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forward together · saam vorentoe · masiye phambili

Control in Uncertainty

Creating Autonomous Vehicles in a Dynamic World

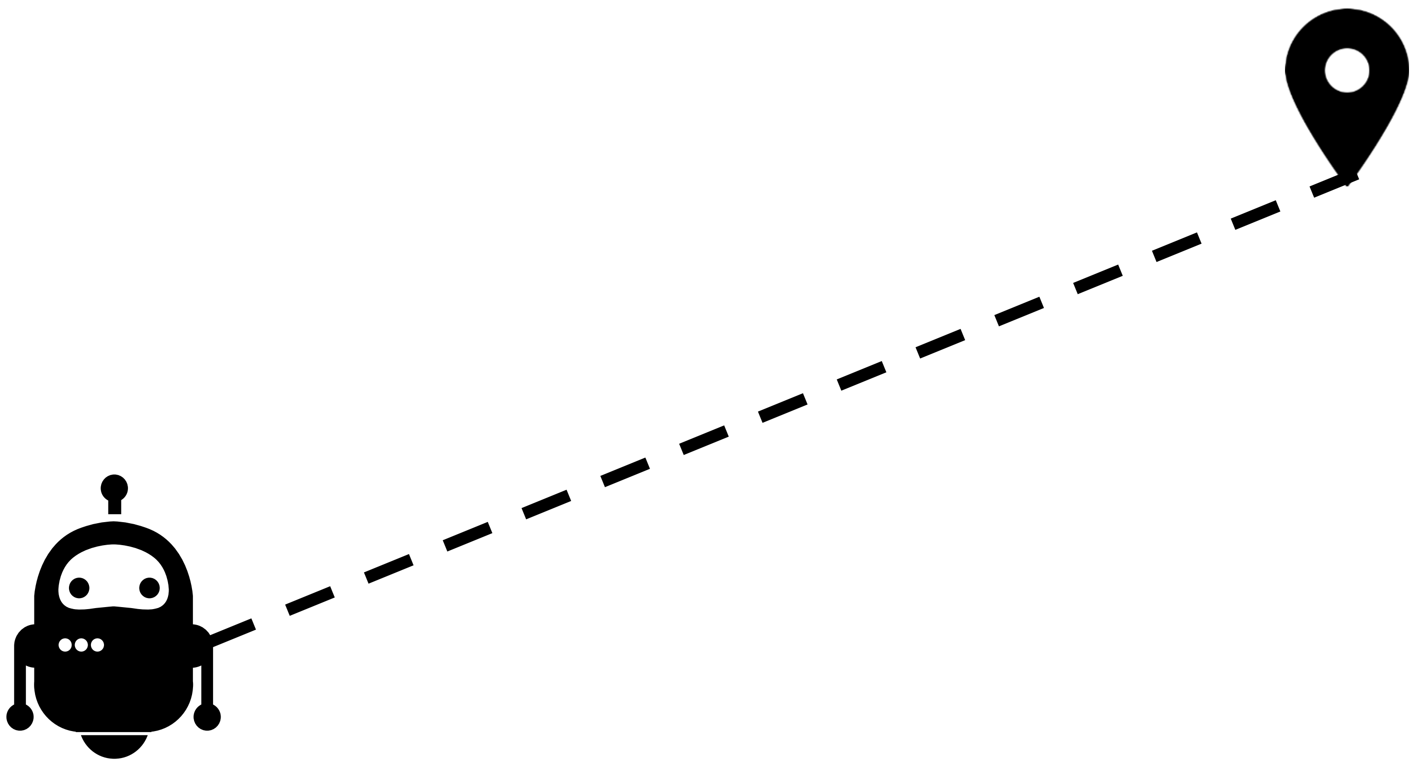
07 June 2019

The Control Problem

Objective = Robot needs to reach the goal

The Control Problem

Objective = Robot needs to reach the goal



The Control Problem

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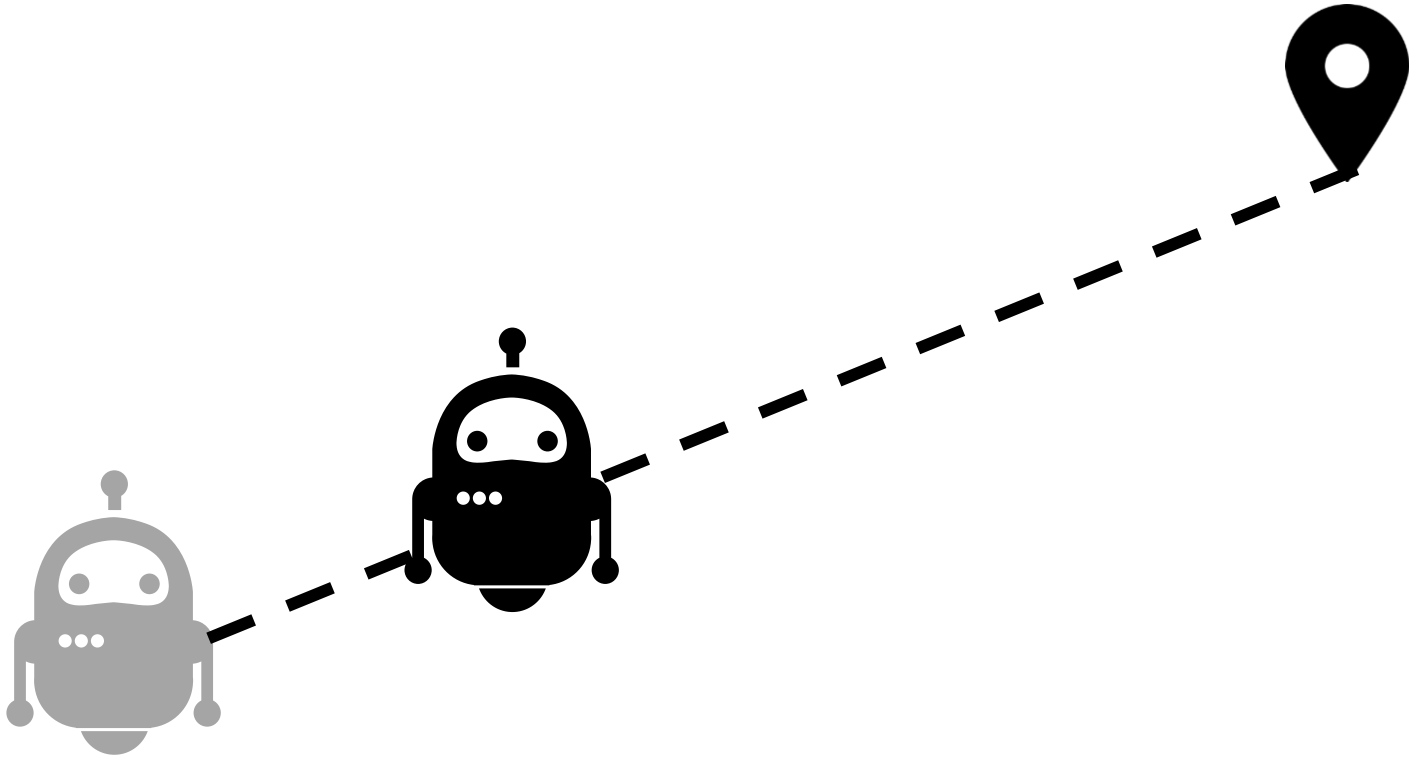

The Control Problem

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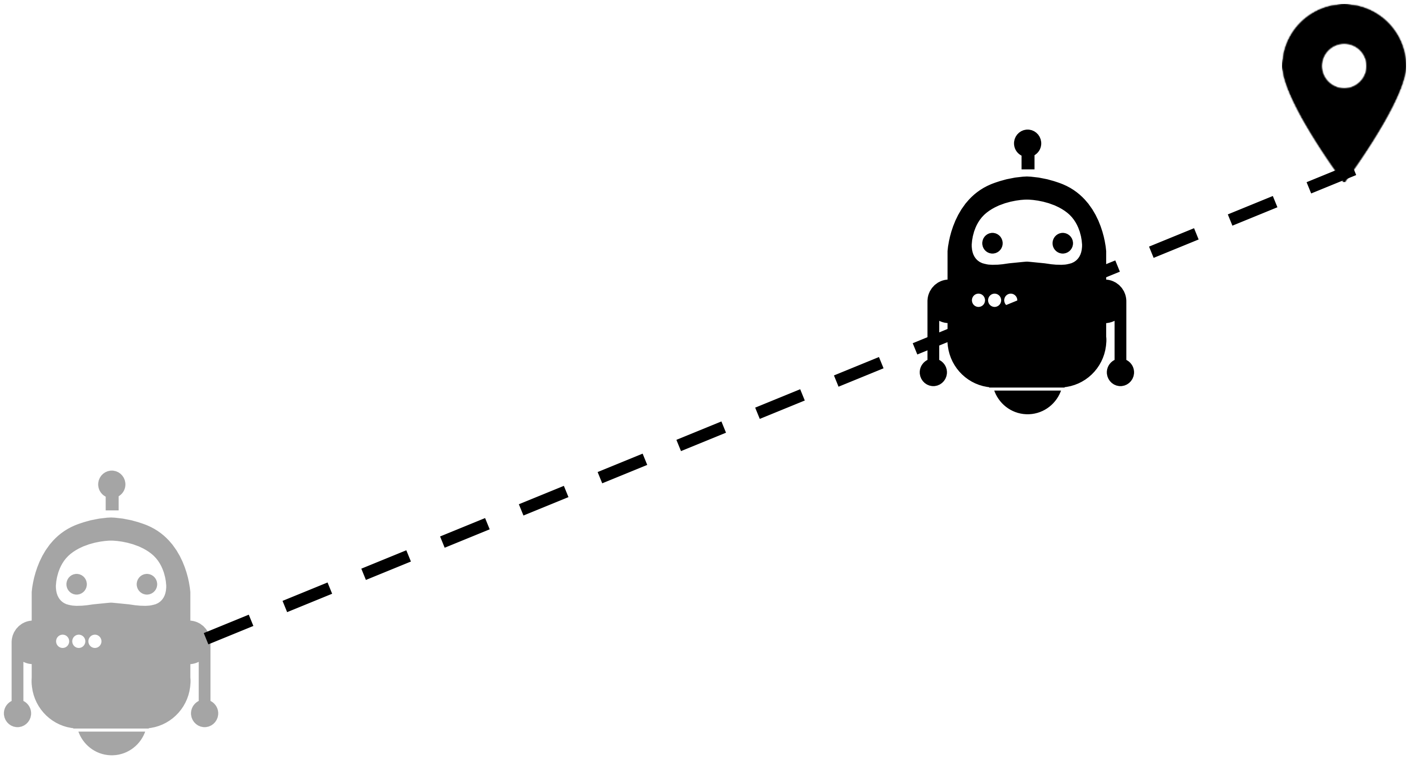
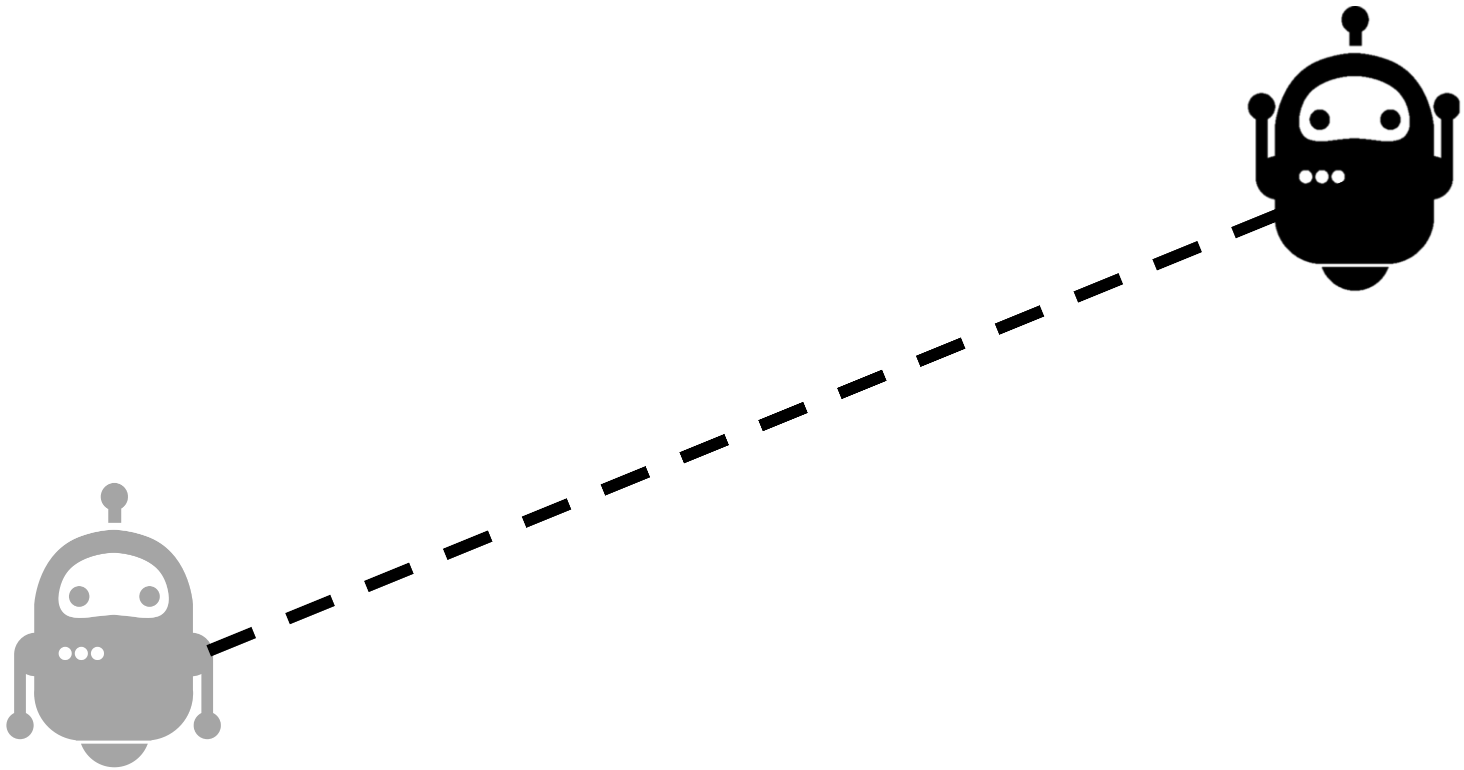


