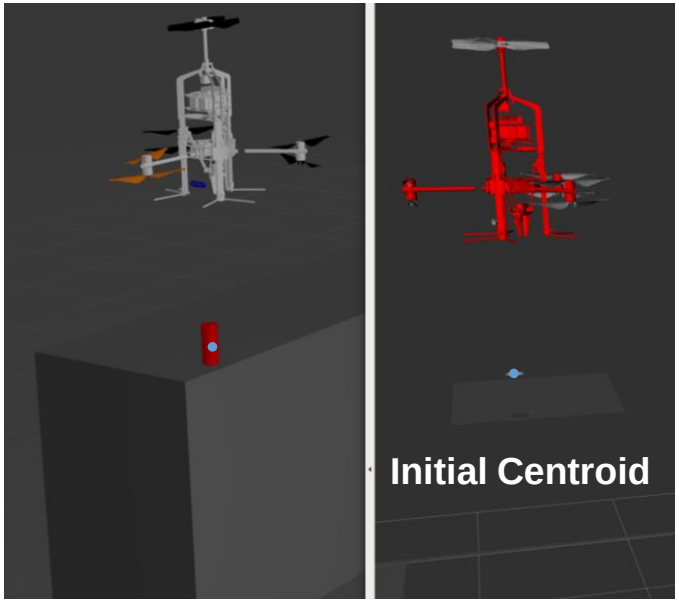


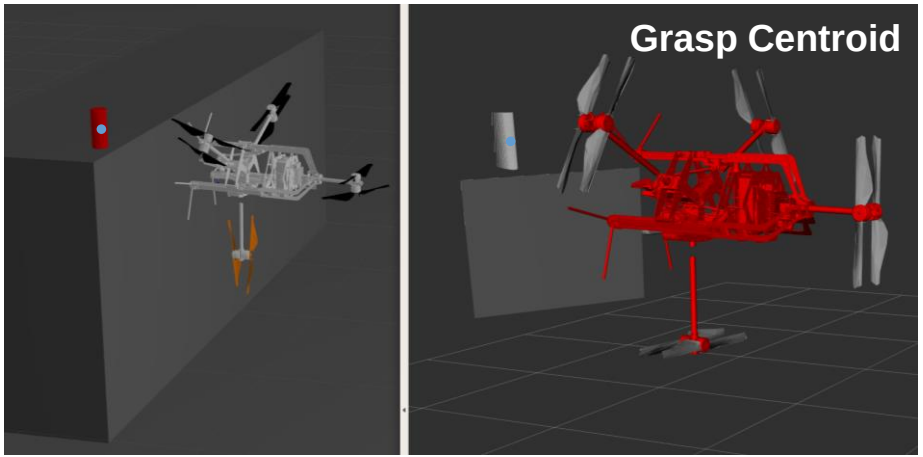


Precision – Location Error of Side Grasp

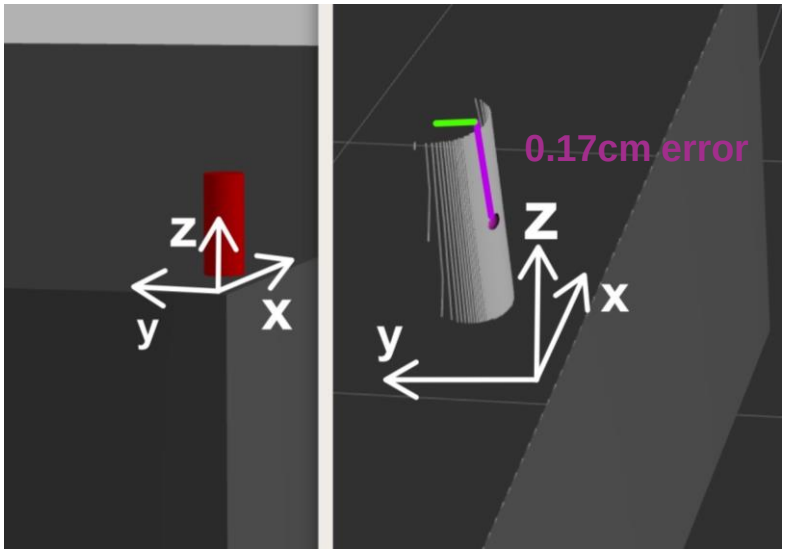


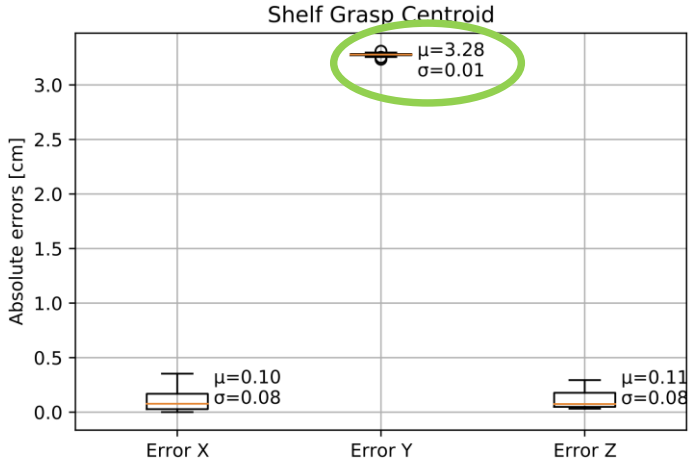
Precision – Location Error of Side Grasp





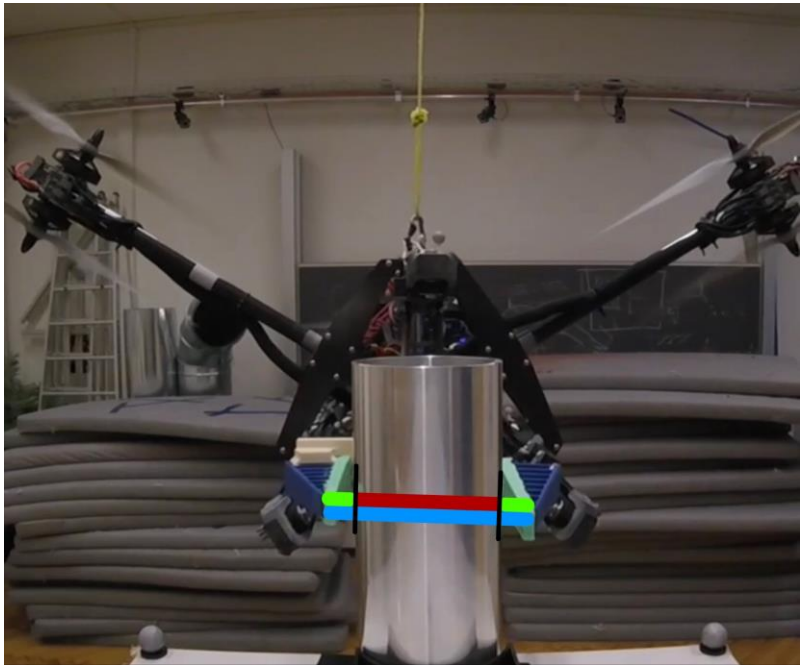
Precision – Location Error of Side Grasp



