Drone Search and Rescue Project

EL2425 - Automatic Control Project Course

Allan Andre do Nascimento
Cheerudeep Chintha
Damien Rannenberg

Lukas Bjarre
Marc Sigonius

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- Trajectory generation
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- Demonstration

Drones

CrazyFlie 2.0 - Small & affordable drone

Applications

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Beyond Search and Rescue

Domino’s case of pizza delivery (New Zealand - 2016) [1]

Catastrophical Events

Inaccessible Zones

War Zones

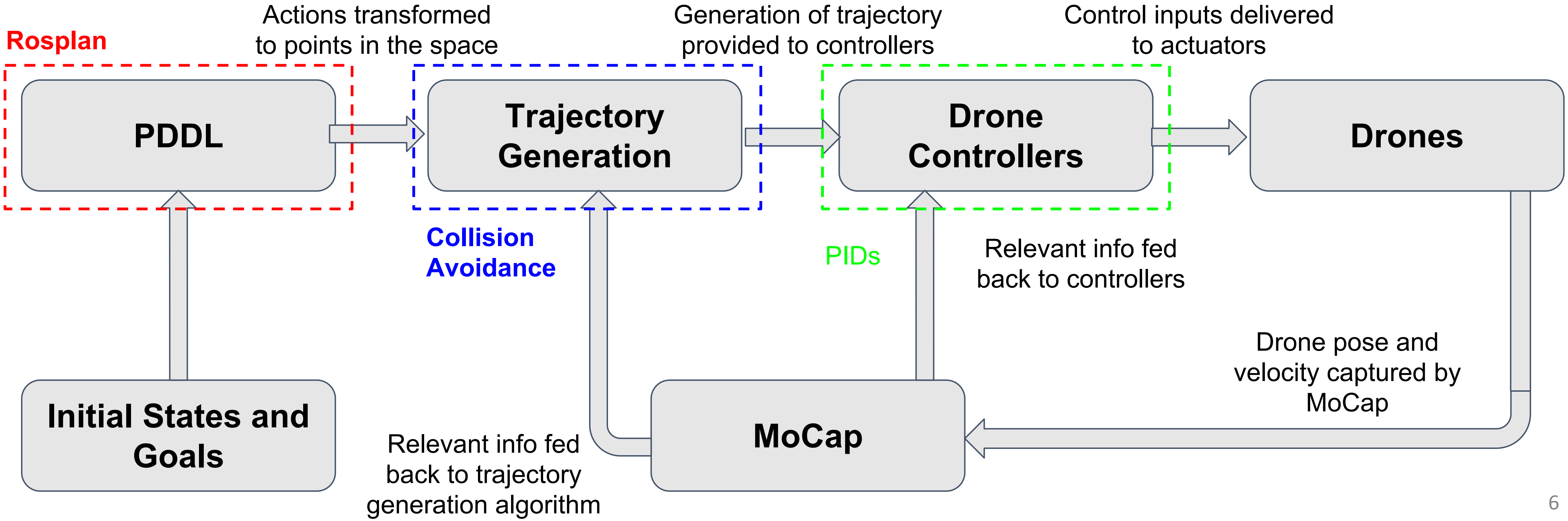
Let the drones take the risk

Introduction

- Project Main Task:
  - Design and implement a multi-agent system capable of transporting (virtual) supplies to selected regions.
  - Drones must work together without collision.
  - Plan of actions must be done automatically