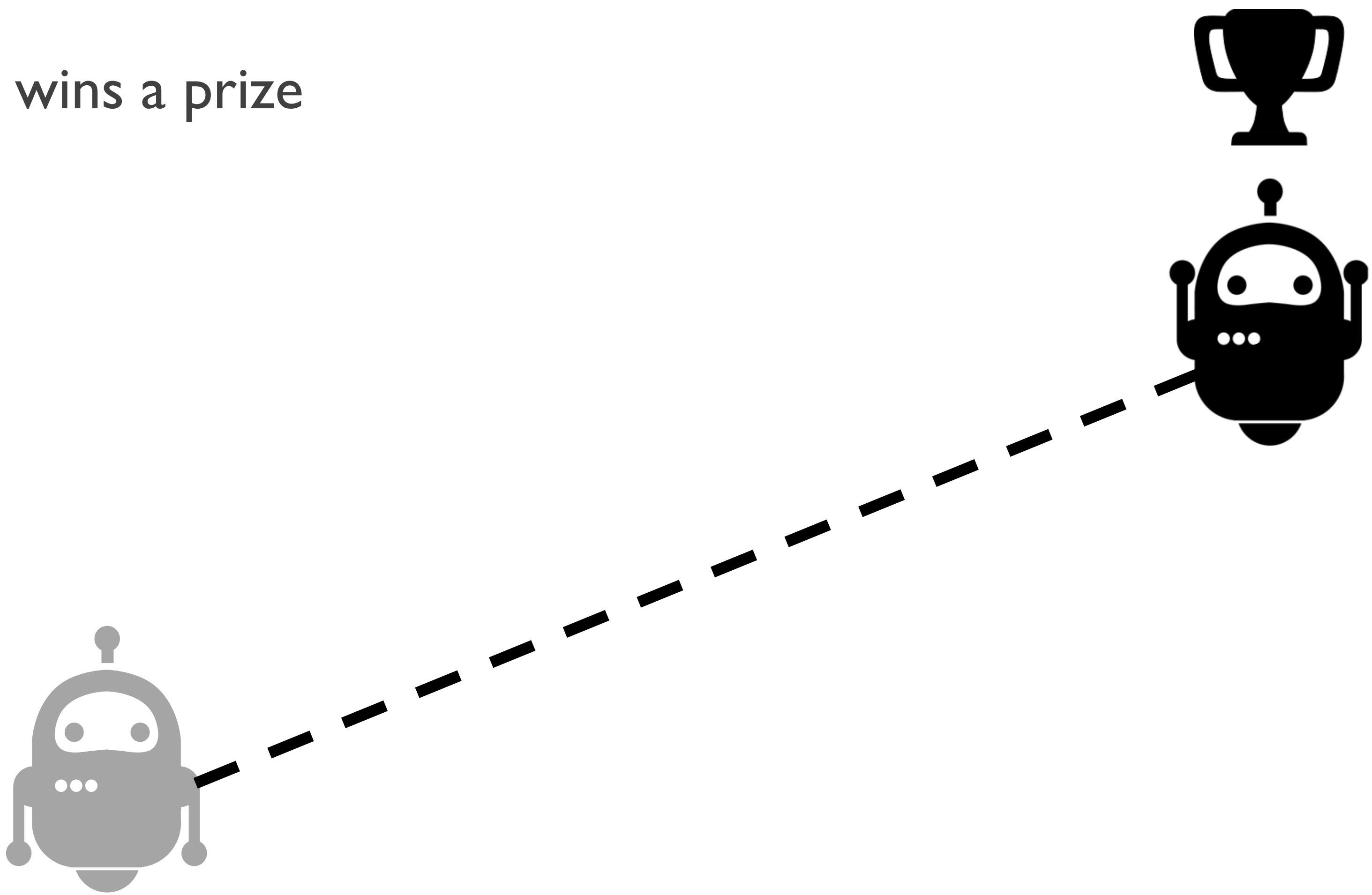
The Control Problem

Robot reached the goal



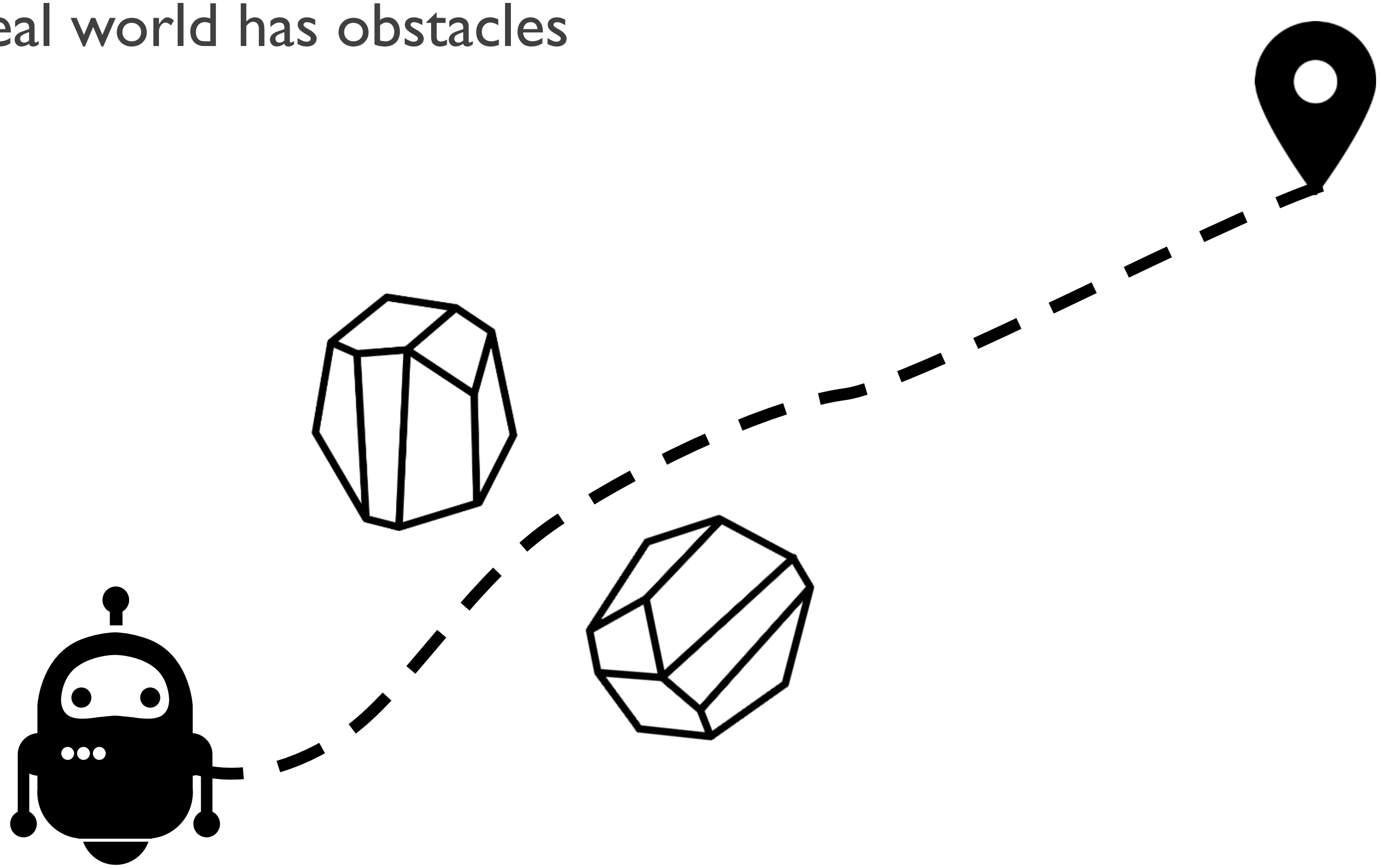
The Control Problem

Robot wins a prize



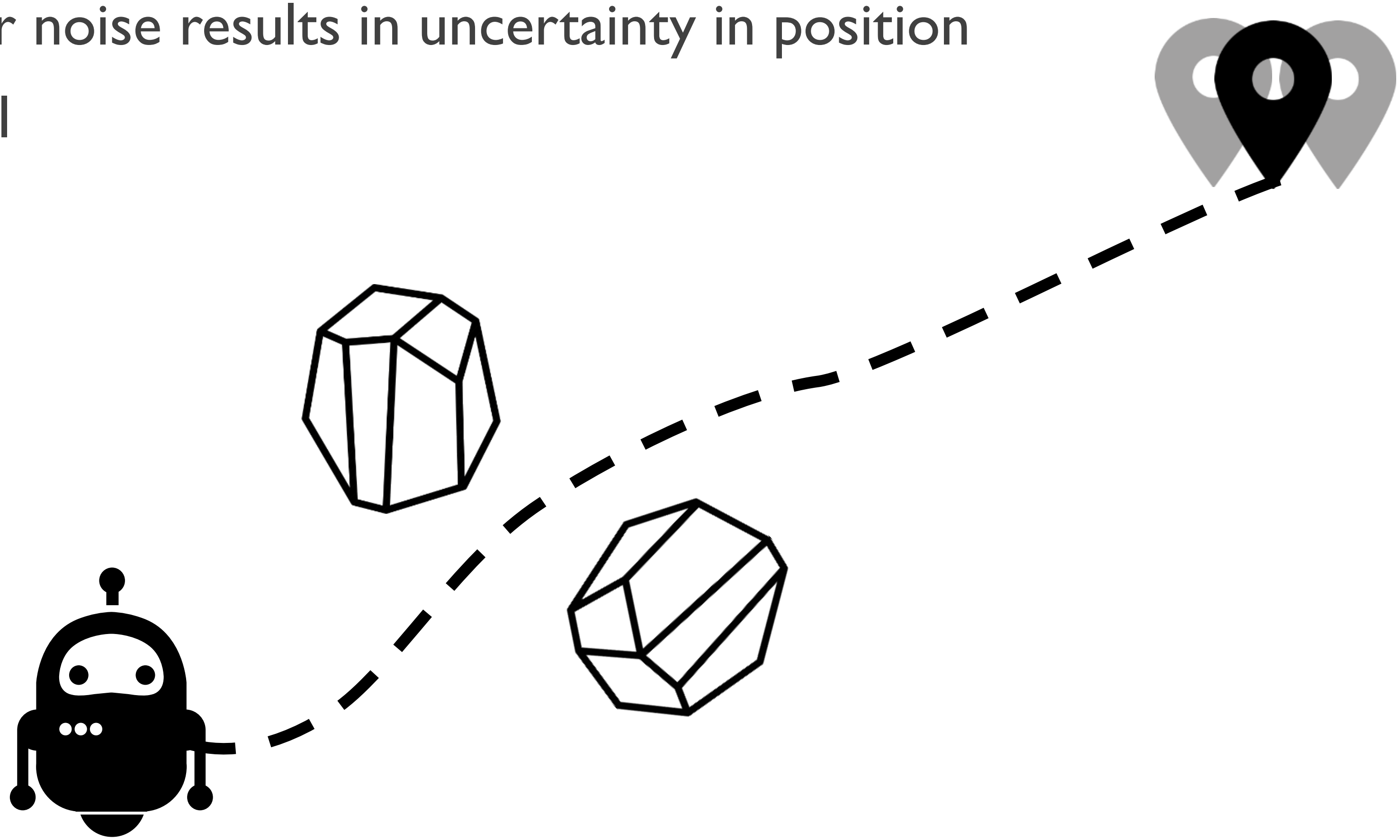
The **Real** Control Problem

The real world has obstacles



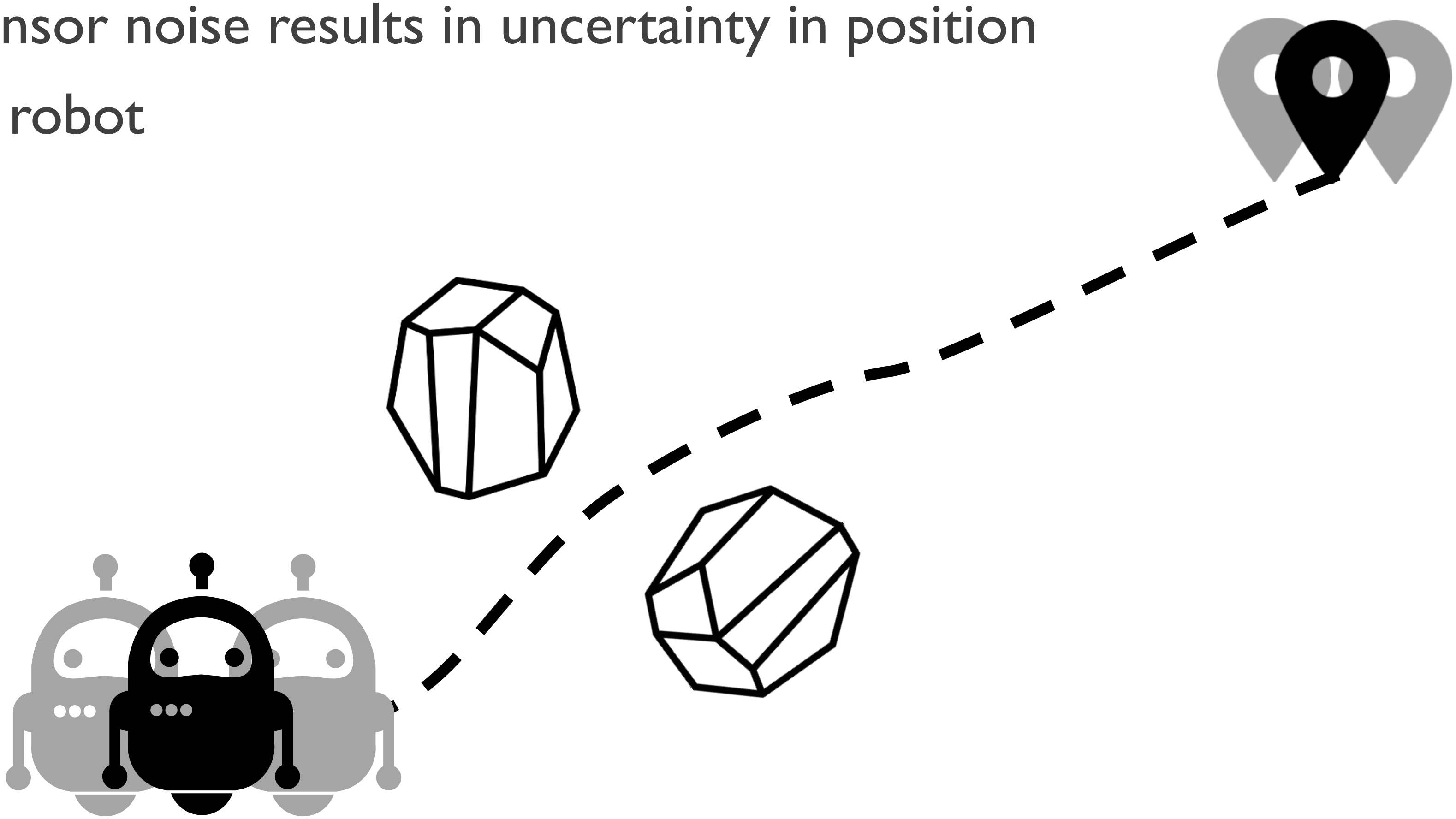
The **Real** Control Problem

Sensor noise results in uncertainty in position of goal



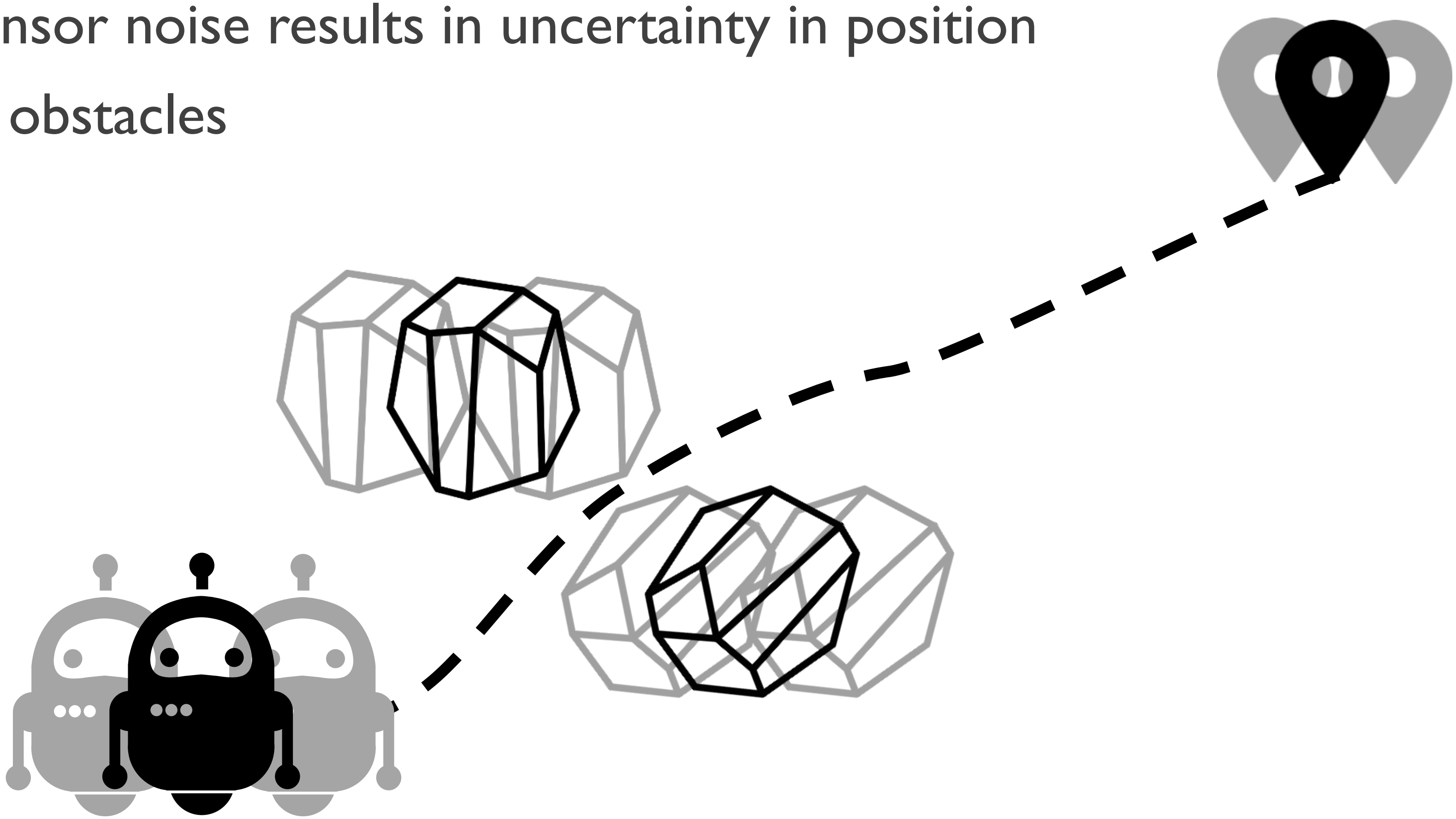
The **Real** Control Problem

Sensor noise results in uncertainty in position of robot



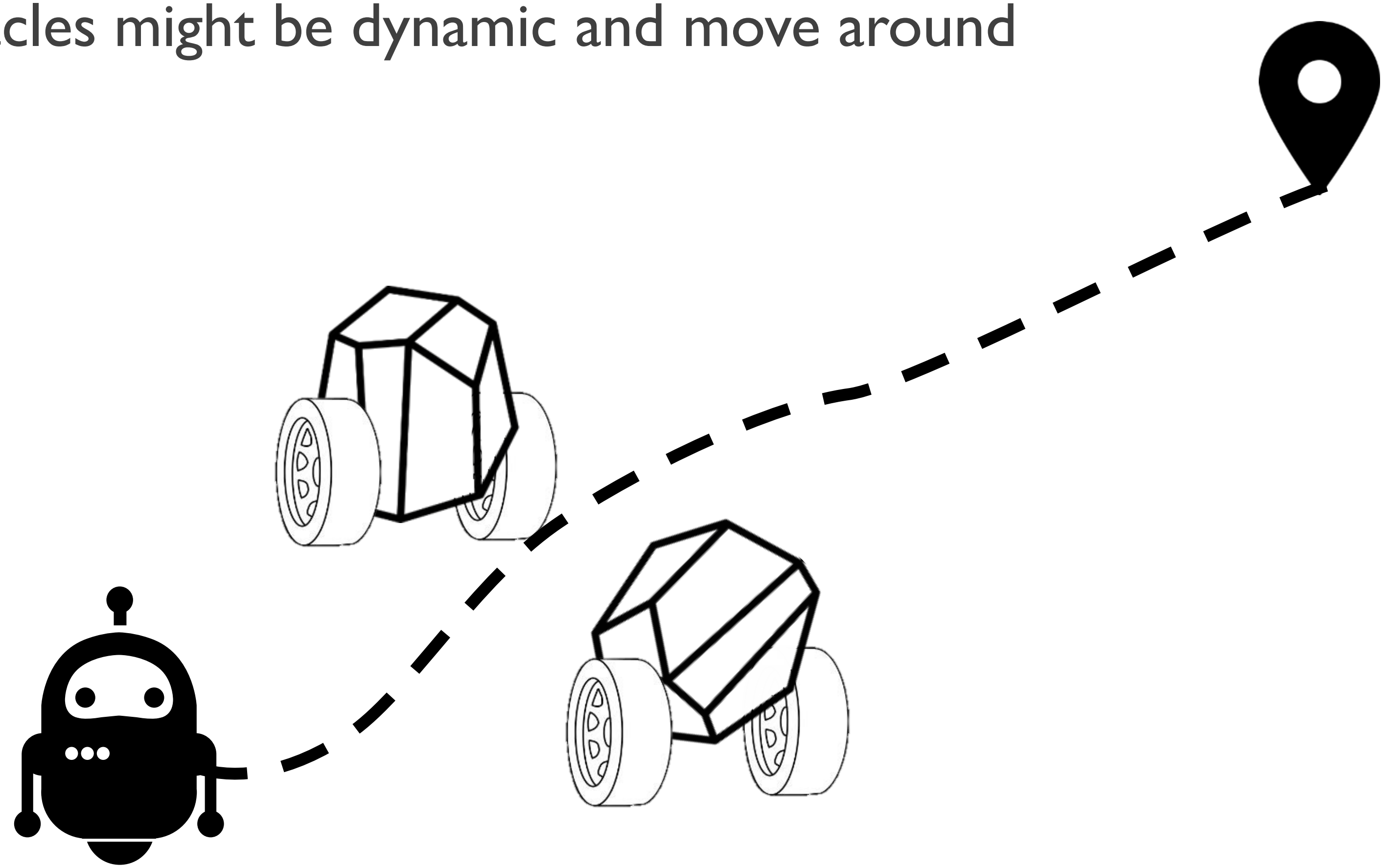
The **Real** Control Problem

Sensor noise results in uncertainty in position of obstacles



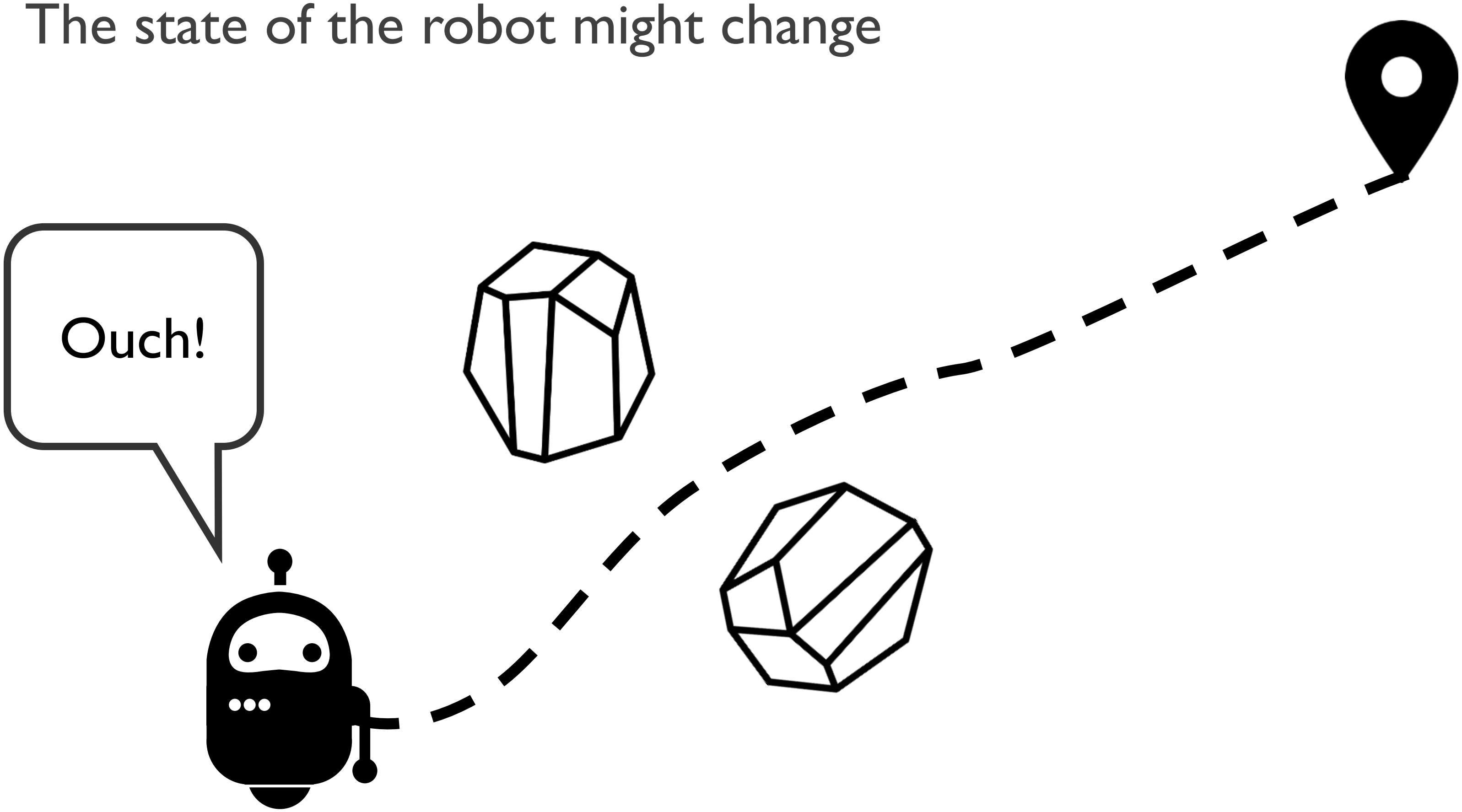
The **Real** Control Problem

Obstacles might be dynamic and move around



The **Real** Control Problem

The state of the robot might change



Electronic Systems Laboratory

- At the ESL we aim to solve the **real** control problem
- Postgraduate Laboratory, part of the Electrical and Electronic Engineering department
- Specialises in the control and automation of space satellites, aircraft, and ground vehicles
- Founded in 1992 as space systems laboratory
- Developed SUNSAT, the first South African satellite (launched and commissioned in 1999)

Electronic Systems Laboratory

Electronic Systems Laboratory

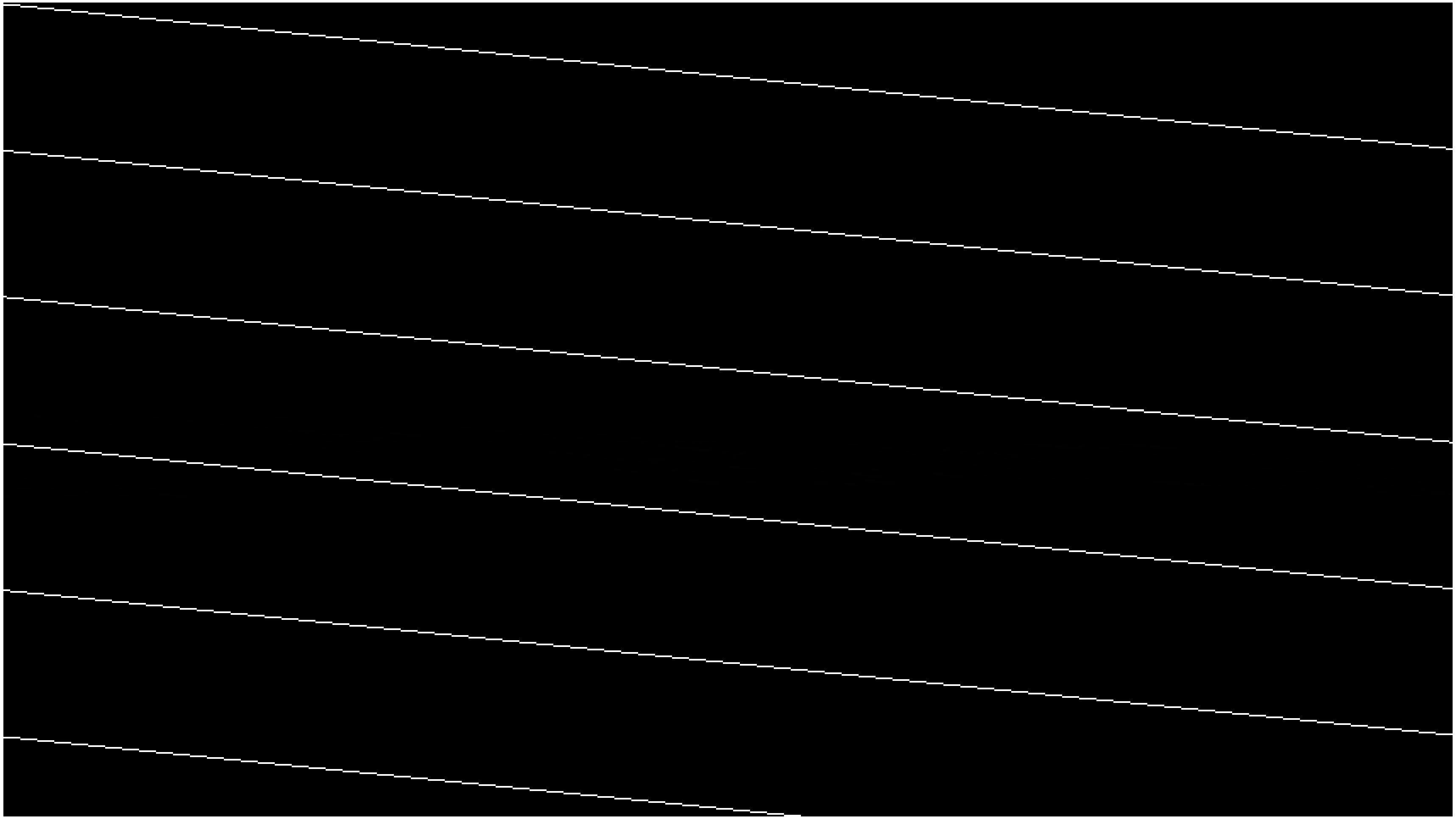
- Currently have
  - 6 full-time academics
  - 5 PhD students
  - 20 Masters students
- Graduates are employed:
  - Aerospace
  - Embedded Systems
  - Data Science
  - Machine Learning
  - Computer Vision