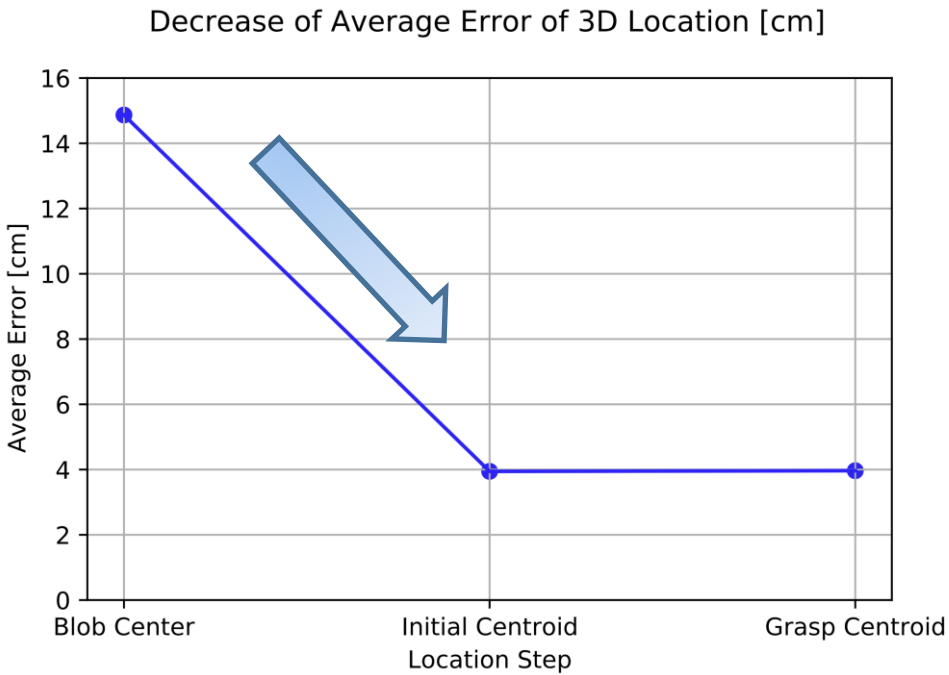


Precision – Location Error of Side Grasp

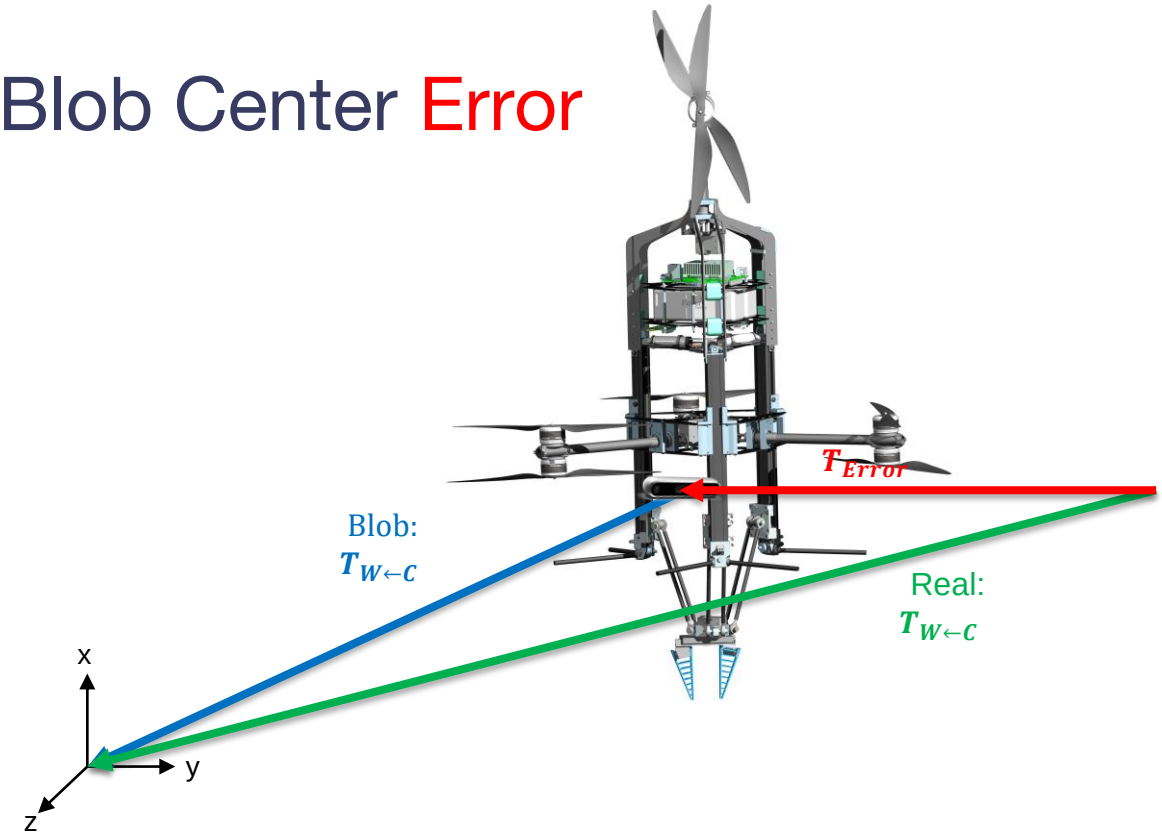
- To compensate pipeline error:
  - At least 0.5cm play in gripper opening width