Project Overview

- **How does it work?**


Rosplan
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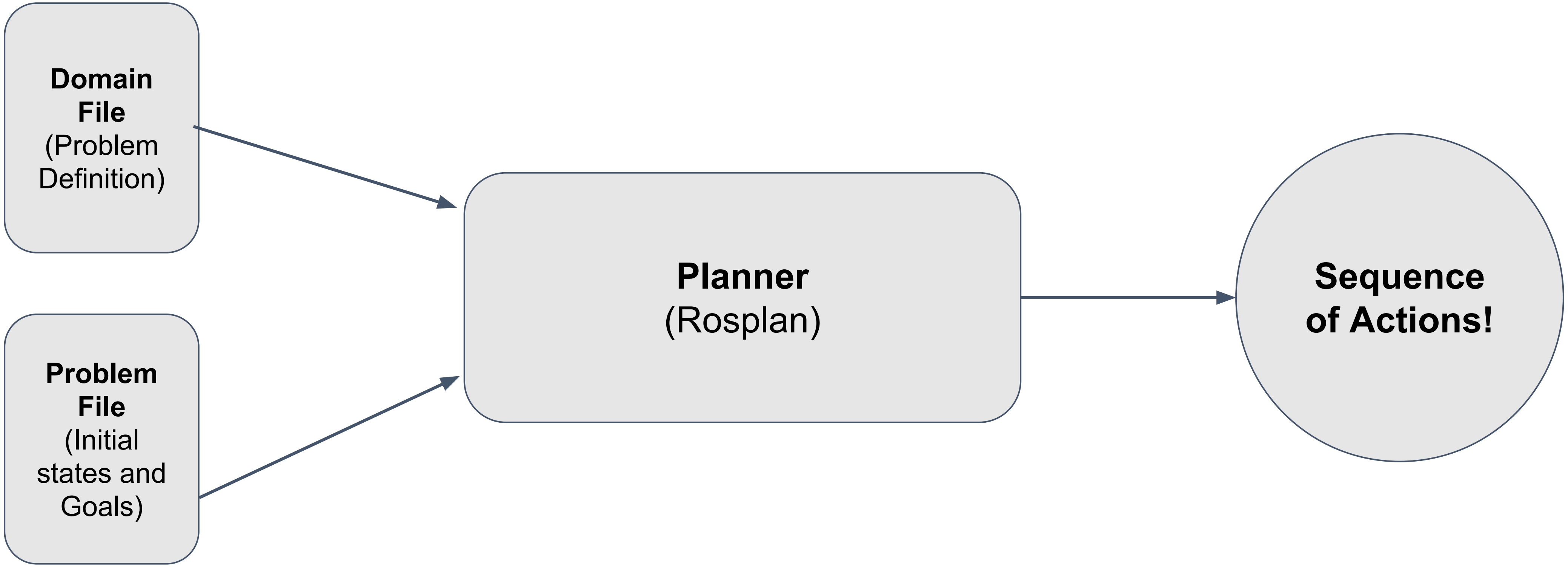
PDDL

- Planning Domain Description Language



Domain File (Problem Definition)

Problem File (Initial states and Goals)

Planner (Rosplan)

Sequence of Actions!

Domain File

```
(define (domain automated-search-rescue)

    (:requirements :typing)

    (:types drone package location)

    (:constants warehouse1 - location)

    (:predicates
        (at-drone ?d - drone ?l - location)
        (drone-ground ?d - drone)
        (drone-fly ?d - drone) )

    (:action TAKEOFF
        :parameters (?d - drone)
        :precondition (drone-ground ?d)
        :effect (and (not (drone-ground ?d))
                    (drone-fly ?d))
    )
```