  - Software

Electronic Systems Laboratory

- Practical research activities have resulted in commercial products and services with the creation of private companies:
  - SunSpace (now Denel Spaceteq) - provider of high-performance small- and medium-sized satellites and related systems and solutions
  - S-Plane - aerospace company specialising in the delivery of complete certification-ready Automation, Simulation, Communication and Ground Control Solutions for manned, unmanned and optionally piloted aircraft systems.
  - CubeSpace - design, build, test and support innovative, high quality, miniaturized satellite components, with a strong focus on control systems

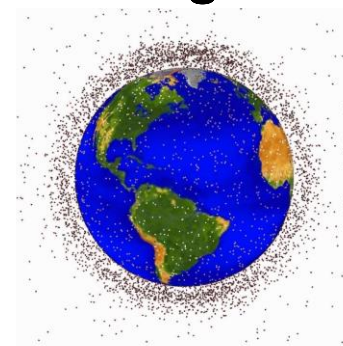
Space Vehicles

Focus on embedded systems and algorithms for attitude control system (ADCS)



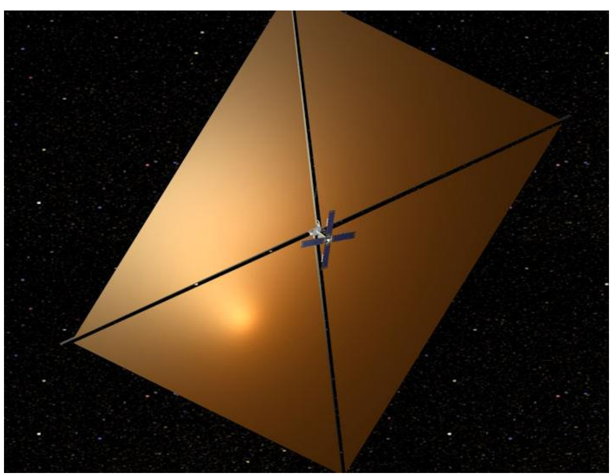
Space Vehicles

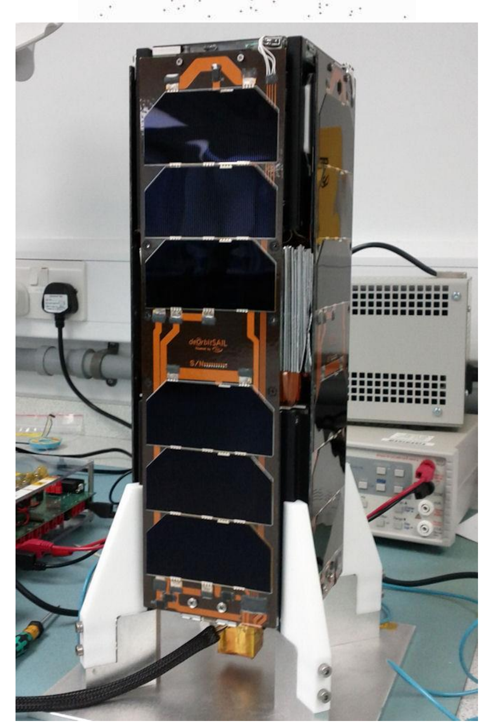
Estimated 5,500 tons of man made objects currently orbiting earth, less than 2000 operational satellites



1. EU FP7 DeOrbitSail Project
2. EU FP7 RemoveDebris Project
3. EU FP7 QB50 Earth Science Mission

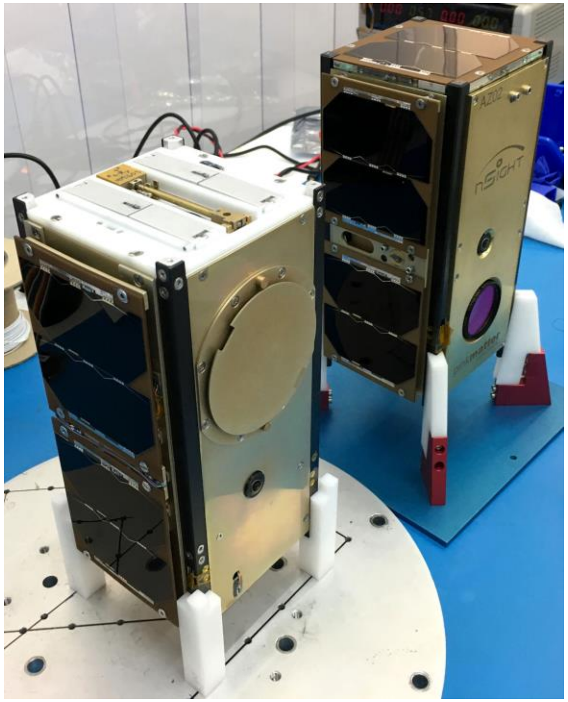
deOrbitSAIL

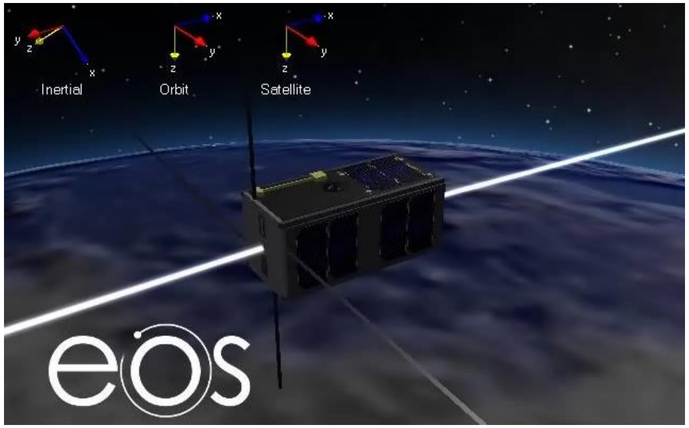


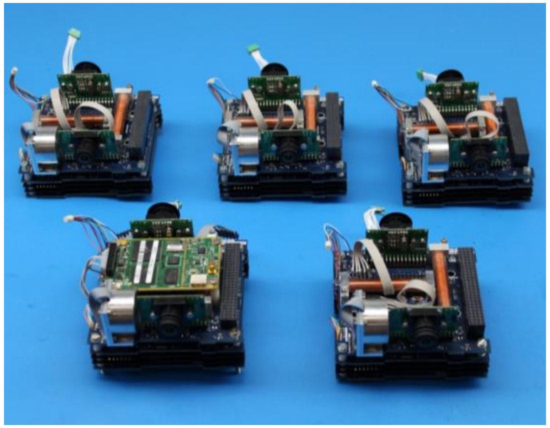


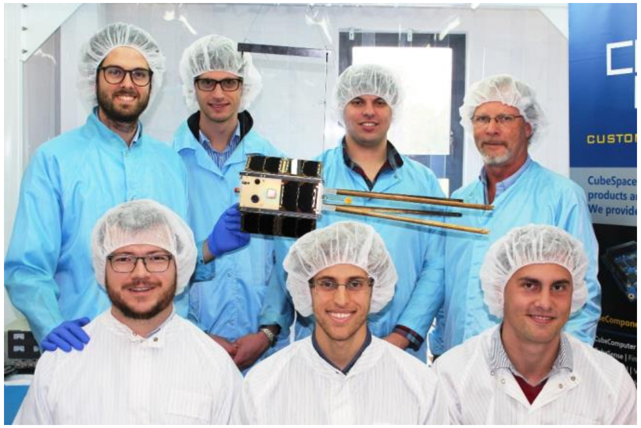
Space Vehicles

- Developed and built 18 ADCS units along with Surrey Space Centre for participants
- South Africa’s QB50 Satellites
  - ZA-AeroSat 2U CubeSat from Stellenbosch University (ESL & CubeSpace)
  - nSight-1 2U CubeSat from Space Commercial Services (SCS)