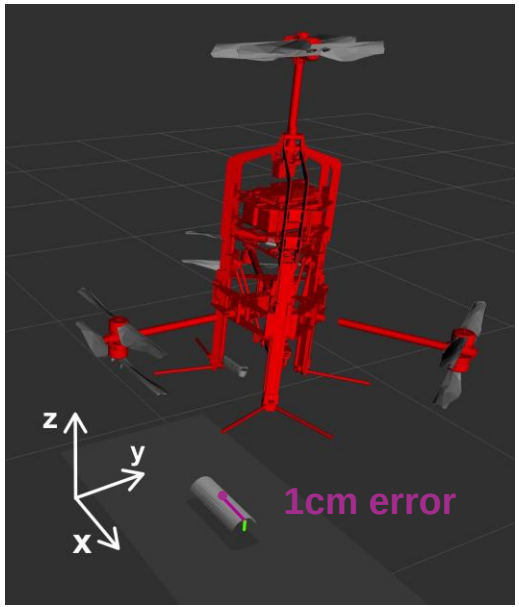
Precision – Location Error of Top Grasp

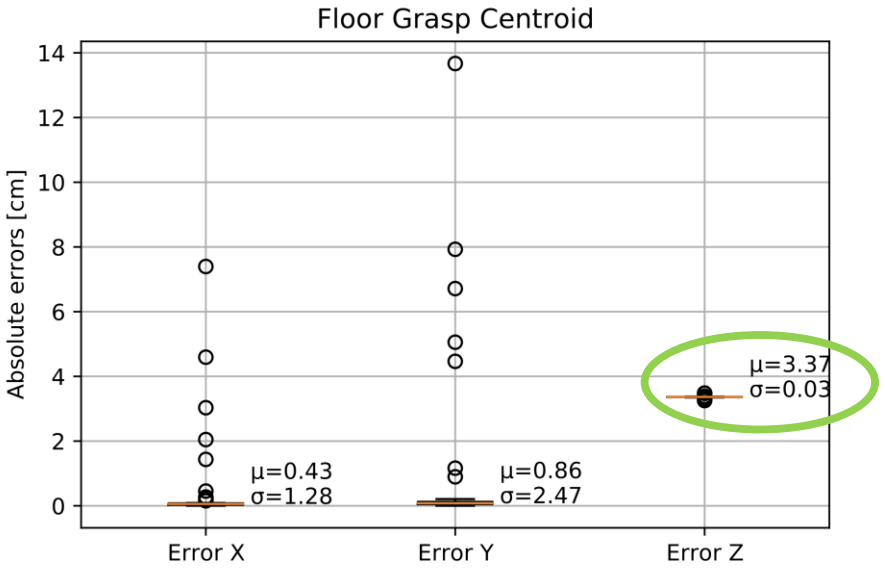


Blob Center Error



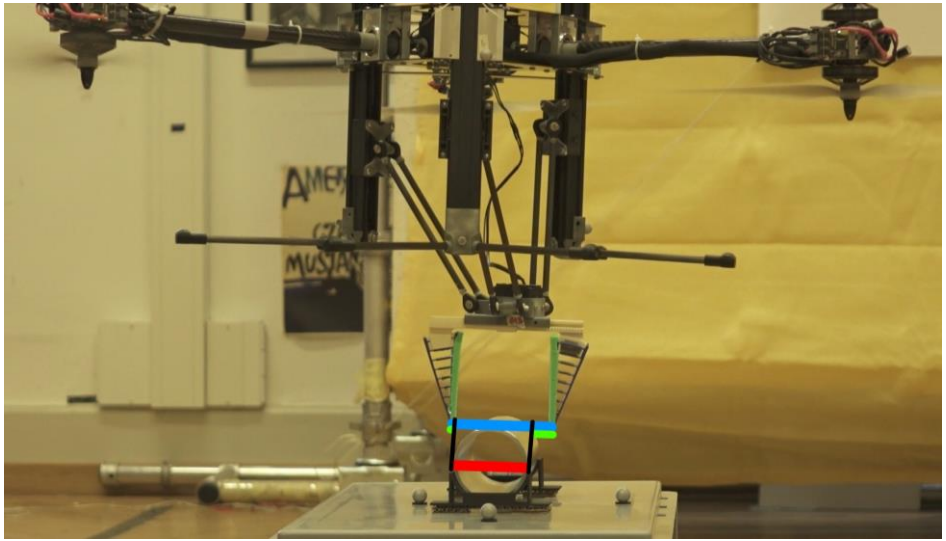
Precision – Location Error of Top Grasp



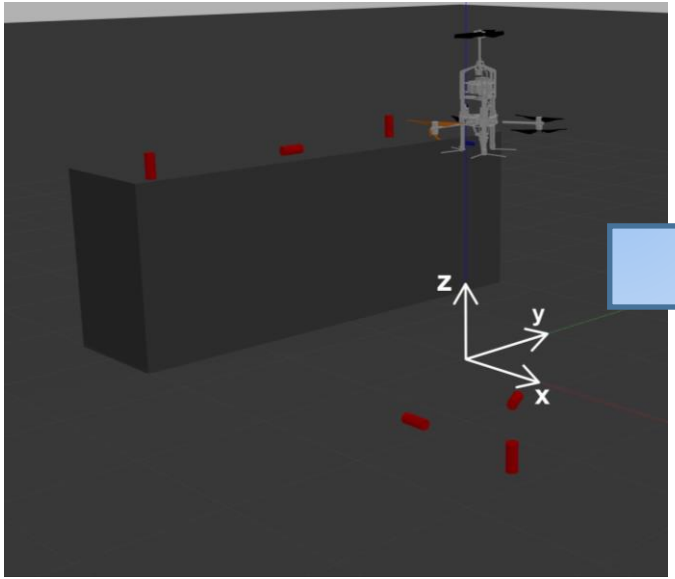


Precision – Location Error of Top Grasp

- To compensate pipeline error:
  - At least 2cm play in gripper opening width



Outlook



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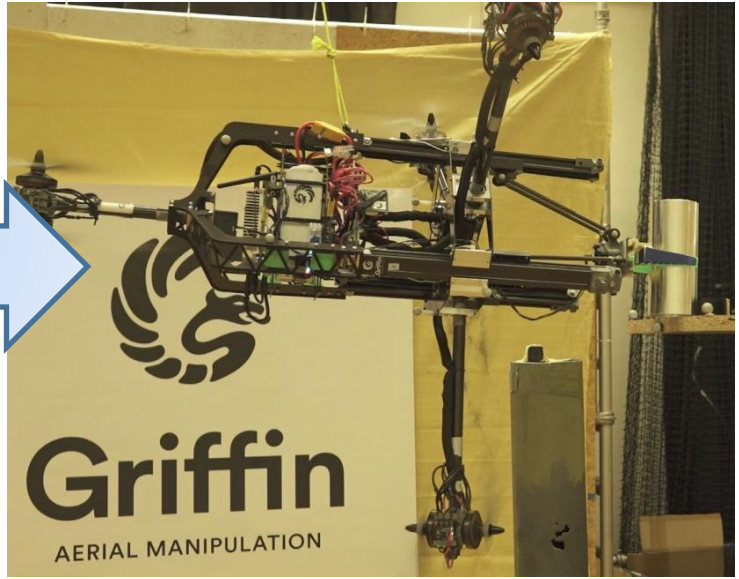
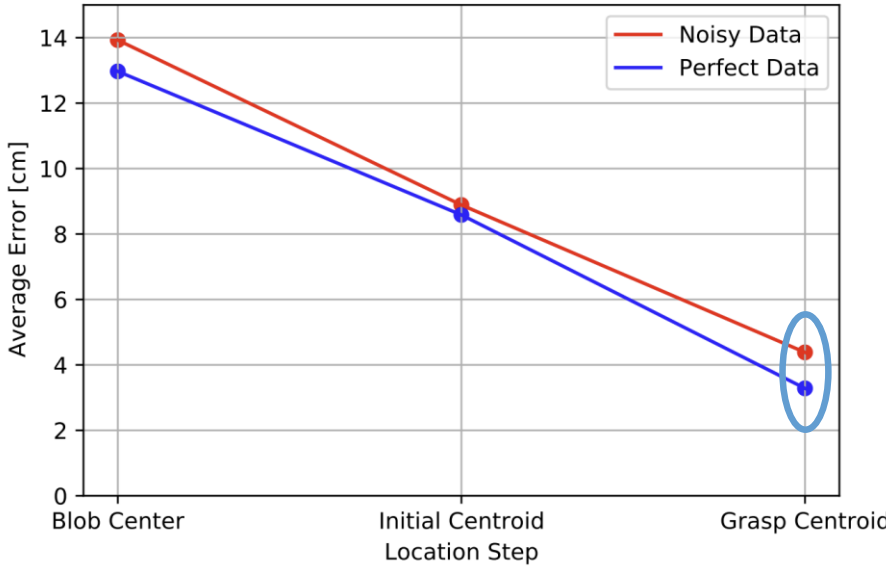
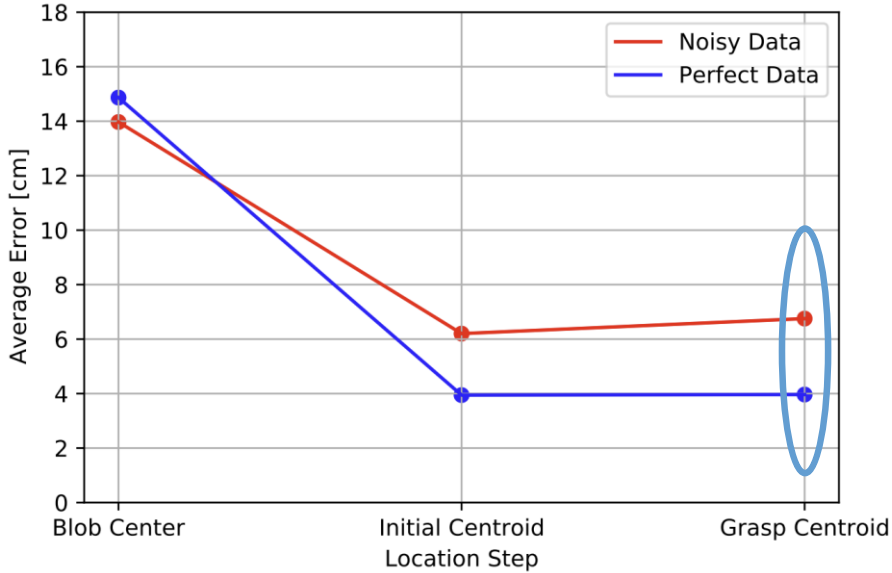