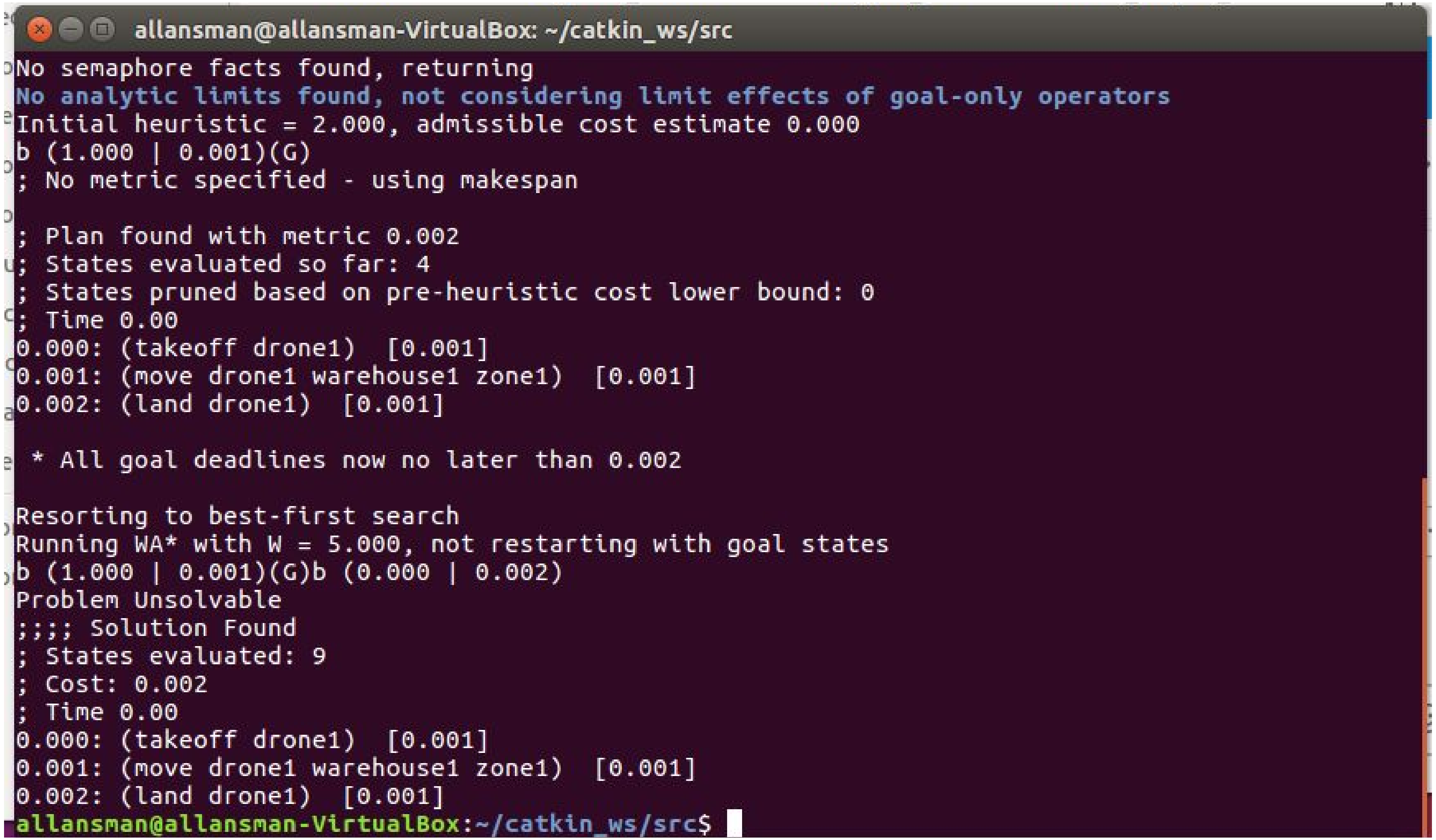
```
(:action LAND
        :parameters (?d - drone)
        :precondition (drone-fly ?d)
        :effect (and (drone-ground ?d)
                    (not (drone-fly ?d)))
    )


    (:action MOVE
        :parameters (?d - drone ?from ?to - location)
        :precondition (and (at-drone ?d ?from)
                            (drone-fly ?d))
        :effect (and (at-drone ?d ?to)
                    (not (at-drone ?d ?from)))
    )
)
```

Problem File

```
(define (problem search-rescue)

    (:domain automated-search-rescue)

    (:objects drone1 - drone
              zone1 - location
    )

    (:init
        (at-drone drone1 warehouse1)
        (drone-ground drone1)

    )
```

```
(:goal (and
        (at-drone drone1 zone1)
        (drone-ground drone1)

        )
    )
)
```