Space Vehicles

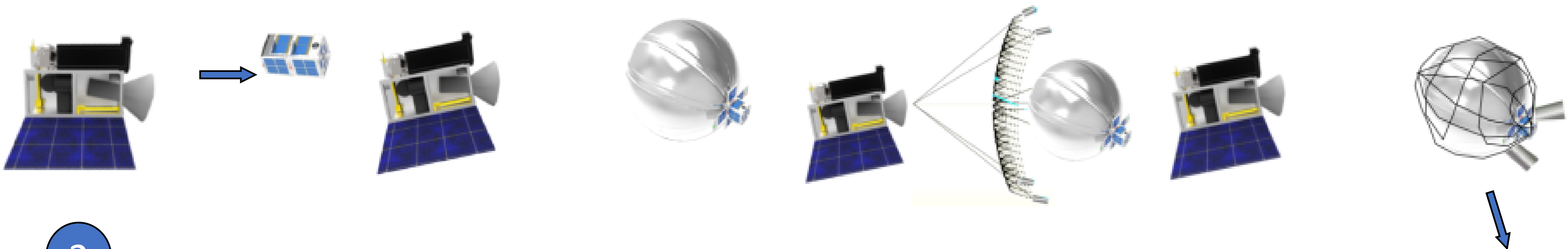
California, USA

Space Vehicles

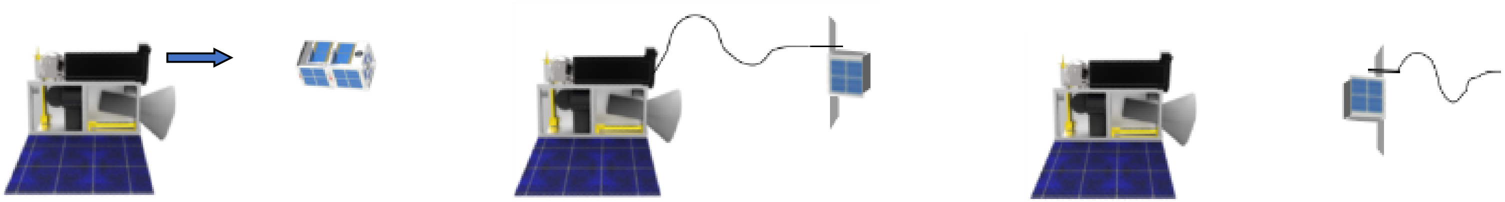
East London, South Africa

Space Vehicles

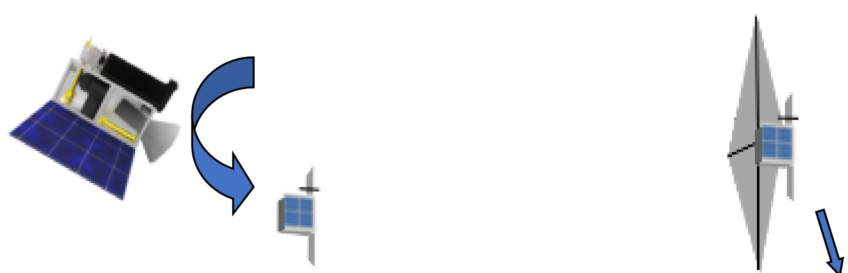
1 Net capture experiment



2 Harpoon capture experiment



3 Vision Based Navigation



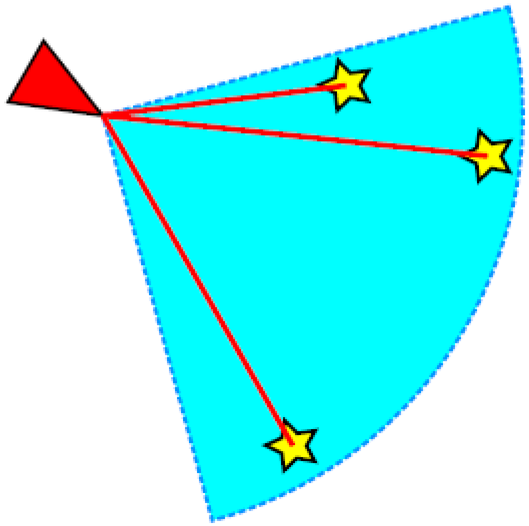
Space Vehicles

Air Vehicles

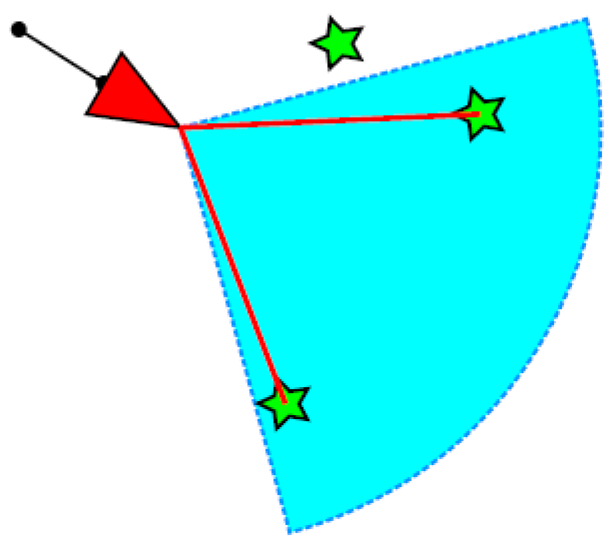
Air Vehicles

Air Vehicles

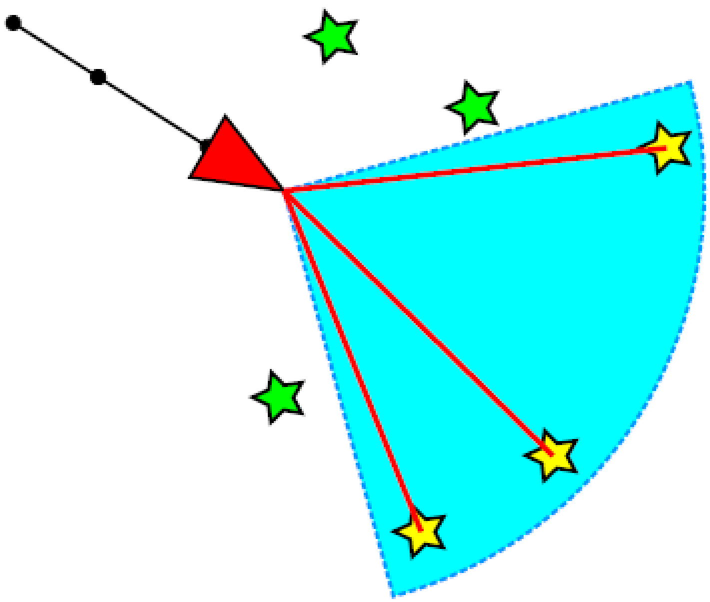
Land Vehicles



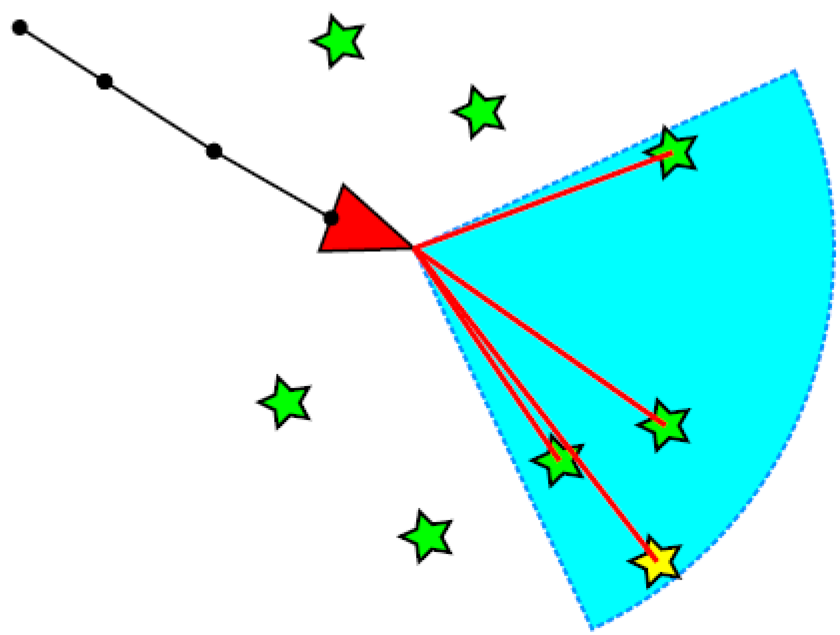
Land Vehicles



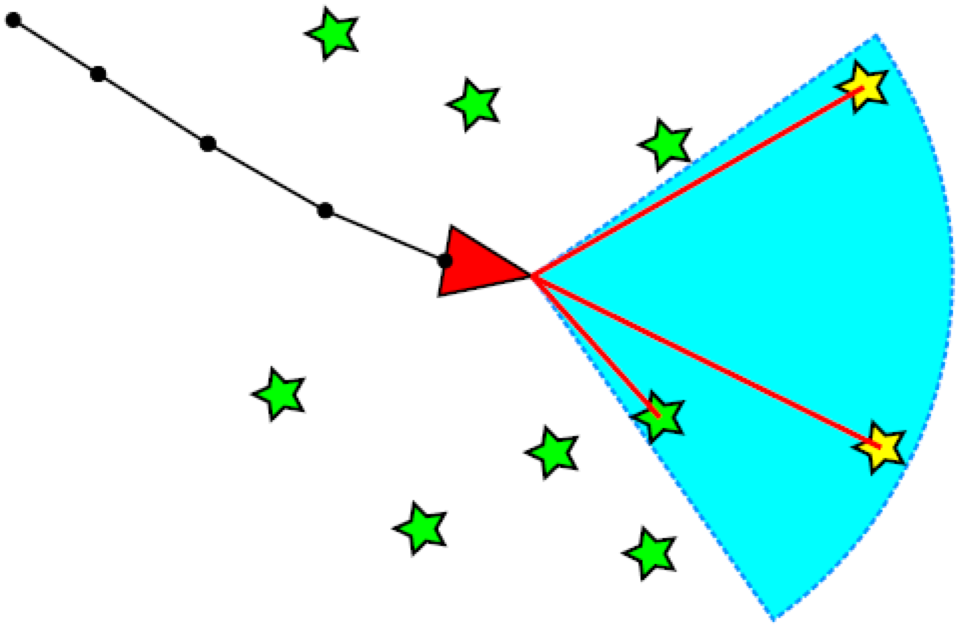
Land Vehicles