Outlook – Noisy Odometry

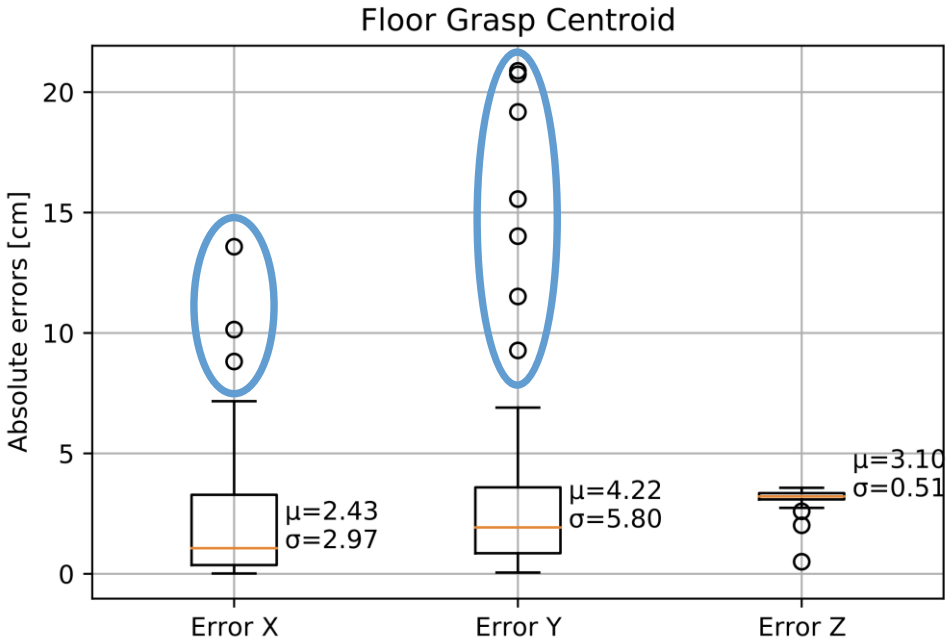
Side Grasp



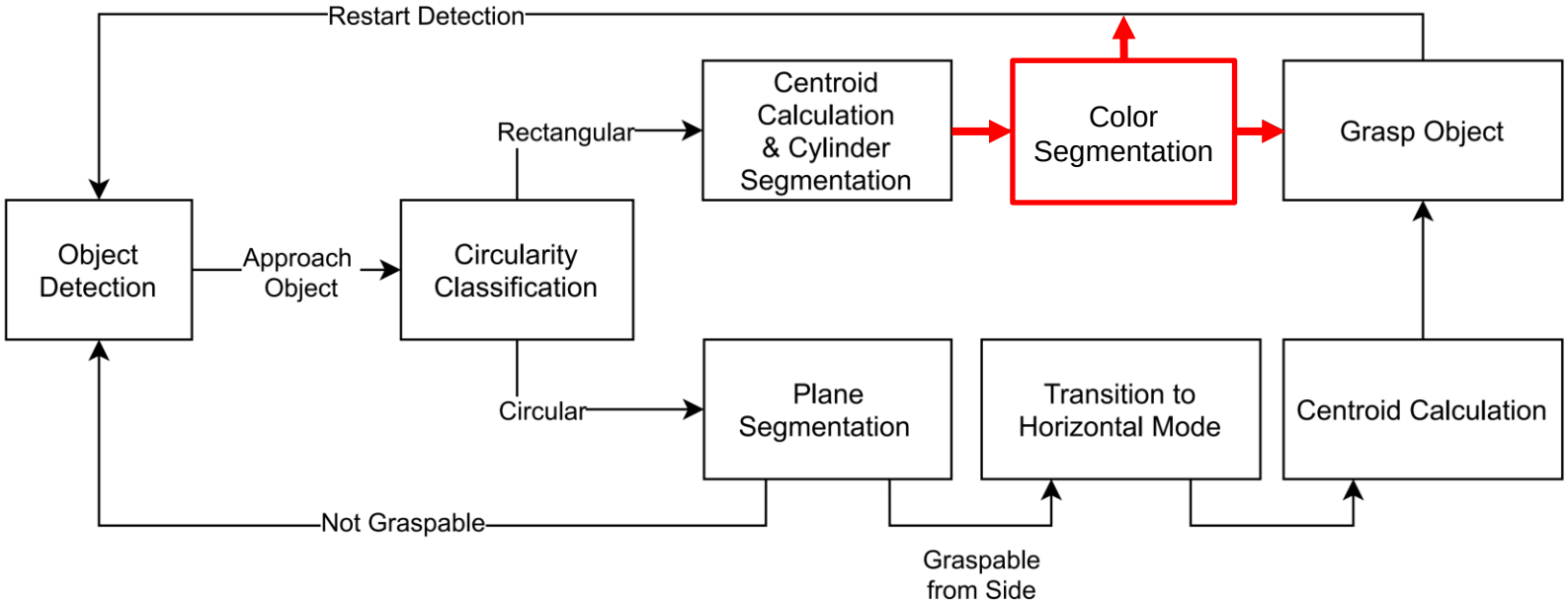
Top Grasp



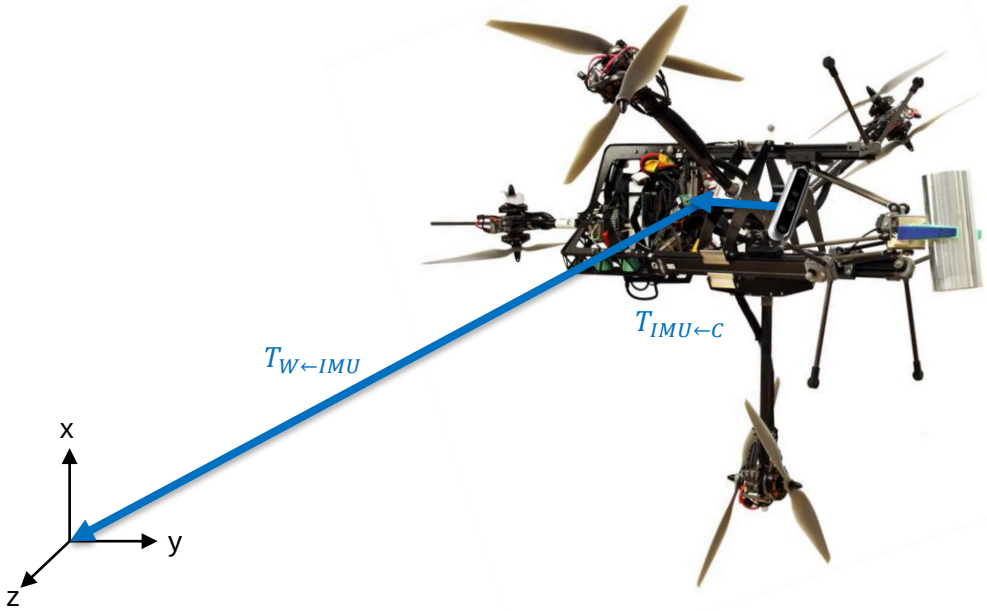
Outliers – Noisy Odometry



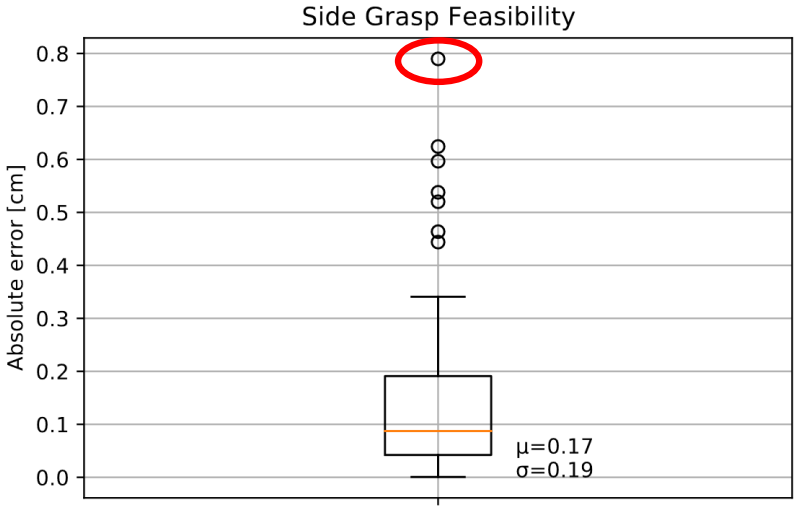
Outlook – Outlier Rejection

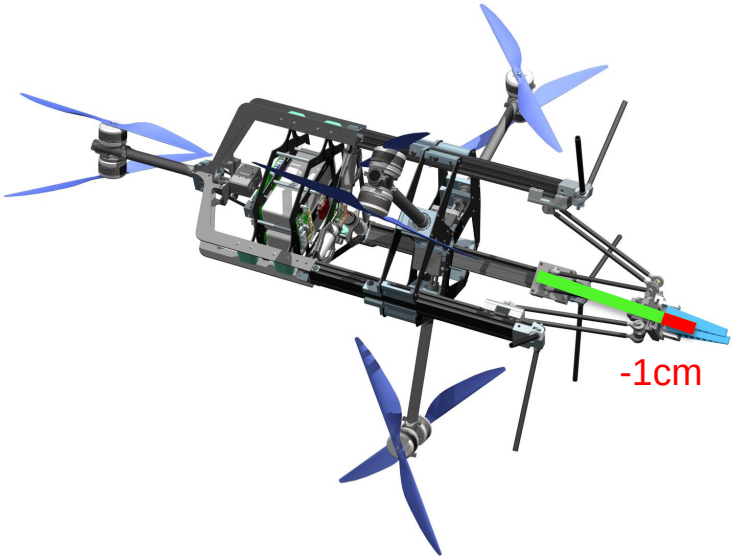


Outlook – Real World

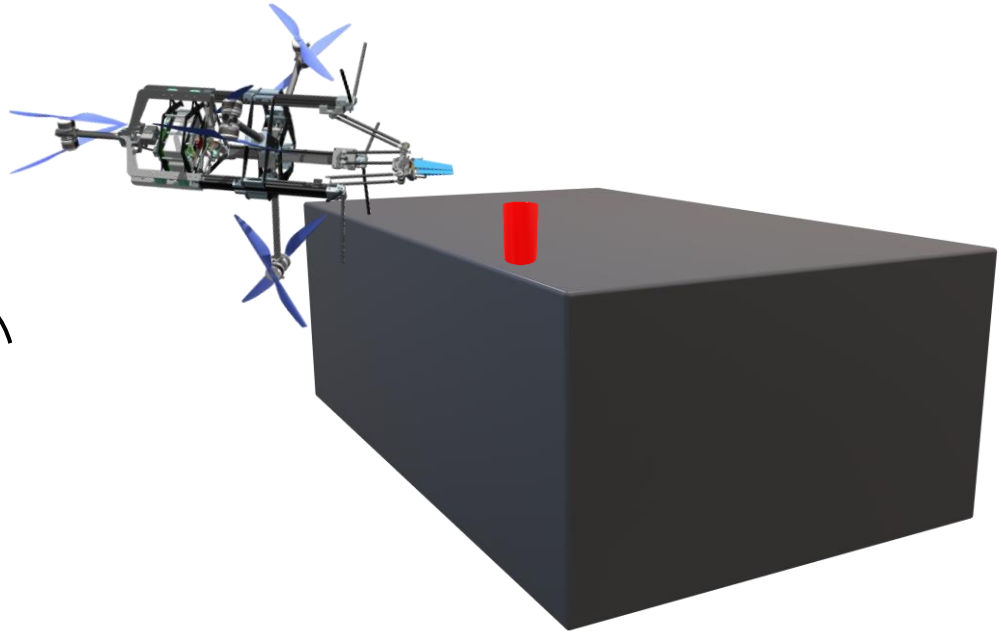


Outlook – Real World





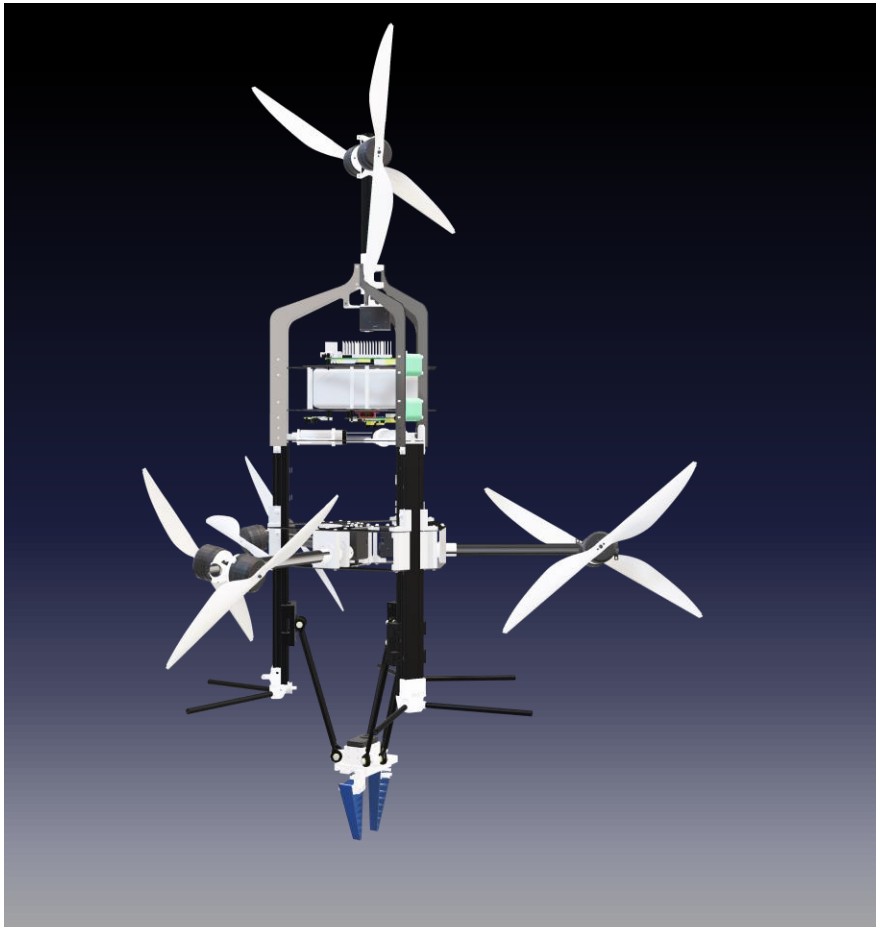
Conclusion



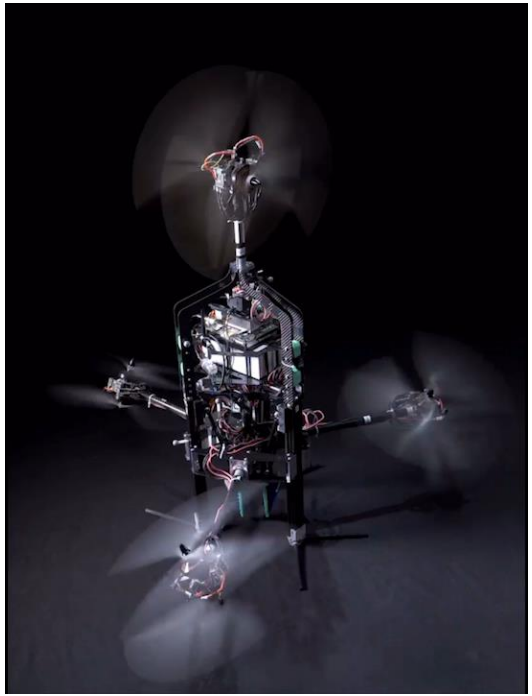
Backup Slides

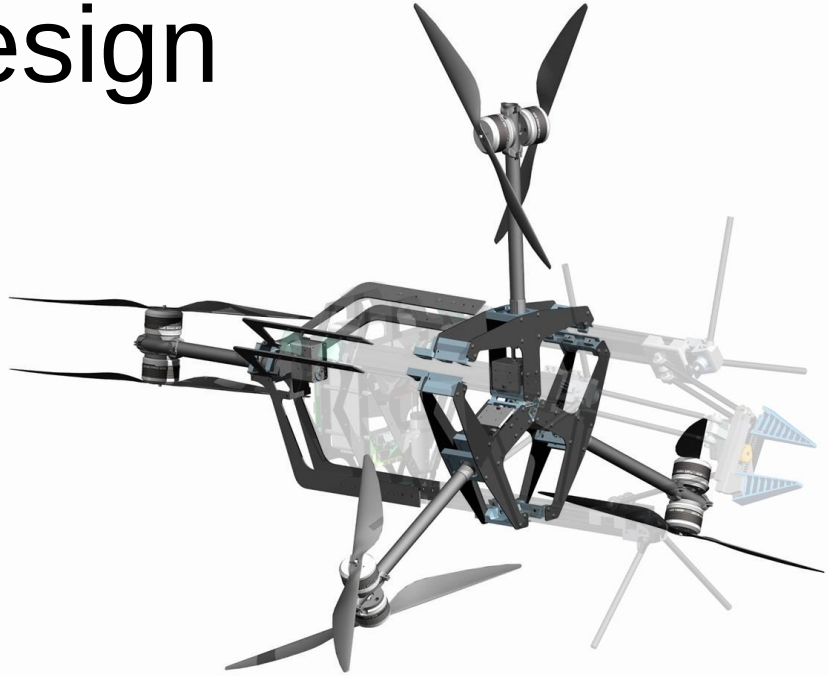