PDDL

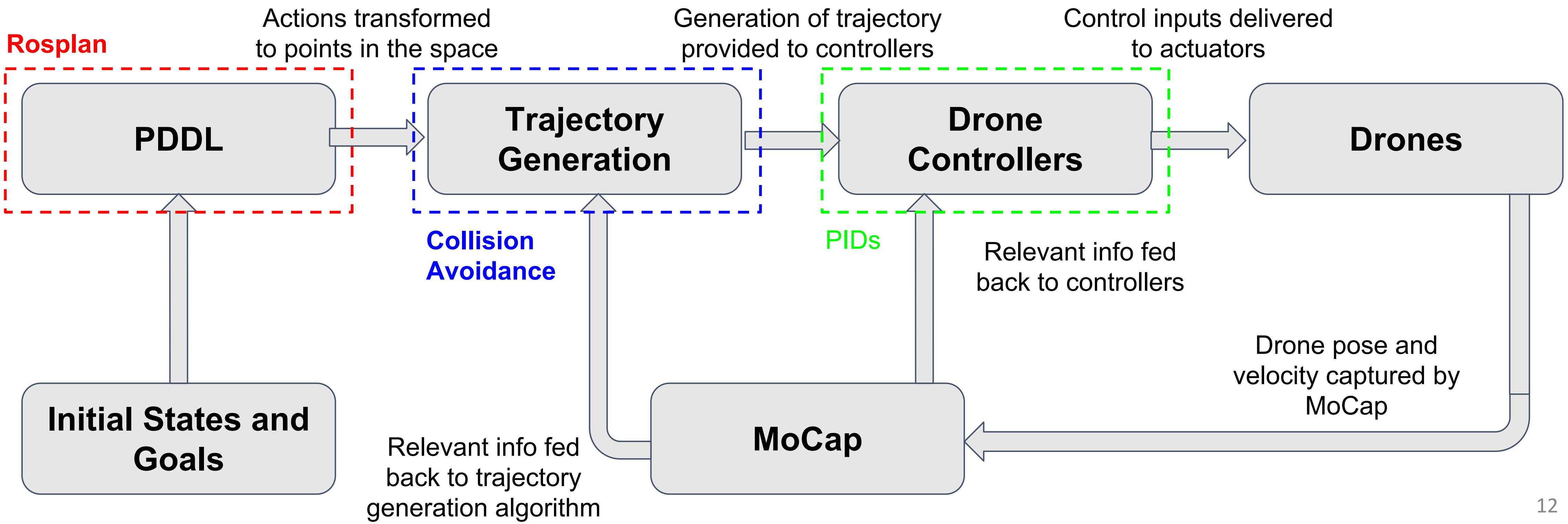


```
No semaphore facts found, returning
No analytic limits found, not considering limit effects of goal-only operators
Initial heuristic = 2.000, admissible cost estimate 0.000
b (1.000 | 0.001)(G)
; No metric specified - using makespan

; Plan found with metric 0.002
; States evaluated so far: 4
; States pruned based on pre-heuristic cost lower bound: 0
; Time 0.00
0.000: (takeoff drone1)  [0.001]
0.001: (move drone1 warehouse1 zone1)  [0.001]
0.002: (land drone1)  [0.001]

 * All goal deadlines now no later than 0.002

Resorting to best-first search
Running WA* with W = 5.000, not restarting with goal states
b (1.000 | 0.001)(G)b (0.000 | 0.002)
Problem Unsolvable
;;;; Solution Found
; States evaluated: 9
; Cost: 0.002
; Time 0.00
0.000: (takeoff drone1)  [0.001]
0.001: (move drone1 warehouse1 zone1)  [0.001]
0.002: (land drone1)  [0.001]
allansman@allansman-VirtualBox:~/catkin_ws/src$ 
```

PDDL

- In this project
  - A cost function was defined (optimization purposes)
  - Actions are: Takeoff, Land, Load, Unload and Move
  - Solver used is Optic (makes use of Cplex)
  - Plan is given in parallel to drones