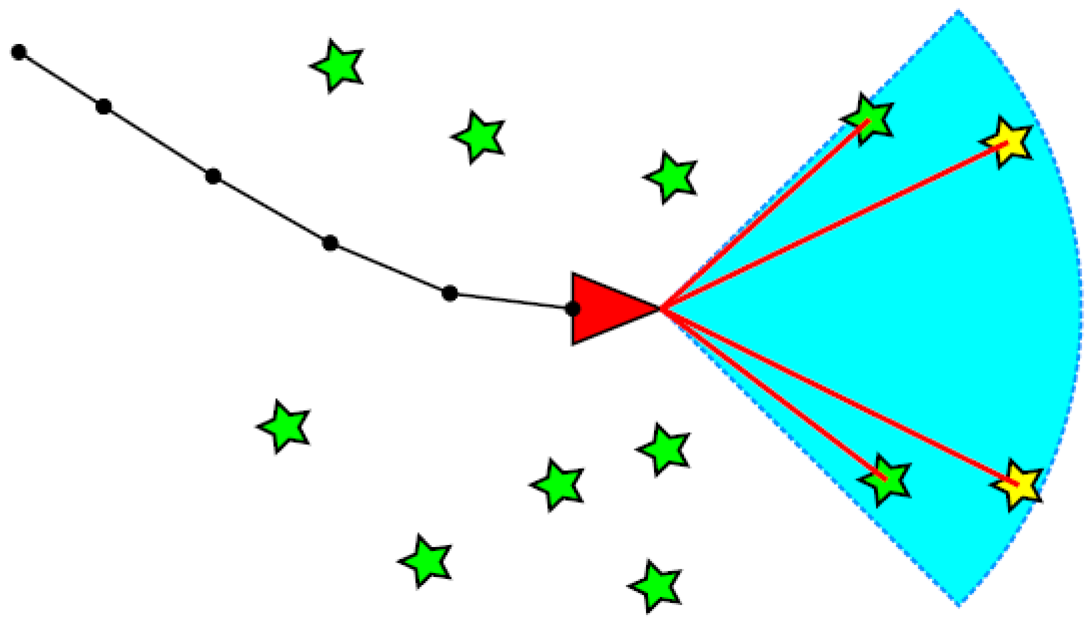
Land Vehicles



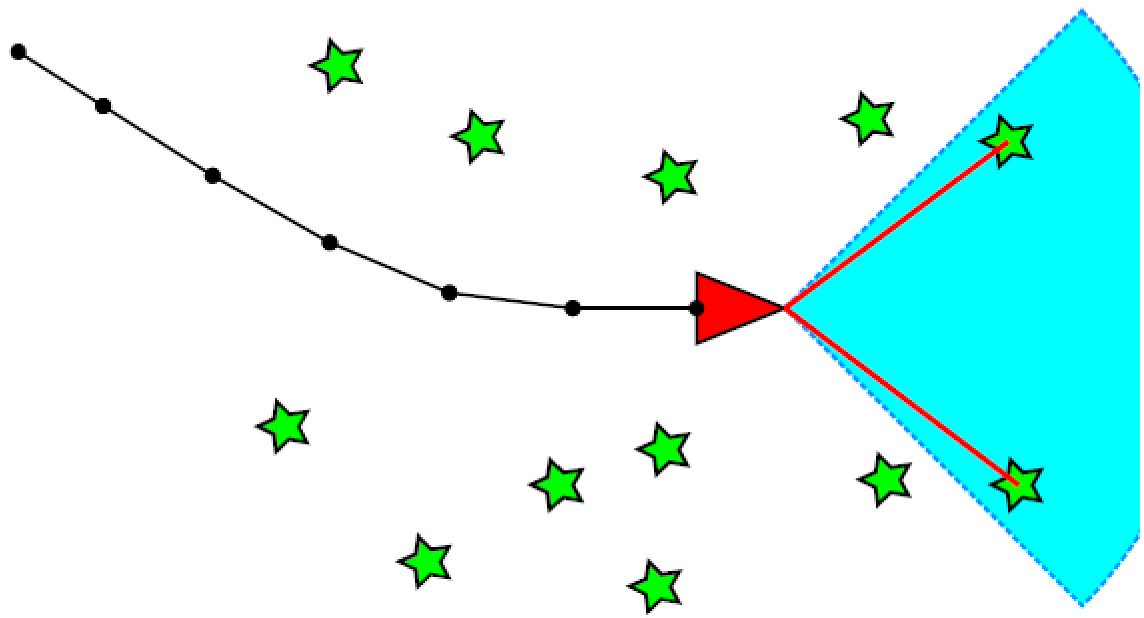
Land Vehicles



Land Vehicles



Land Vehicles



Land Vehicles

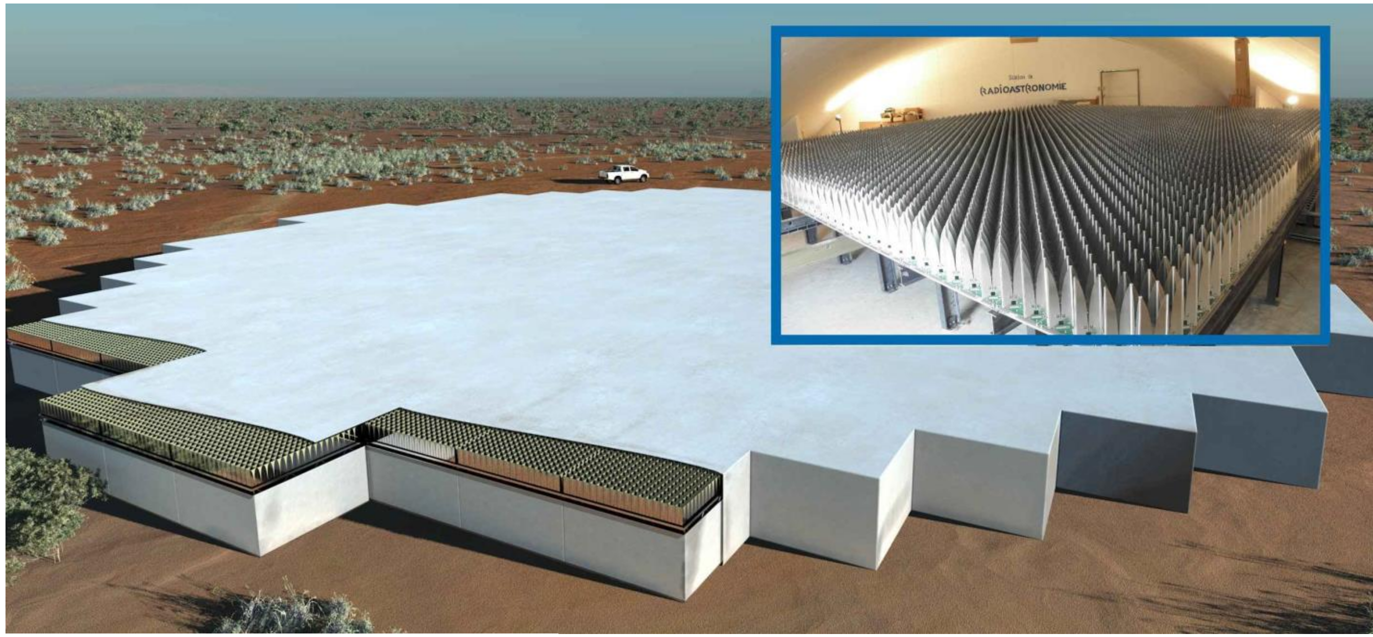
Input images

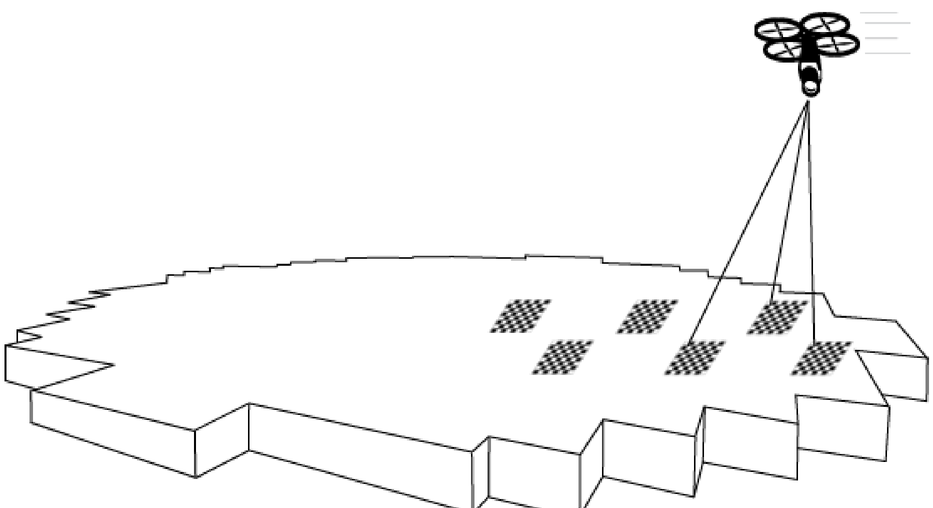
section 7.1
page 64

Left image

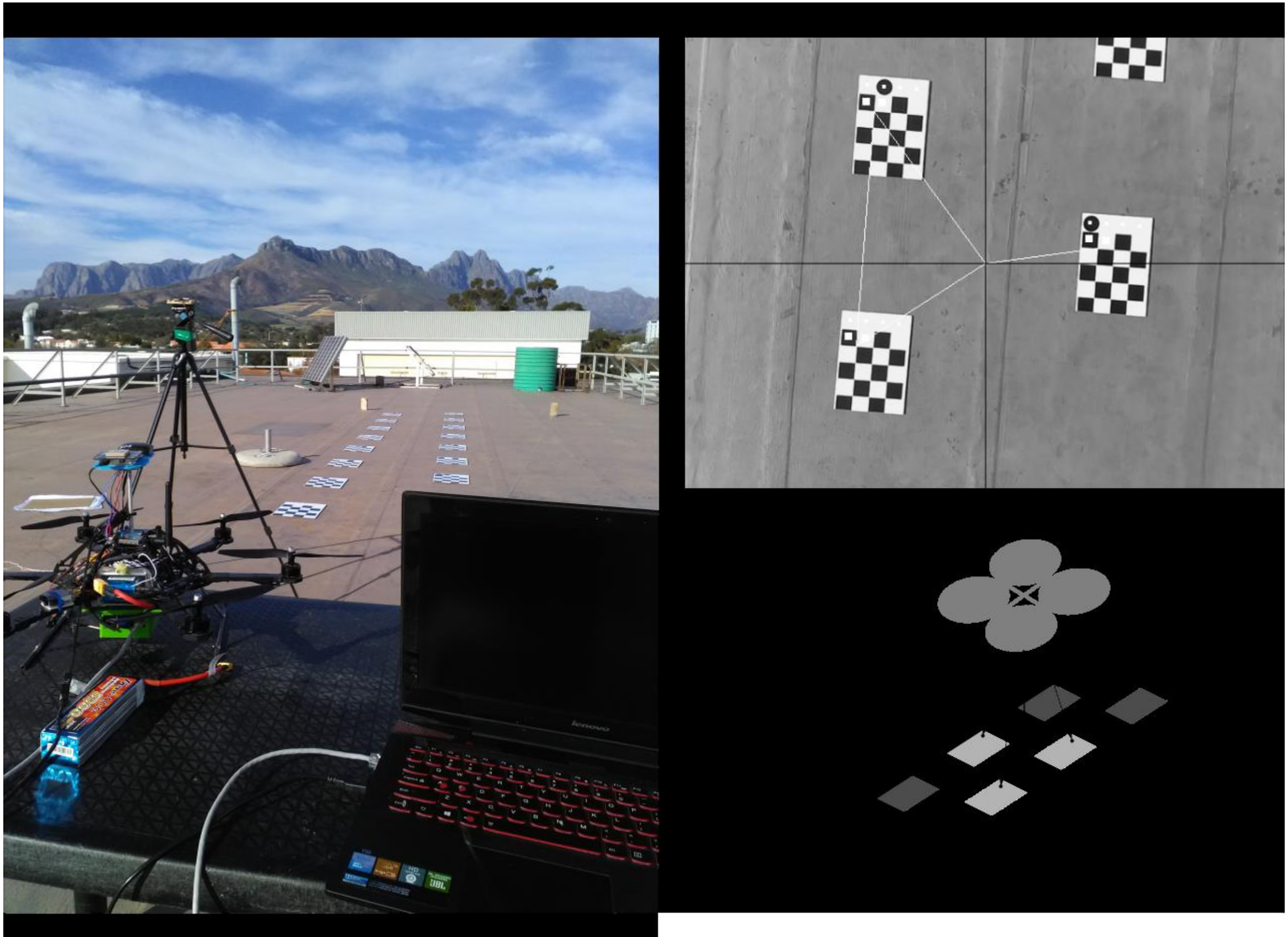
Right image

Land Vehicles

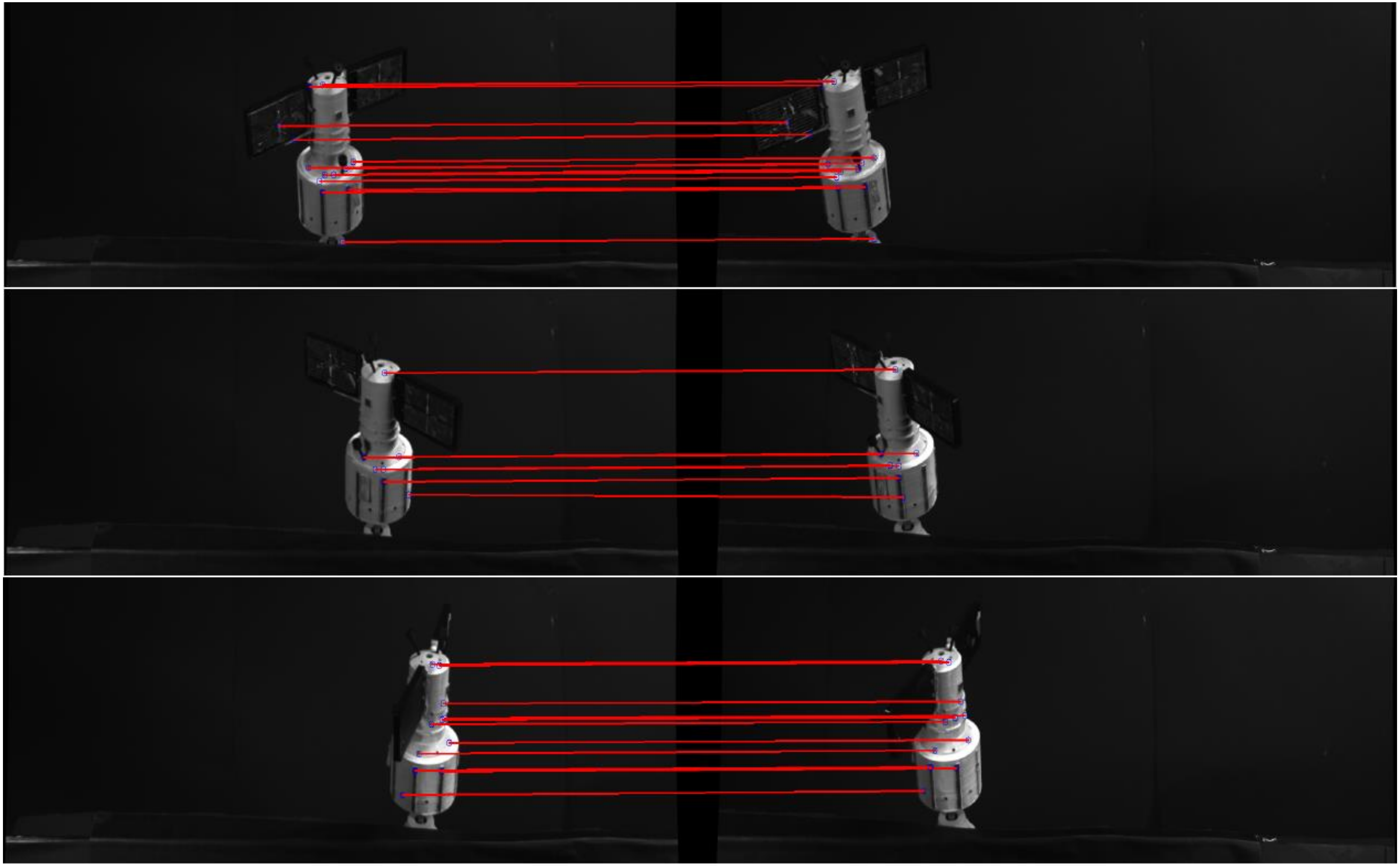




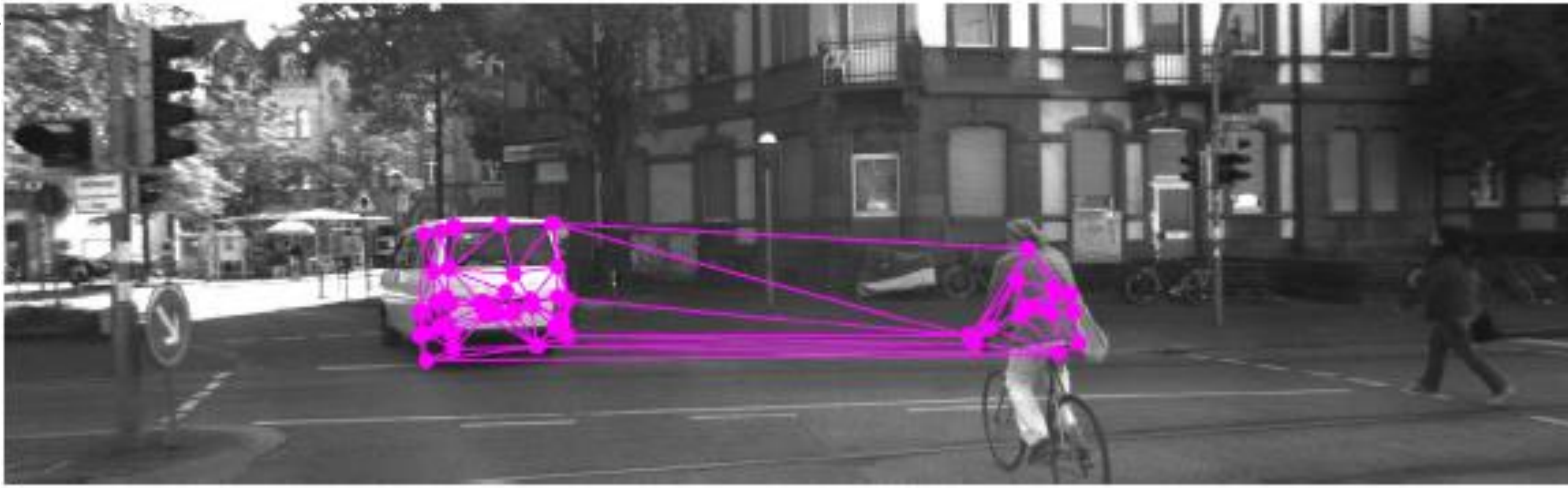
Land Vehicles



Land Vehicles



Land Vehicles



Land Vehicles

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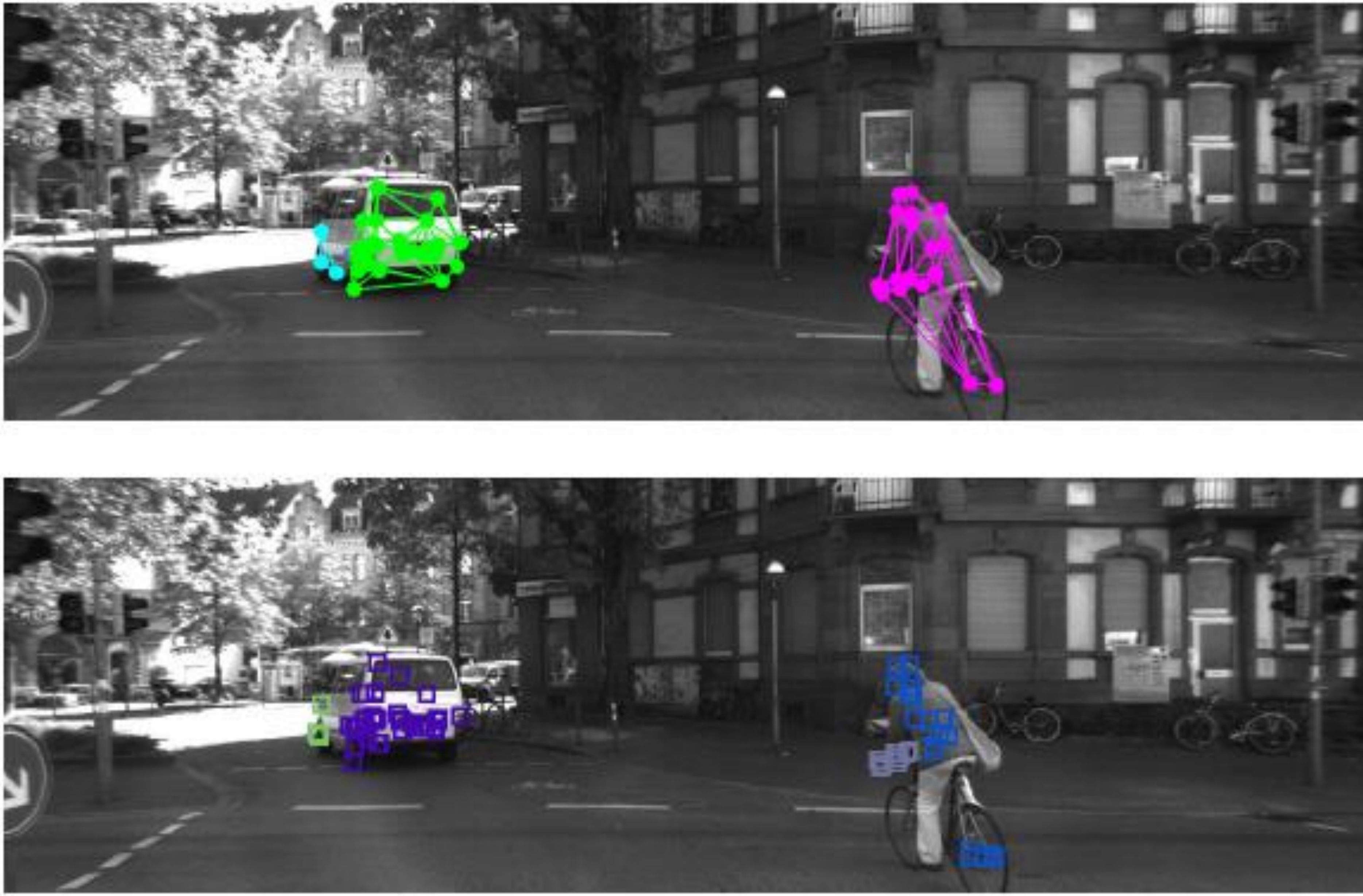