PrisMAV

Prismatic **M**icro **A**erial **V**ehicle

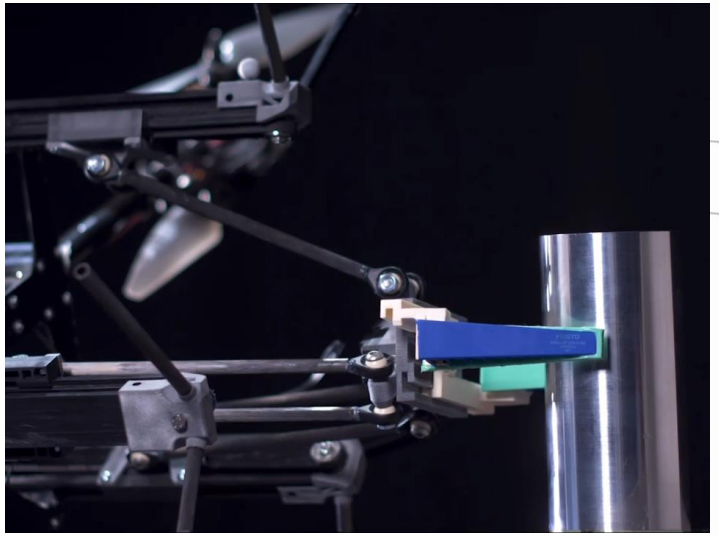


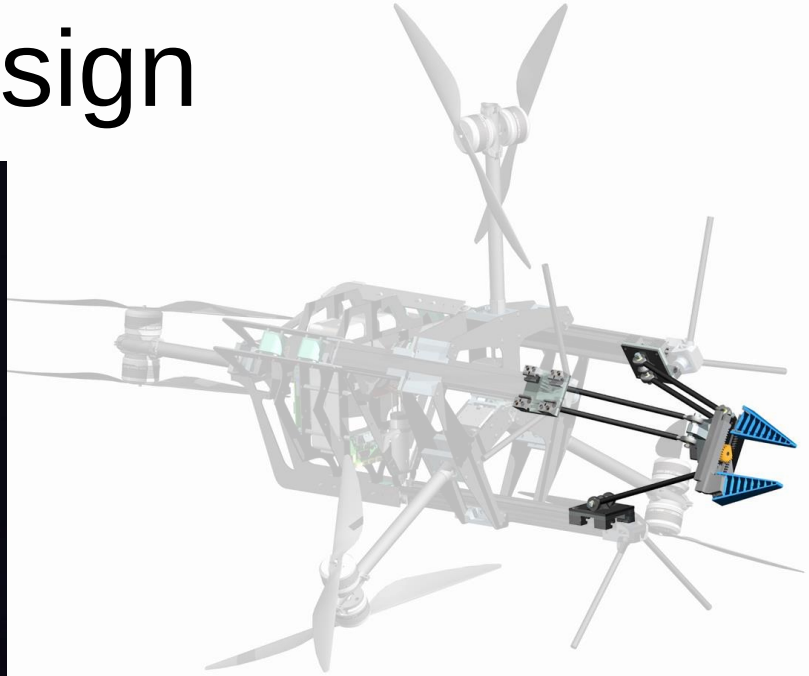
PrisMAV – Design



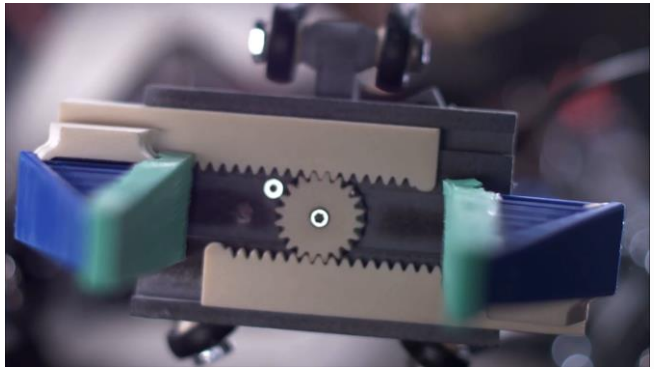


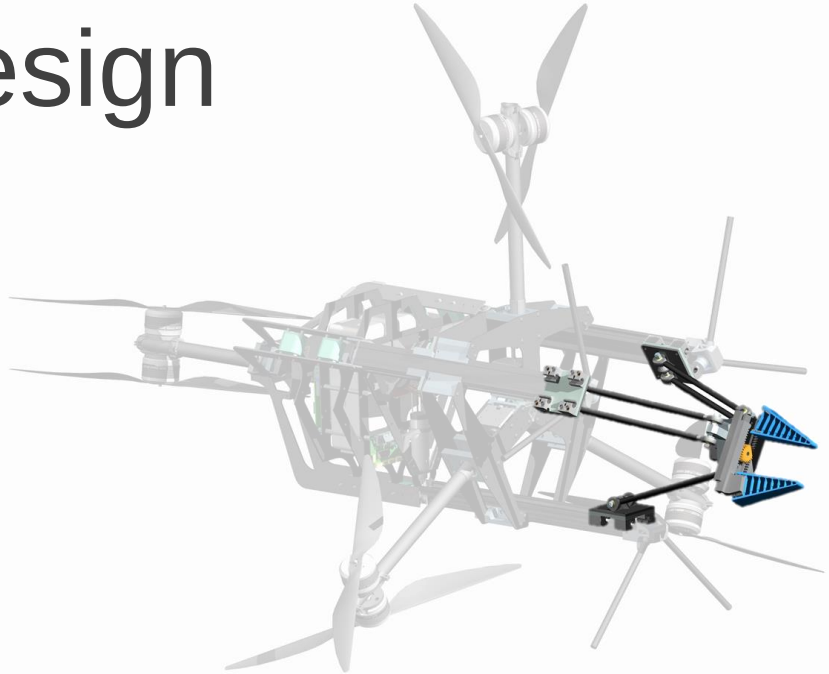
PrisMAV – Design



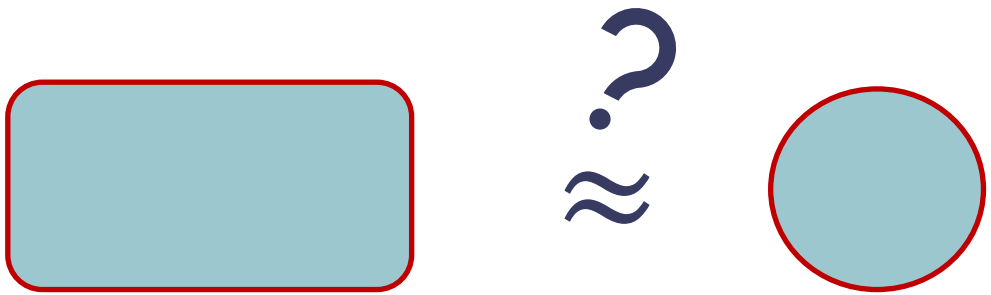


PrisMAV – Design





Circularity Classification



$$C = \frac{4\pi * A}{P * P}$$

Circularity Classification

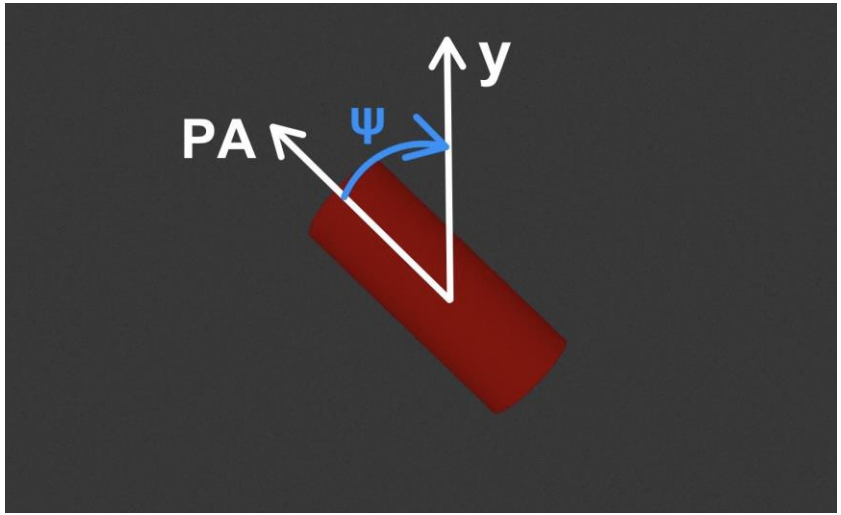
- $C = \frac{4\pi * A}{P * P}$