Project Overview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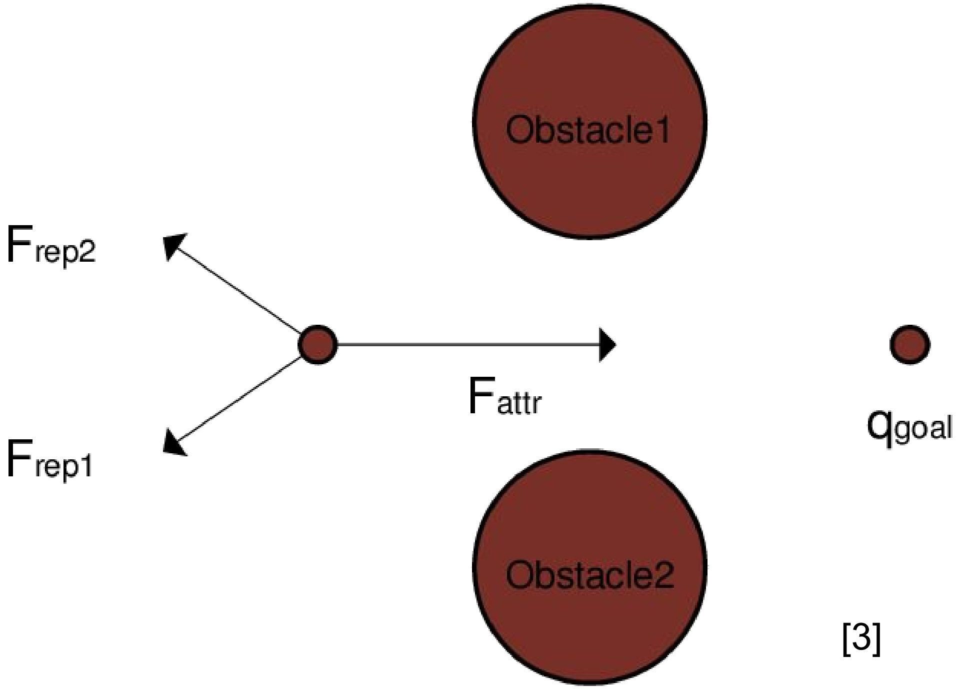
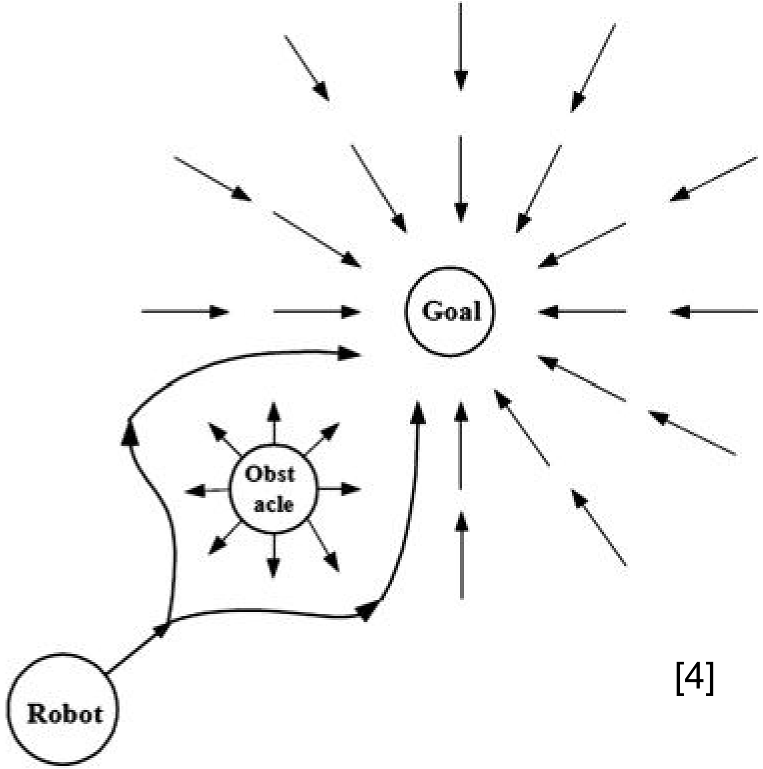
Trajectory generation

- **Originally based on the artificial potential field method [2]**



[3]



[4]

Trajectory generation

In this project:

- **Collision avoidance is included by the “repulsive term”**

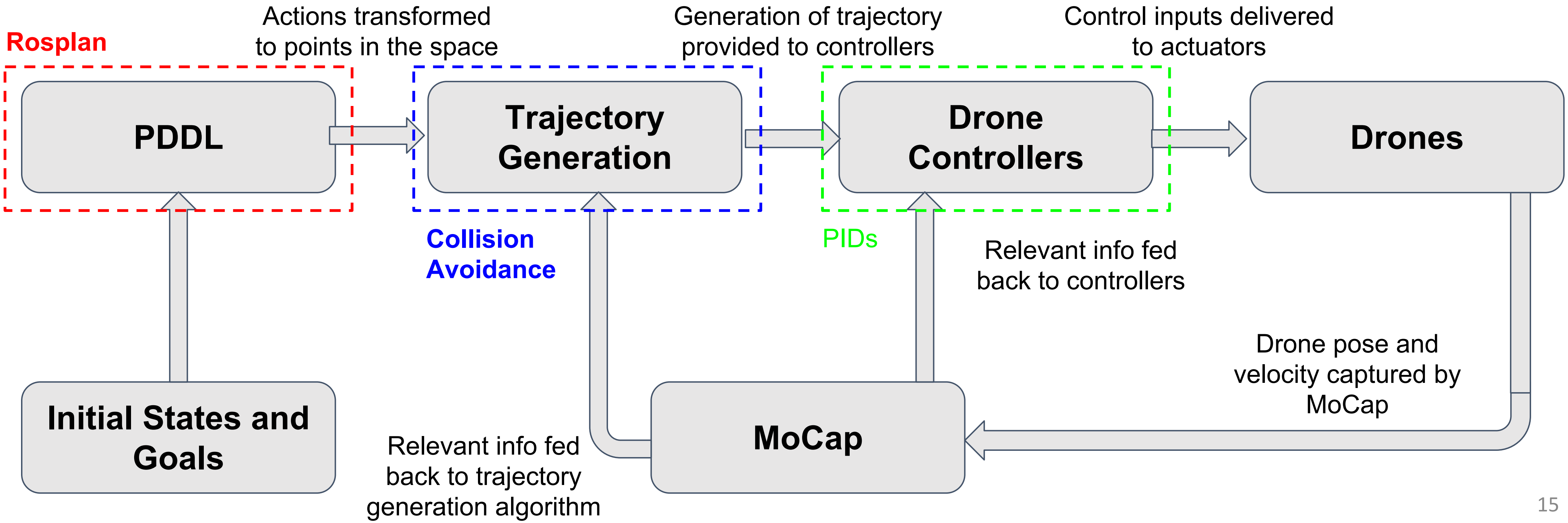
$$\sum_{combinations(i,j)} \frac{1}{Q_1||x_i - x_j||_2}$$