Land Vehicles

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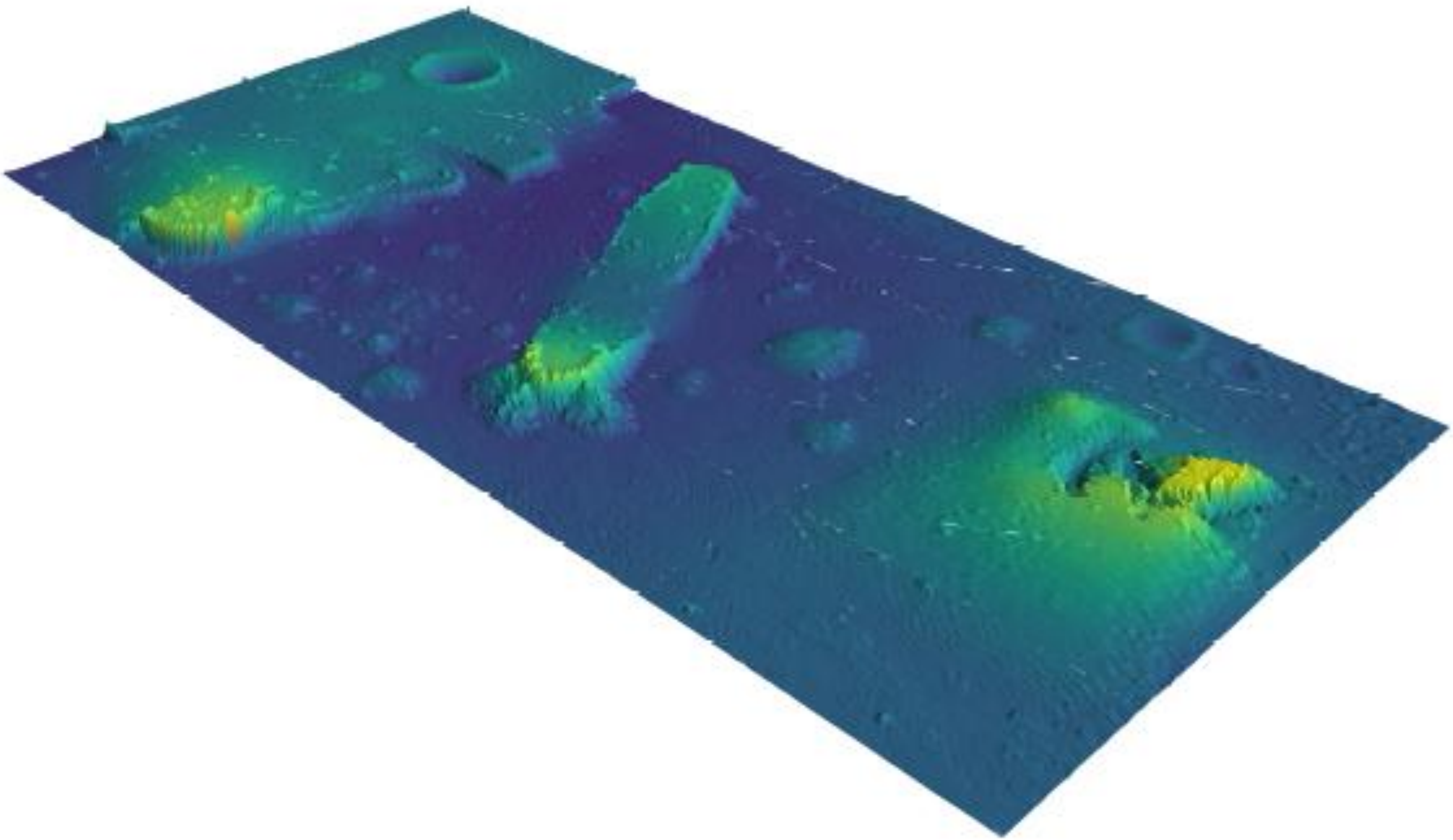
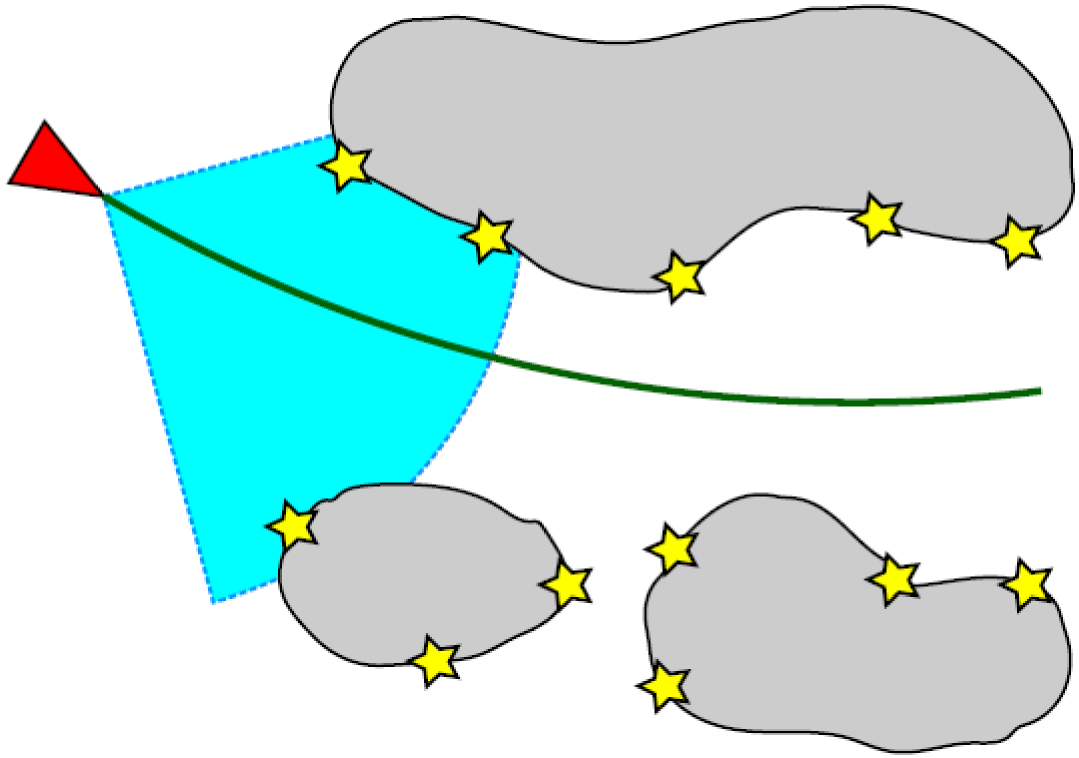


Land Vehicles



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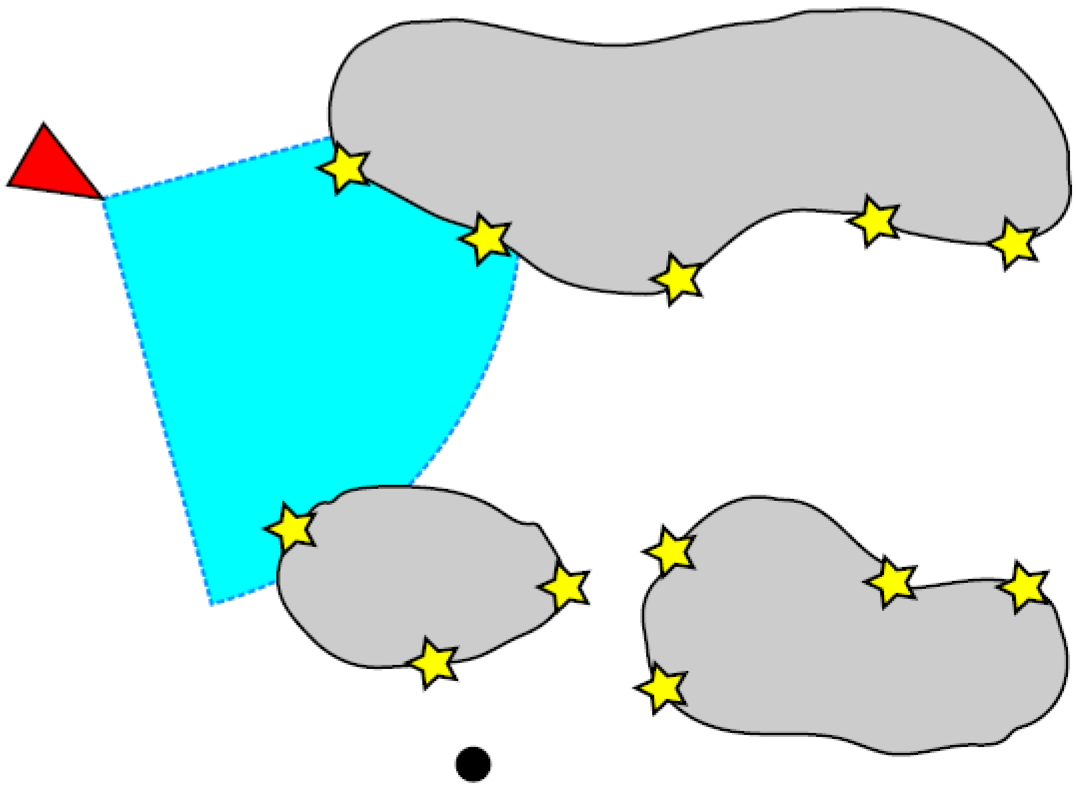

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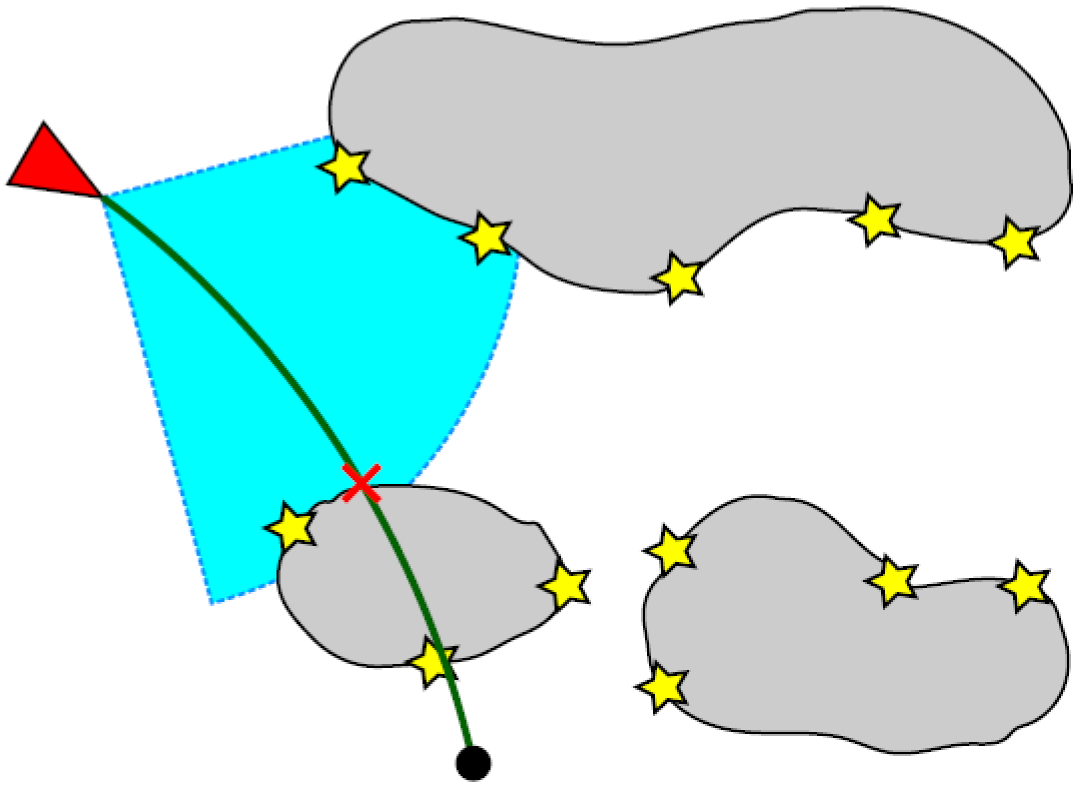

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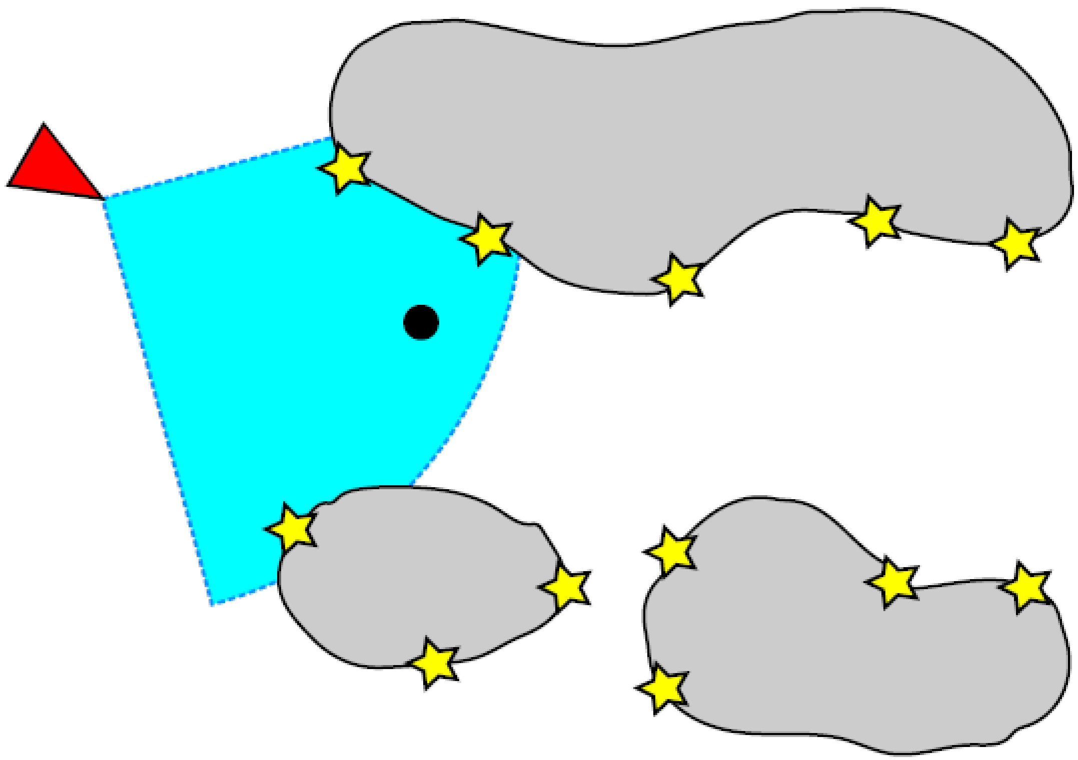

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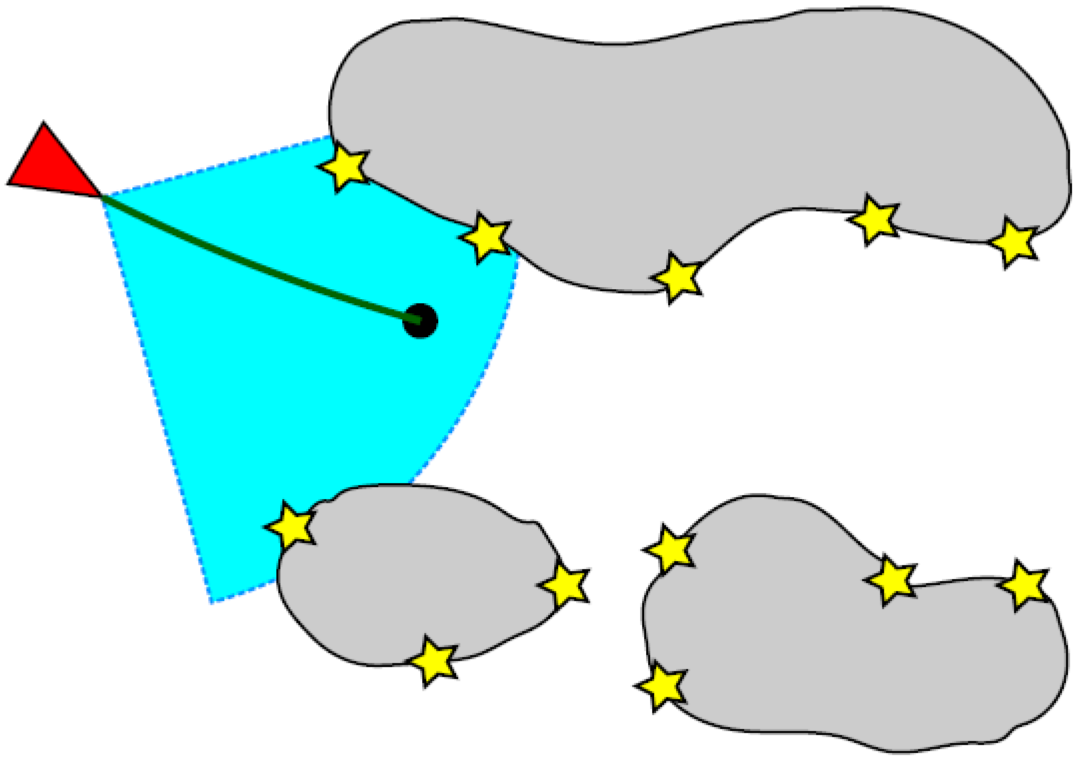

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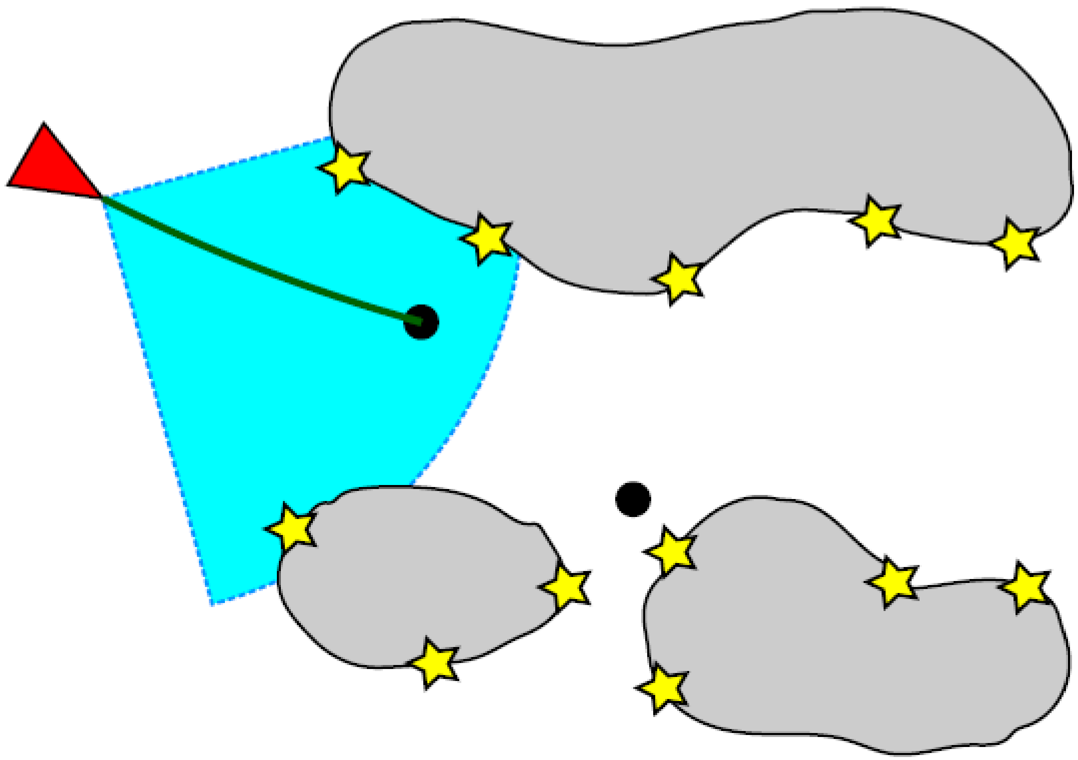