- Threshold Value: Rectangle area and perimeter with l = 0.2m and w = 0.08m

  $\Rightarrow C_{rec} = \frac{4\pi * l * w}{(2l+2w)^2} = 0.64$

  Safety Factor: $\boldsymbol{C_{max}} = 1.25 * C_{rec} = \mathbf{0.8}$

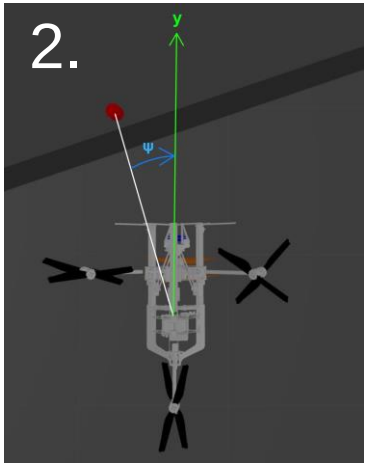
Cylinder Segmentation

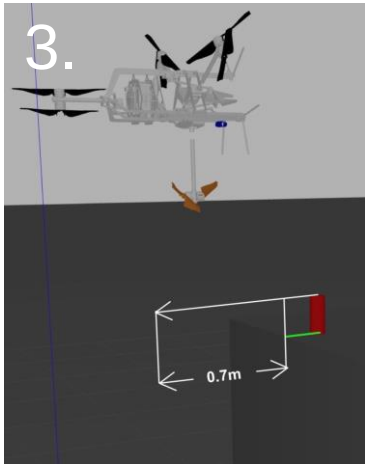
- Adapt yaw angle ψ
- Principal Axis PA
- Camera axis y
- $\psi = \cos^{-1}\left(\frac{PA \cdot y}{\|PA\| \cdot \|y\|}\right)$



Transition

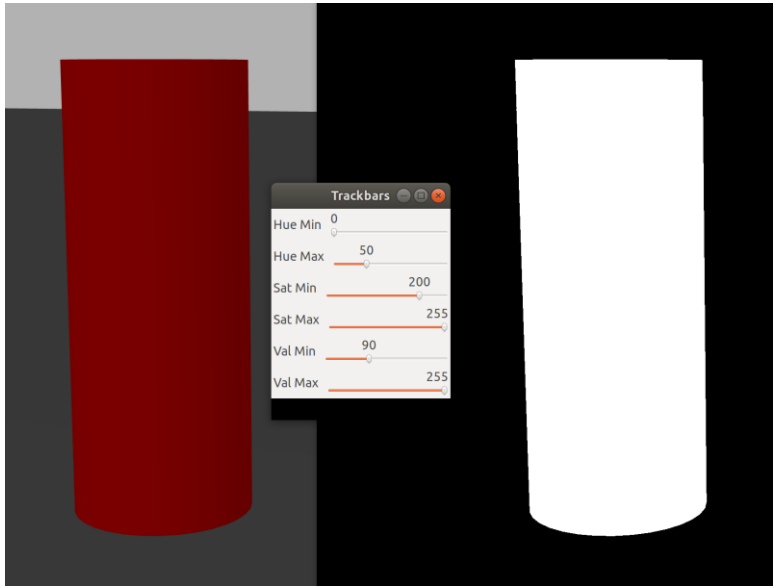
1. Roll by 90 degrees
2. Adapt yaw angle
3. Approach grasp position