- **Goal attained by minimization of “attractive term”**

$$Q_2||X - X_{target}||_2$$

- **Optimizing over multiple time steps with constraints in distance**

Project Overview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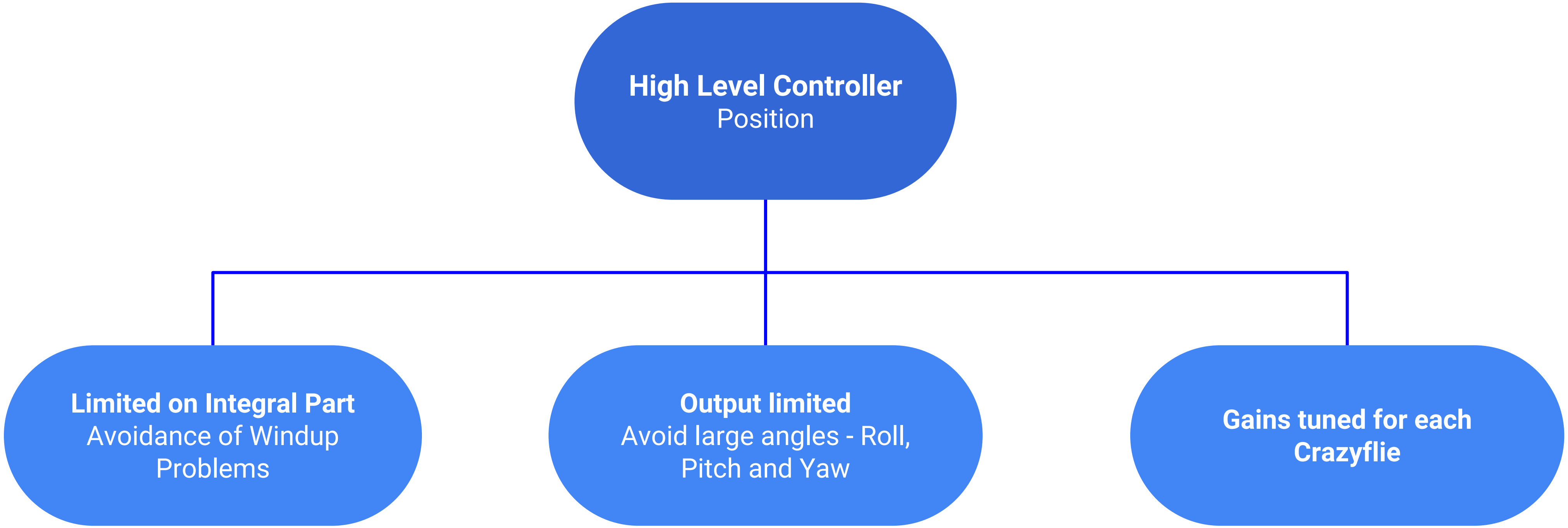
Controllers

	Low Level Controller Attitude (Roll, Pitch, Yaw)	**High Level Controller** Position
Type	PID	PID
Input	Target Attitude & Current Attitude	Target Position (Traj. gen) & Current Position (MoCap)
Output	PWM for individual motors	Yaw, Pitch, Roll - To low level controller
Frequency		30 Hz
Implementation	Controller already on Crazyflie	Controller Implemented as a ROS Node