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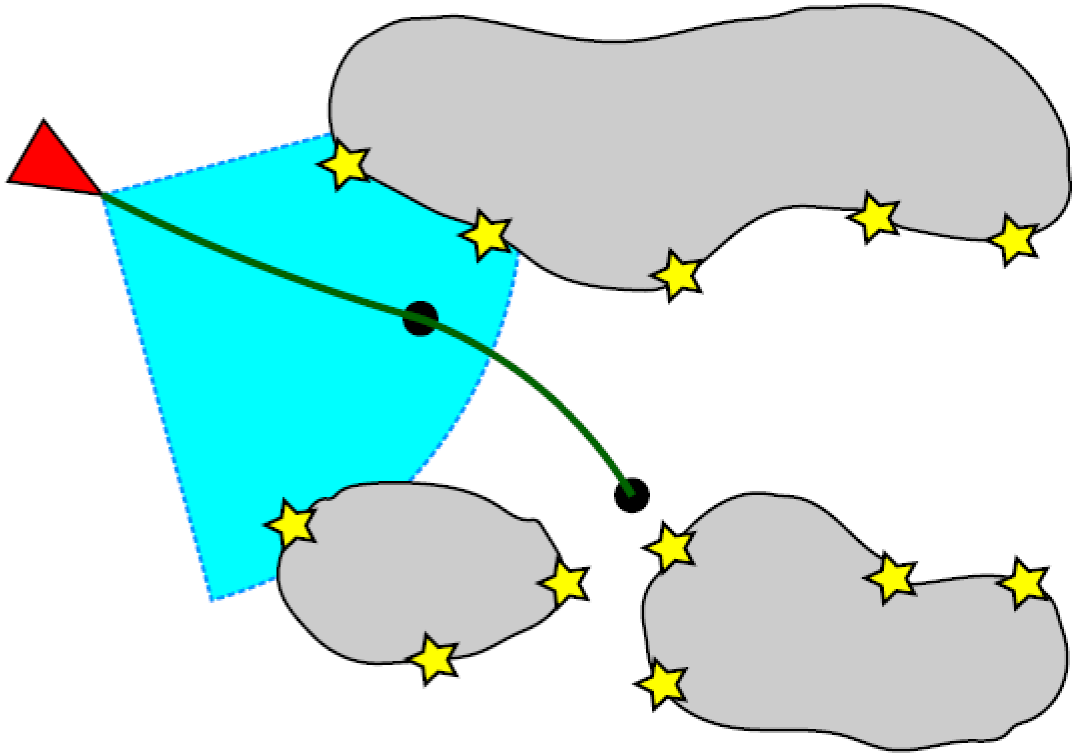

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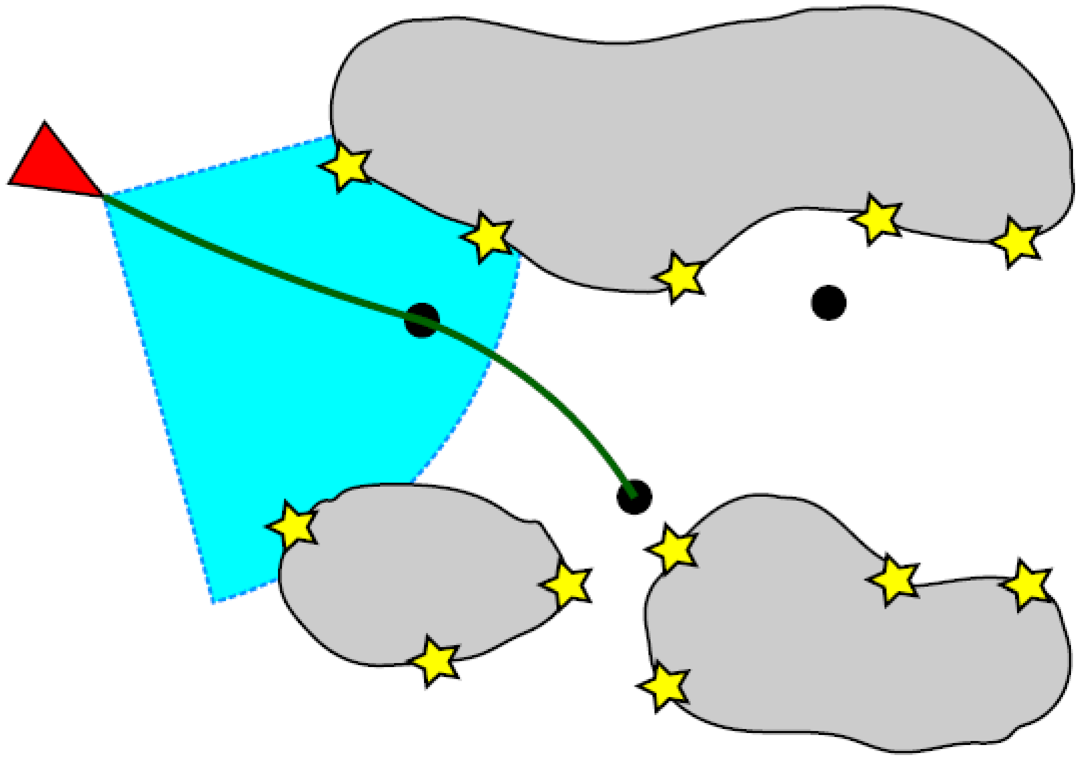

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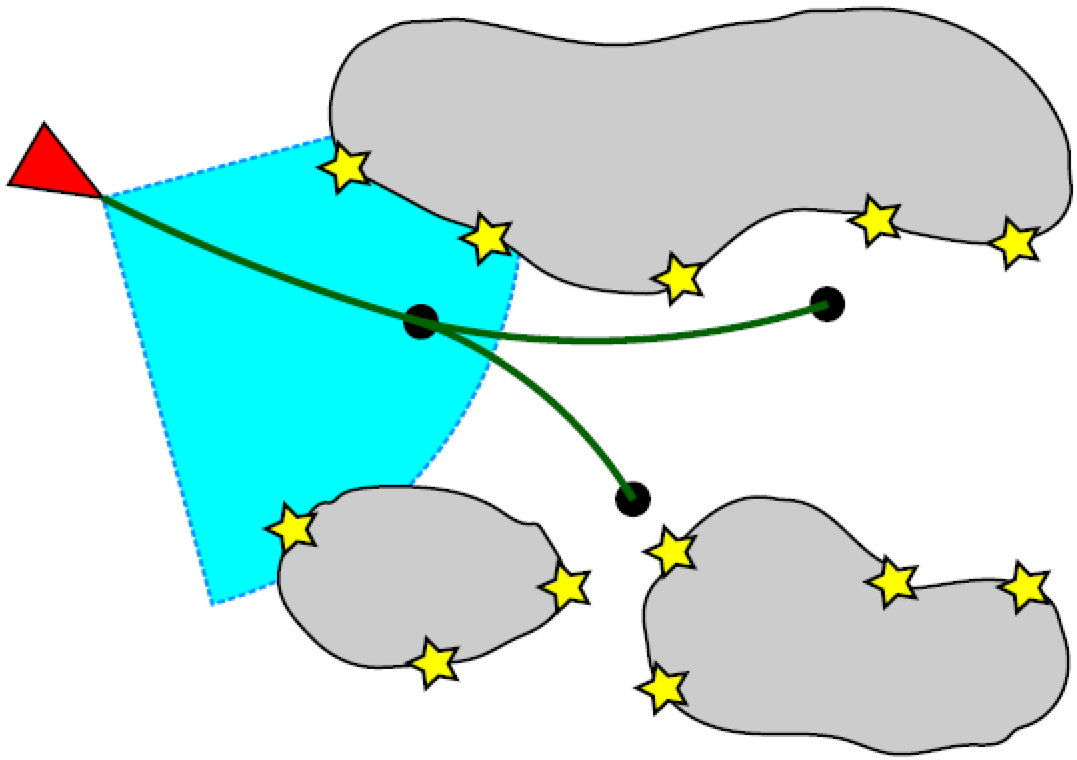

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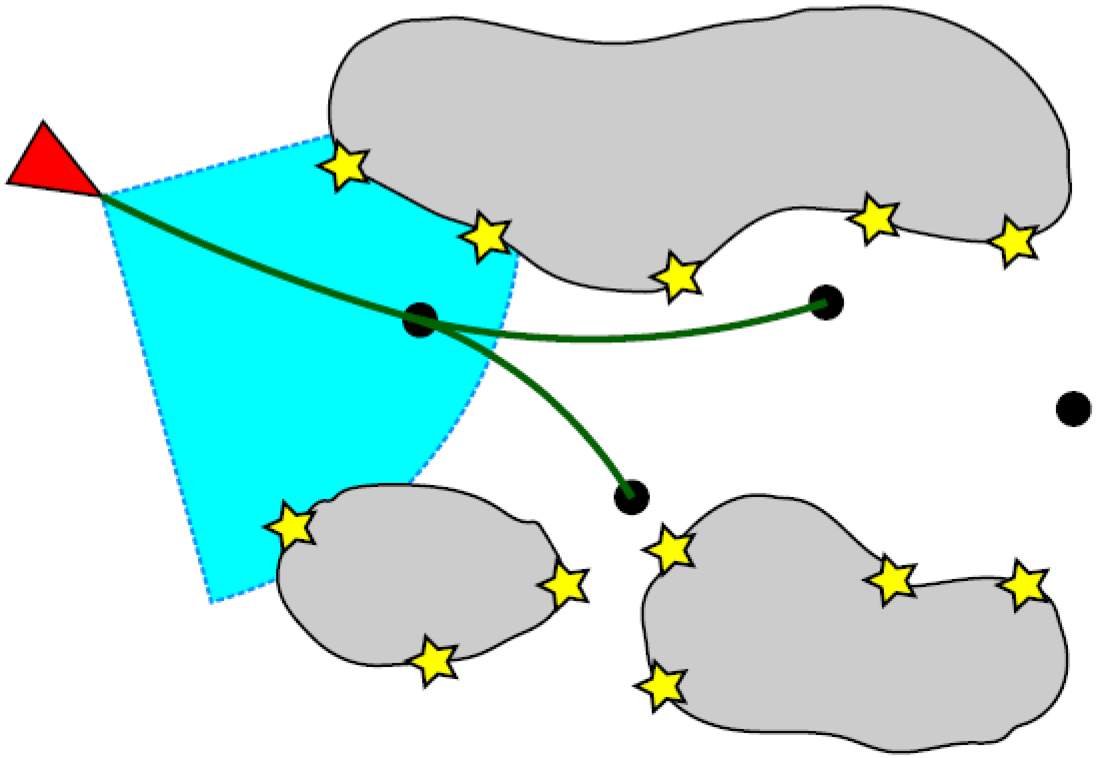

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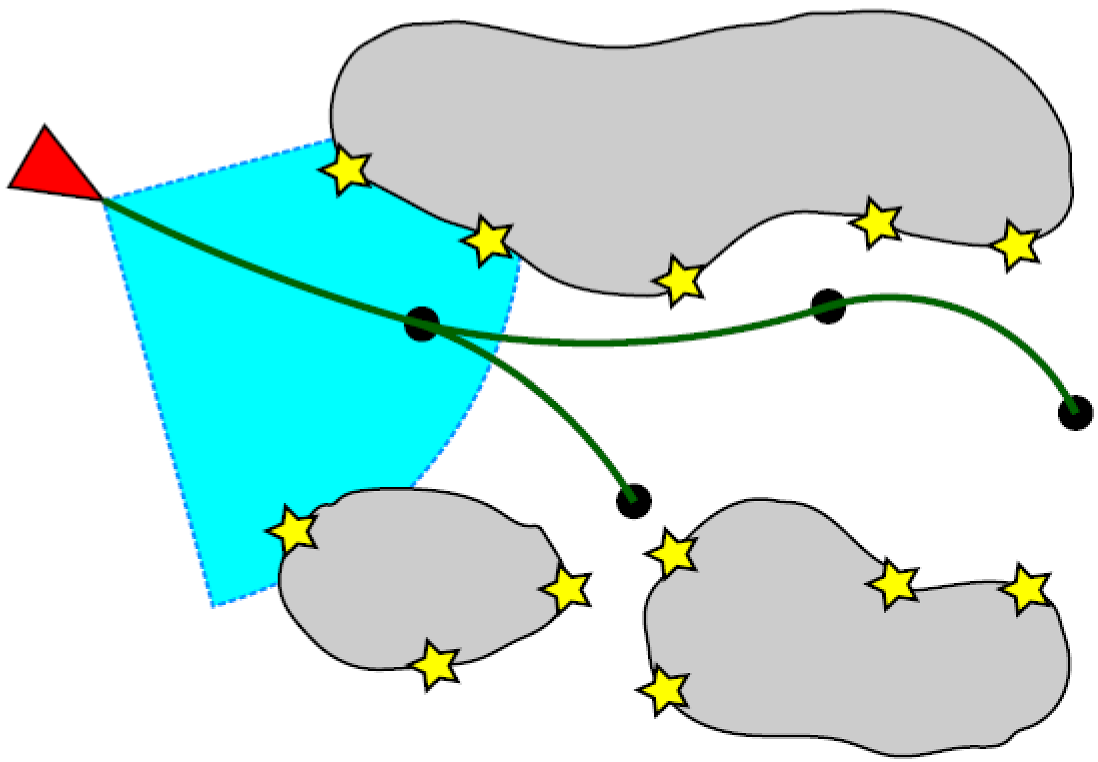

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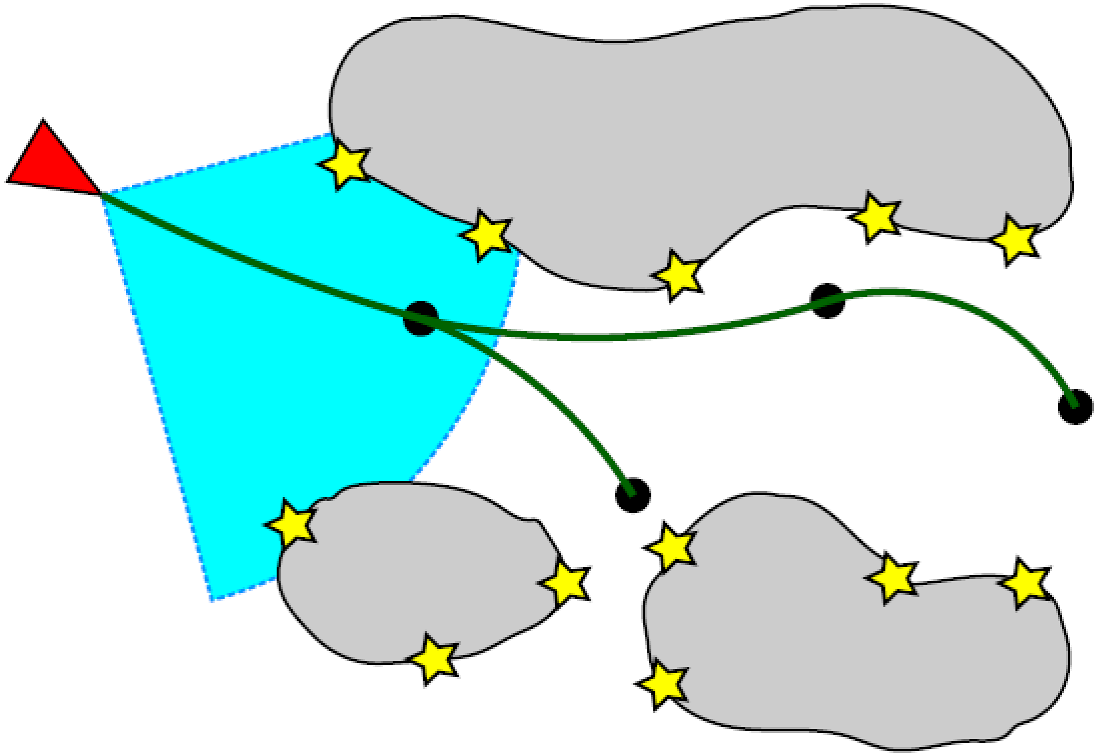


Land Vehicles

Representation of the map for the path planner algorithm

Aerial view of the Engineering Faculty, Stellenbosch

Future Autonomous Systems

- Future autonomous systems will:
  - have increased autonomy.
    - Ability to execute a mission even in the presence of uncertainties (robust autonomy)
    - Be able to adapt to unknown scenarios (intelligent autonomy)
  - be more distributed with a collective function.
    - Specialised systems working together to perform a common task

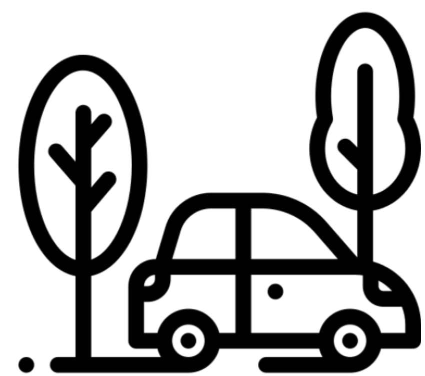
Future Autonomous Systems

- Can we build systems that learn how to drive and handle information similar to a human?
- How does a pilot learn to fly?
  - Learn how to fly from textbook and instructor and write a test
  - Train flying within simulator (number of hours)
  - Train flying a real plane with another pilot observing (number of hours)
  - Get license, still need to maintain number of hours