Color Segmentation

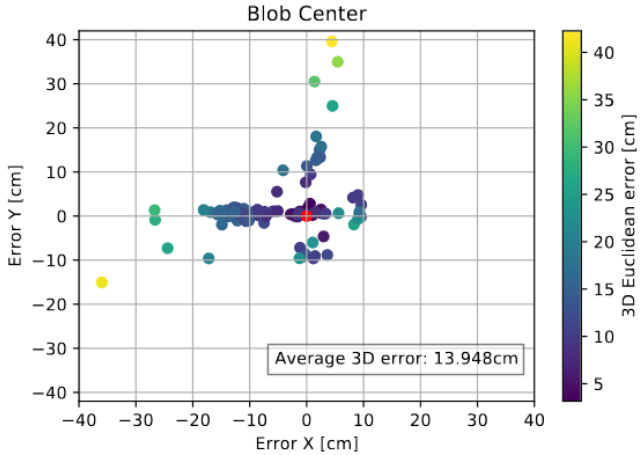
- Adapt threshold values
  => Binary mask



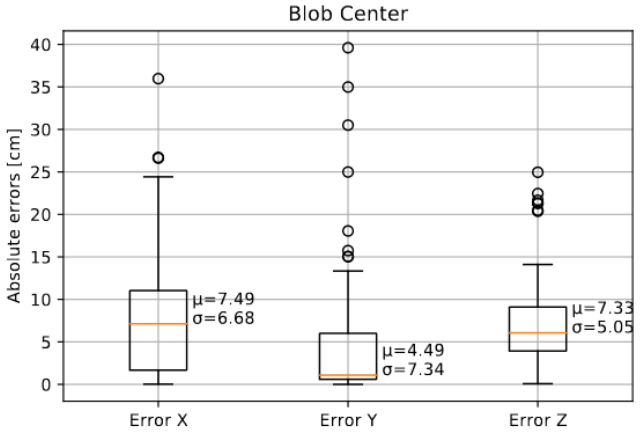
Computational Effort

Pipeline Step	**Computational Time [s]**	**Relative Time [%]**
Color Segmentation	0.15	9.3
Centroid Calculation	0.01	0.6
Circularity Classification	0.15	9.3
Cylinder Segmentation	1.3	80.2
Plane Segmentation	0.01	0.6
Overall	**1.62**	**100.0**

Blob Center Location Error

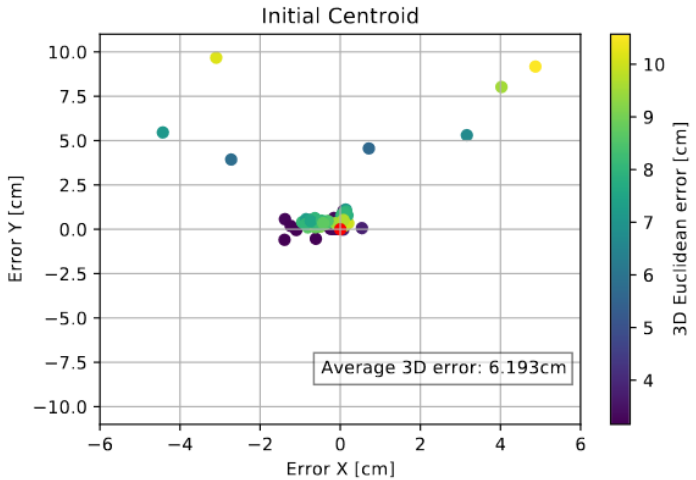


(a) Location error in xy-plane.

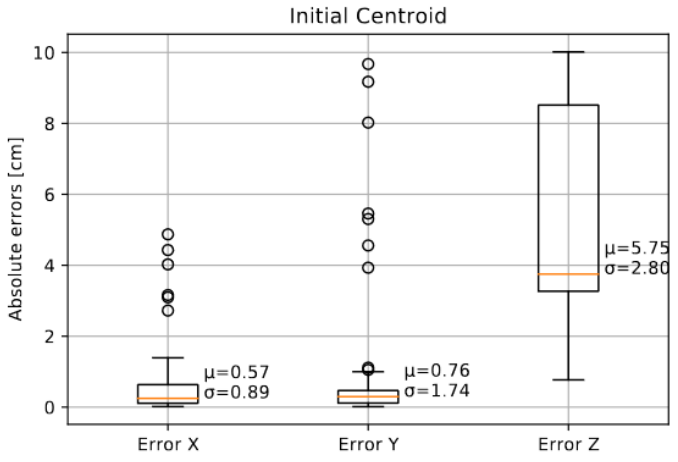


(b) Box plot with absolute errors in x, y and z location

Initial Centroid Location Error

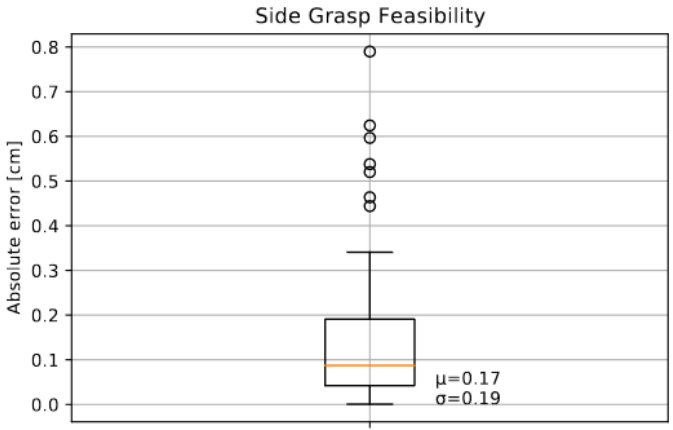


(a) Location error in xy-plane.

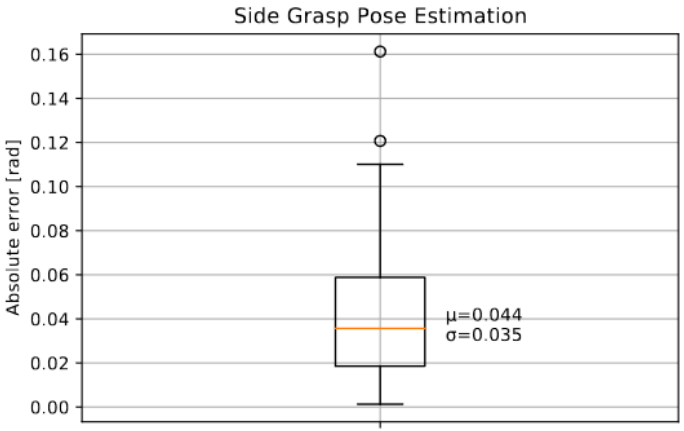


(b) Box plot with absolute errors in x, y and z location

Plane Segmentation Error



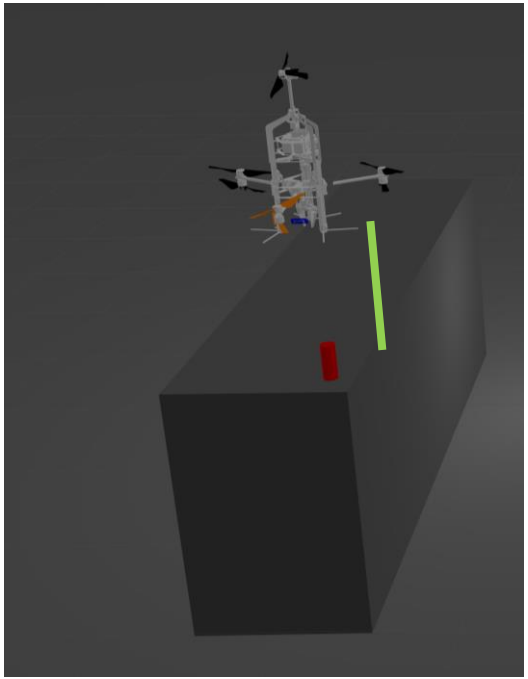
(a) Average error for distance from object center to plane edge used for side grasp feasibility