Controllers



High Level Controller
Position

Limited on Integral Part
Avoidance of Windup Problems

Output limited
Avoid large angles - Roll, Pitch and Yaw

Gains tuned for each Crazyflie

Demonstration

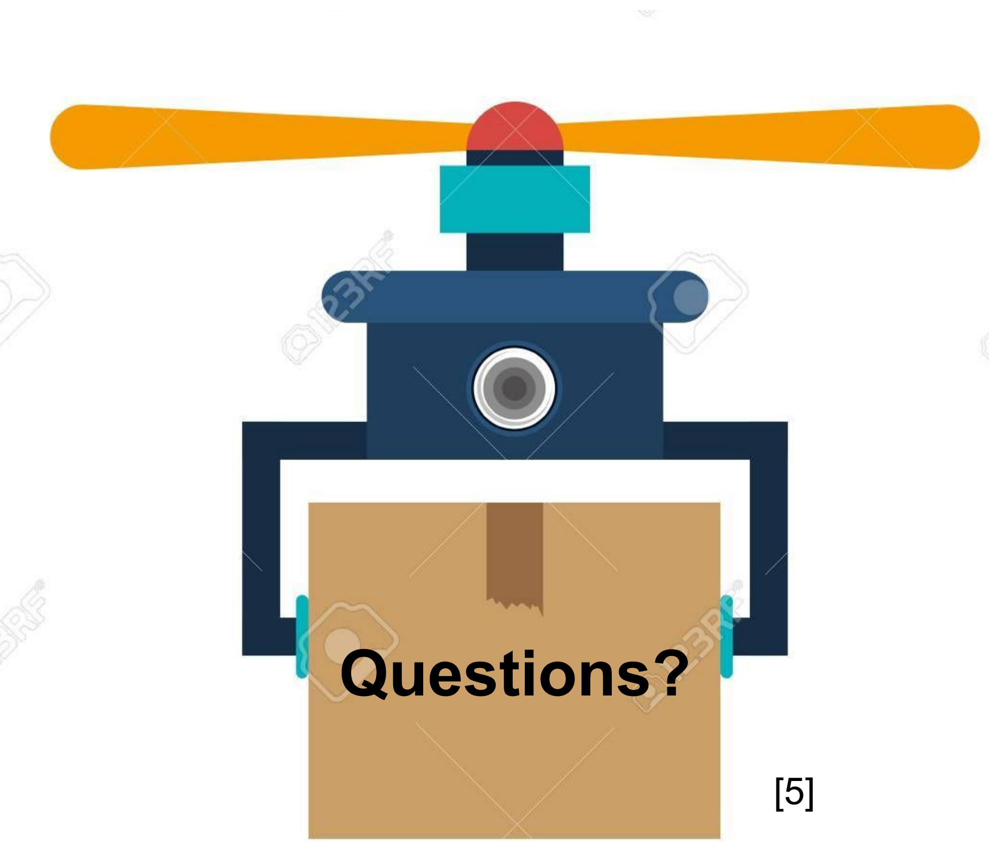
- **Today’s demonstration will be done with:**
  - 4 Drones
  - 4 Departure areas
  - 4 Rescue zones

Demonstration

Four working drones from 4 departure areas and 4 rescue zones

Thank you!

[5]



Questions?

[5]

References:

[1]-https://www.cnbc.com/2016/11/16/dominos-has-delivered-the-worlds-first-ever-pizza-by-drone-to-a-new-zealand-couple.html

[2] - http://journals.sagepub.com/doi/abs/10.1177/027836498600500106

[3]-https://www.researchgate.net/profile/Nadeem_Javaid/publication/237054021/figure/fig1/AS:393251568799747@1470769888555/Fig1-Dead-end-scenario-of-Artificial-Potential-Field-method-symmetric-obstacles.png

[4] - https://ars.els-cdn.com/content/image/1-s2.0-S1367578812000430-gr7.jpg

[5]-https://previews.123rf.com/images/grgroup/grgroup1610/grgroup161001207/63909993-drone-carrying-box-with-one-airscrew-vector-illustration-Stock-Vector.jpg

Demonstration

Slide possibly to be shown in case things don’t work as expected