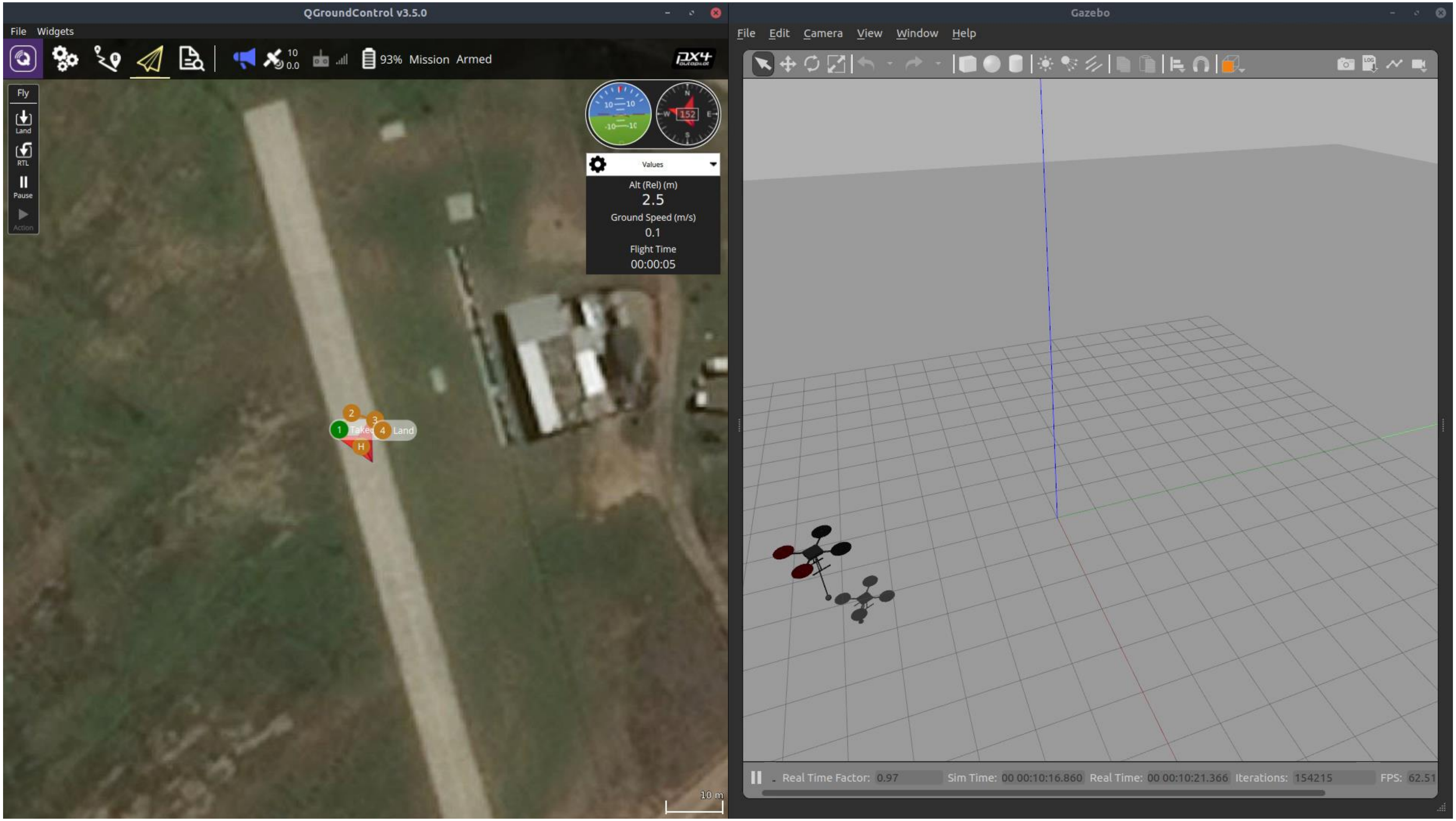


Future Autonomous Systems

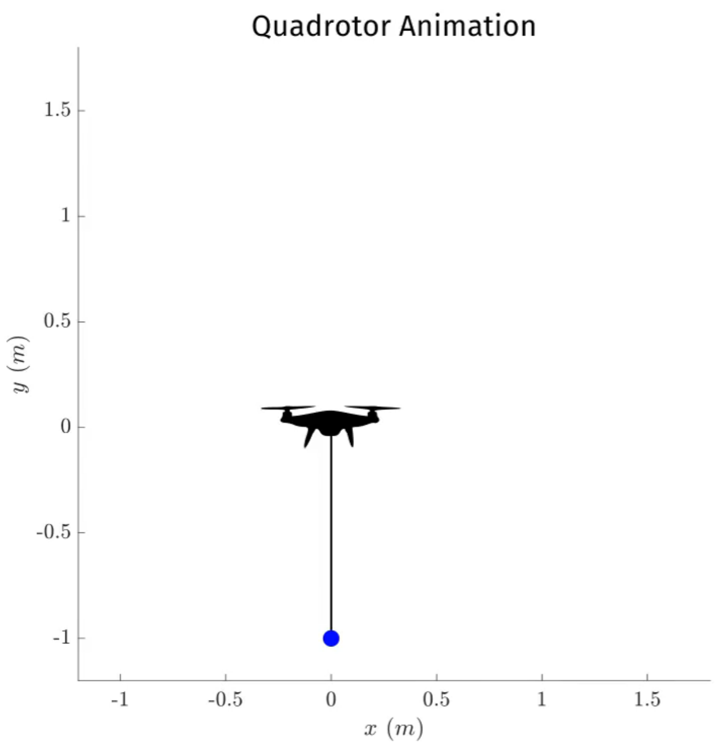
- How do we make decisions when facing uncertainty?
  - handle it with caution and make conservative decision
  - harness previous experiences and try something which we did in a past similar scenario
  - just simply try something and see if it works

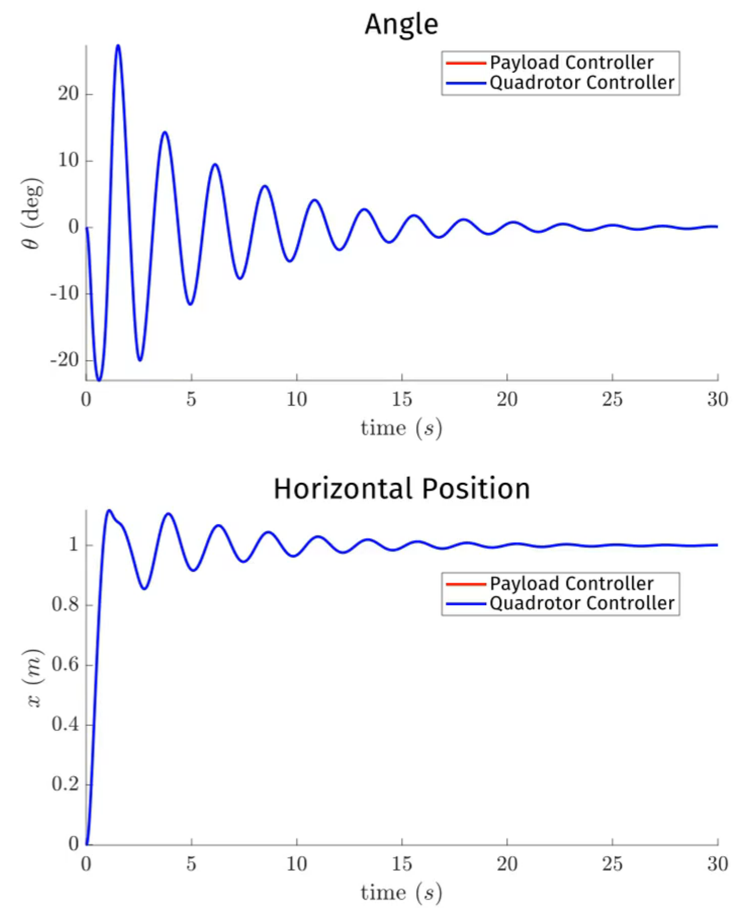


Future Autonomous Systems



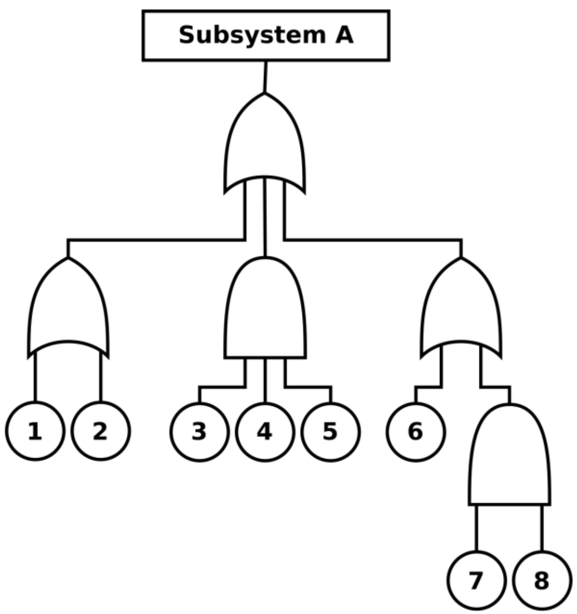
Future Autonomous Systems

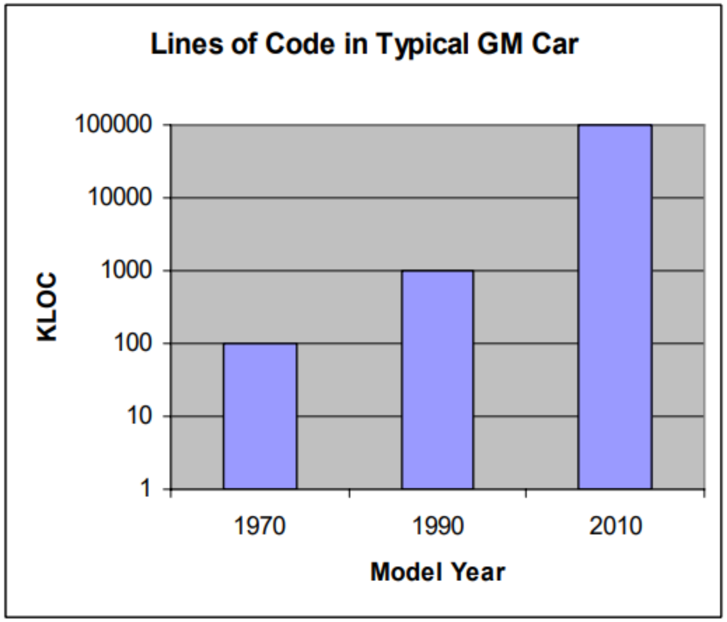




Future Autonomous Systems

- How to generate robust, adaptable systems?
    - Tragic cycle of robust software generation





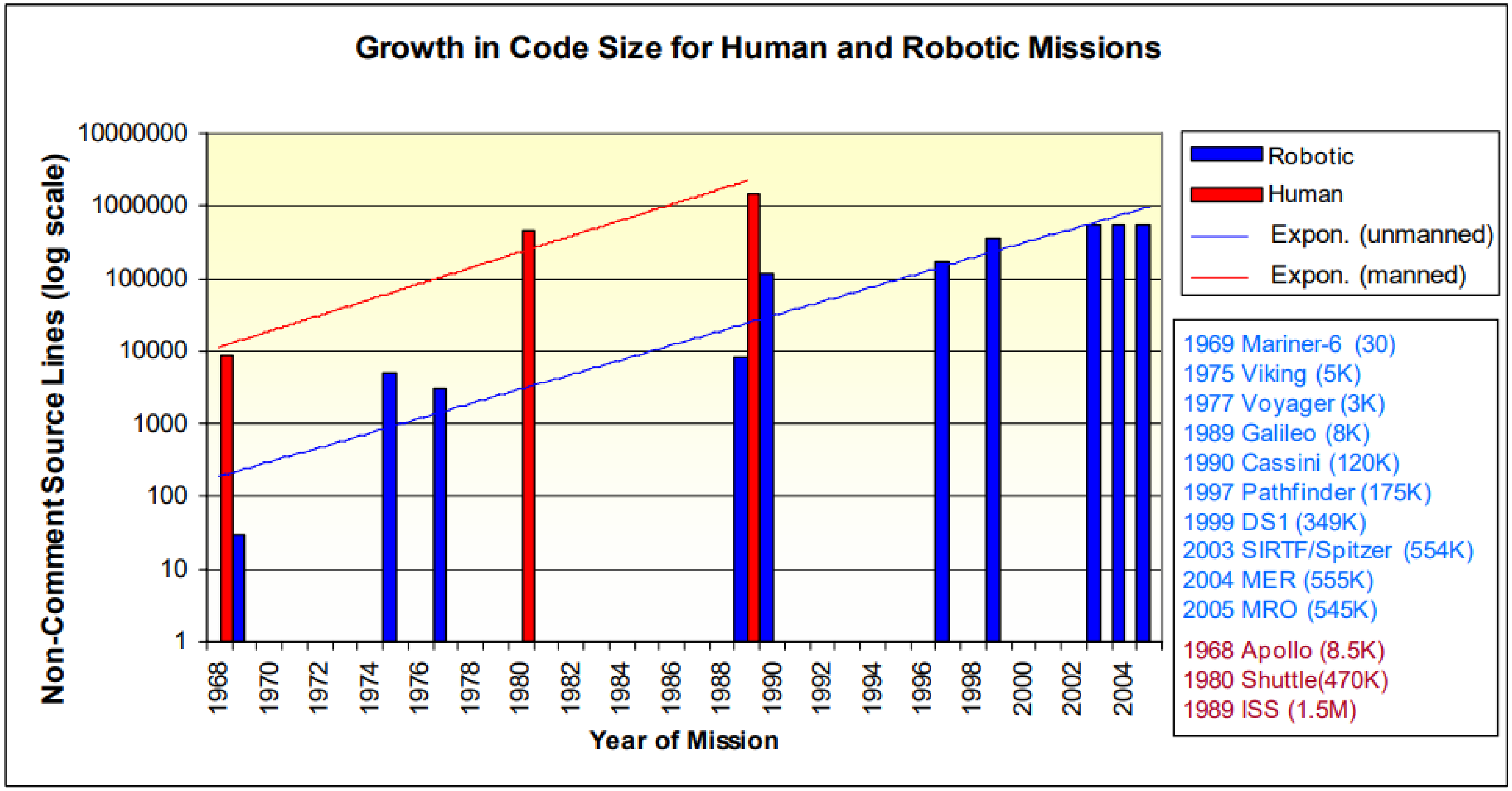
“An exceptionally good software development process can keep defects down to as low as 1 defect per 10,000 lines of code. This means that a system containing 1 million lines of code will have 100 defects, some of which will manifest during mission operations.”

Extract and graph from “NASA Study on Flight Software Complexity”

Future Autonomous Systems

"Industry average bugs per 1000 lines of code at 15-50 and Microsoft released code at 0.5 per 1000, and 0(!) defects in 500,000 lines of code for NASA"

Extract from "Hacker News"



History of flight software growth in human and robotic missions.

Graph from "NASA Study on Flight Software Complexity"

Future Autonomous Systems

- The way to approach the problem is to look at hybrid solutions
  - Combine a number of tools to exploit their own unique advantages
    - Conventional Control – fast and robust
    - Adaptive Control – investigate own performance relative to benchmark
    - Neural Networks – classifying experiences/data
    - Probabilistic Models – reason with uncertain data
    - Many others
- Investigate novel methods/tools of working with uncertainties and the manner in which one develop these tools

Future Autonomous Systems

In the paper "Survey of Advances in Control Algorithms of Quadrotor Unmanned Aerial Vehicle" by Li et al. the following conclusion is made

"

We must admit that vision-based navigation and guidance of quadrotor has become a research hotspot. But we believe that two aspects of quadrotor control will take some years of research in actual applications:

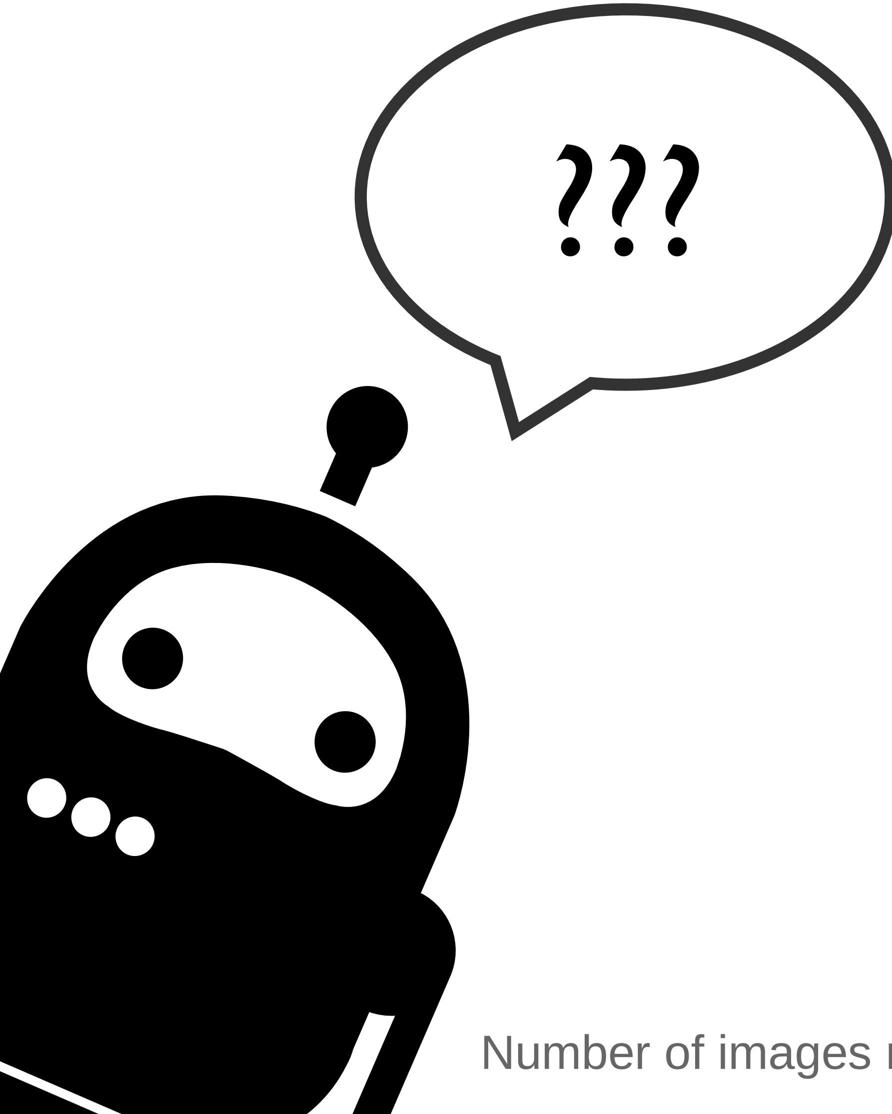
1) Robust controller should be designed to guarantee good flight performance, which can handle uncertainties.

2) Reconfigurable control system should be designed, which can change or switch between different control algorithms under different flight and mission conditions.

So, the use of hybrid control schemes is still the future trend.

"

Questions



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