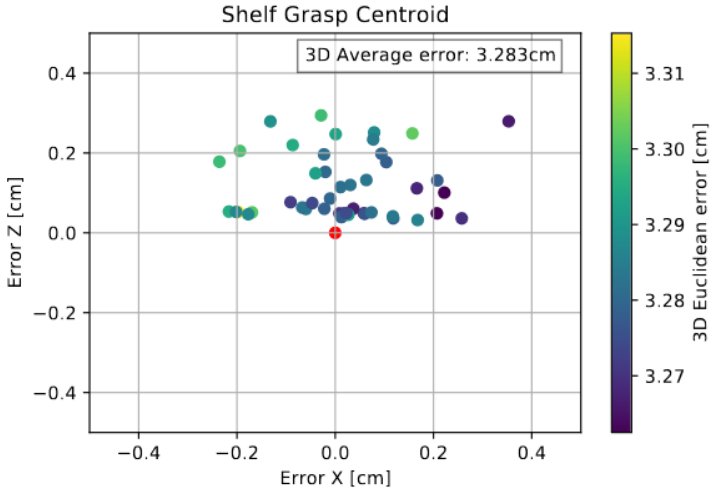
(b) Average error for angle between constructed line and reference frame used for side grasp pose

Plane Segmentation

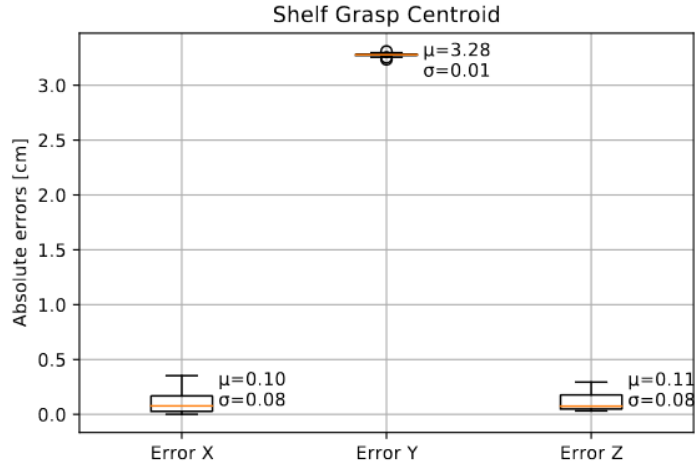
- Threshold Value for plane segmentation
  - Flight height
- Create binary mask
- Find contours



Grasp Centroid Side Grasp

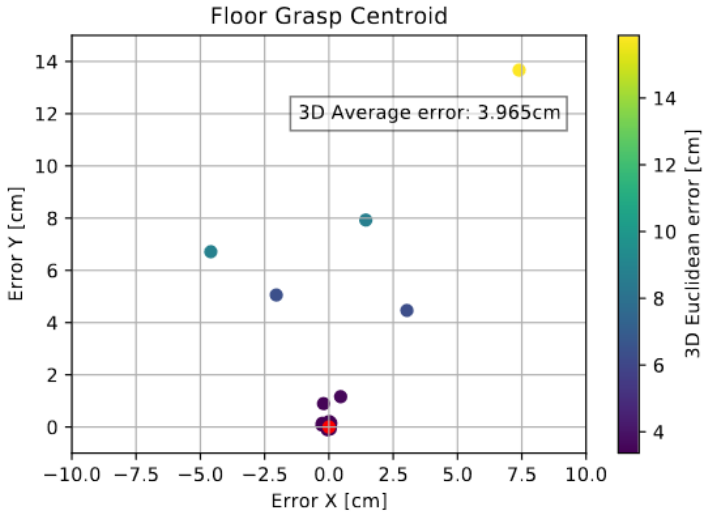


(a) Location error in xz-plane.

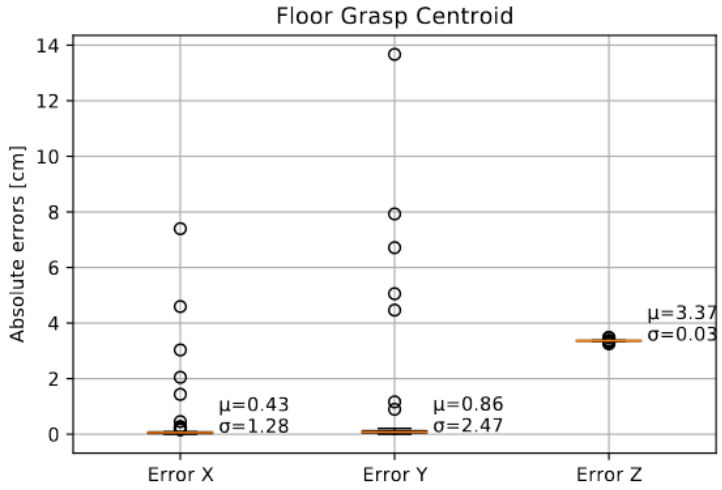


(b) Box plot with absolute errors in x, y and z location

Grasp Centroid Top Grasp



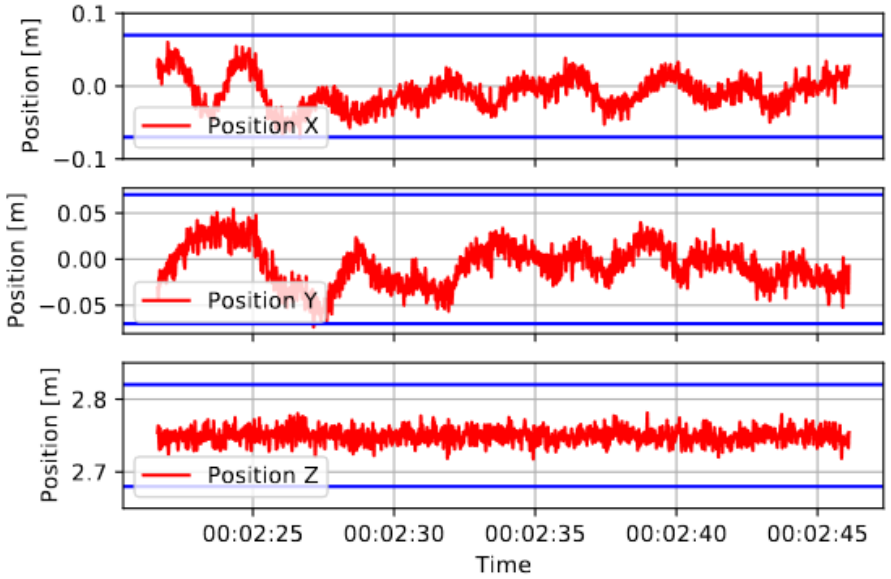
(a) Location error in xy-plane.



(b) Box plot with absolute errors in x, y and z location

Noise Replication

- +/- 7cm



Error Developement Top Grasp without Outliers

2D:

Data	Blob Center Error	Initial Centroid Error	Grasp Centroid Error
Perfect	10.93cm	1.36cm	0.99cm
Noisy	13.08cm	4.26cm	2.29cm
Δ	+19.7%	+213.2%	+131.3%

3D:

Data	Blob Center Error	Initial Centroid Error	Grasp Centroid Error
Perfect	14.87cm	3.95cm	3.97cm
Noisy	15.50	5.42cm	4.12cm
Δ	+4.2%	+37.2%	+3.8%

Error Developement Top Grasp

2D:

Data	Blob Center Error	Initial Centroid Error	Grasp Centroid Error
Perfect	10.93cm	1.36cm	0.99cm
Noisy	11.79cm	5.16cm	5.27cm
Δ	+7.9%	+279.4%	+432.3%

3D:

Data	Blob Center Error	Initial Centroid Error	Grasp Centroid Error
Perfect	14.87cm	3.95cm	3.97cm
Noisy	13.97cm	6.20cm	6.75cm
Δ	-6.1%	+57.0%	+70.0%

Error Developement Side Grasp

2D:

Data	Blob Center Error	Initial Centroid Error	Grasp Centroid Error
Perfect	11.74cm	8.57cm	0.17cm
Noisy	11.60cm	8.68cm	2.19cm
Δ	-1.2%	+1.3%	+1188.2%

3D:

Data	Blob Center Error	Initial Centroid Error	Grasp Centroid Error
Perfect	12.97cm	8.58cm	3.28cm
Noisy	13.93cm	8.89cm	4.38cm
Δ	+7.4%	+3.6%	+33.5%

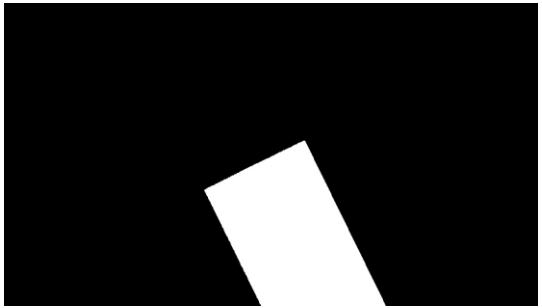
Floor Grasp Centroid Outliers

- Error from blob center propagates to grasp centroid approximation

Blob Center

Initial Centroid

Grasp Centroid



Cylinder Model Fitting

- Random Sample and Consensus Approach (RANSAC)