캡스톤 디자인

- Path Planning

14th Week Progress

A6 Blue

2022/11/29

Path Planning

Search-based
- Dijkstra
- A* - Dijkstra + heuristic cost
- D* - Dynamic A*

Sampling-based
- RRT - Random Tree
- RRT* - RRT + rewire

Artificial Intelligence
- ANN - Artificial Neural Network
- GA - Genetic Algorithm

Our Algorithm

- Design own algorithm
  - A*, D* 기반 : 장애물 회피
- Using python & ROS
  - Simulation
- Using drone
  - 3D path planning
  - Safety distance
  - Cost function optimization

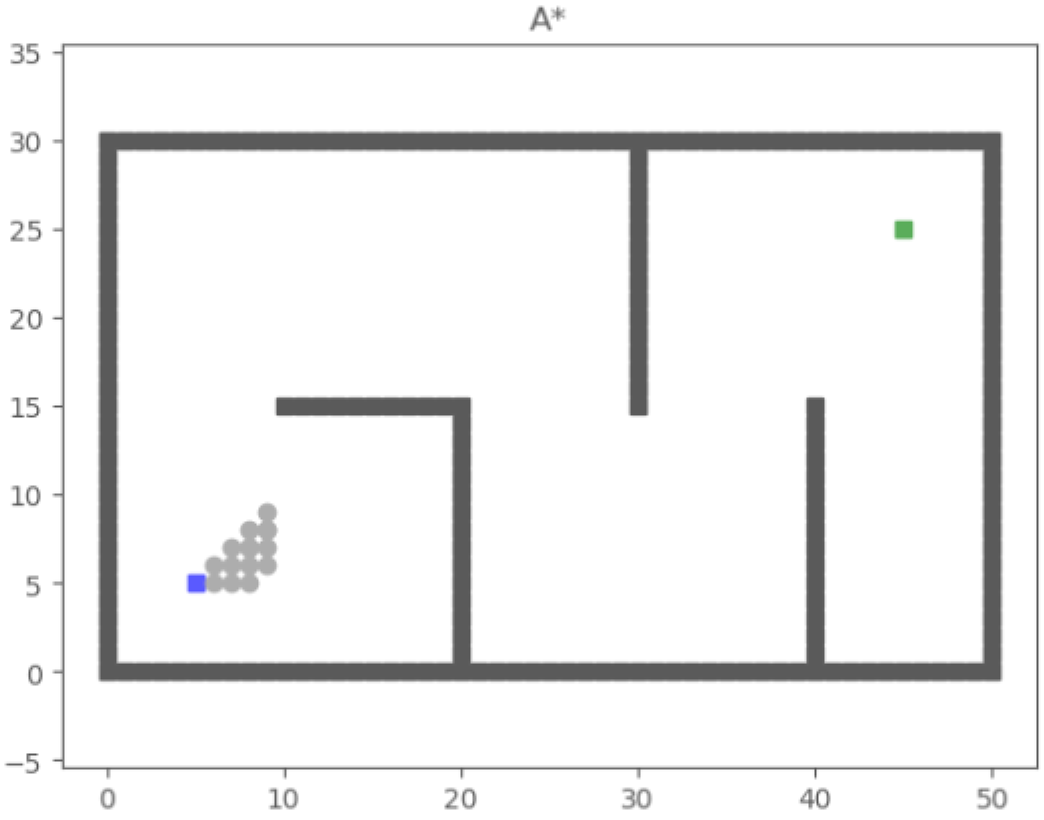
A* Algorithm

- Search-based algorithm
- Dijkstra + heuristic cost

- Cost function : f(n) = g(n) + h(n)

  g(n) : 현재 node까지의 cost

  h(n) : 현재 node부터 목표 node
  까지의 heuristic cost



A* Algorithm

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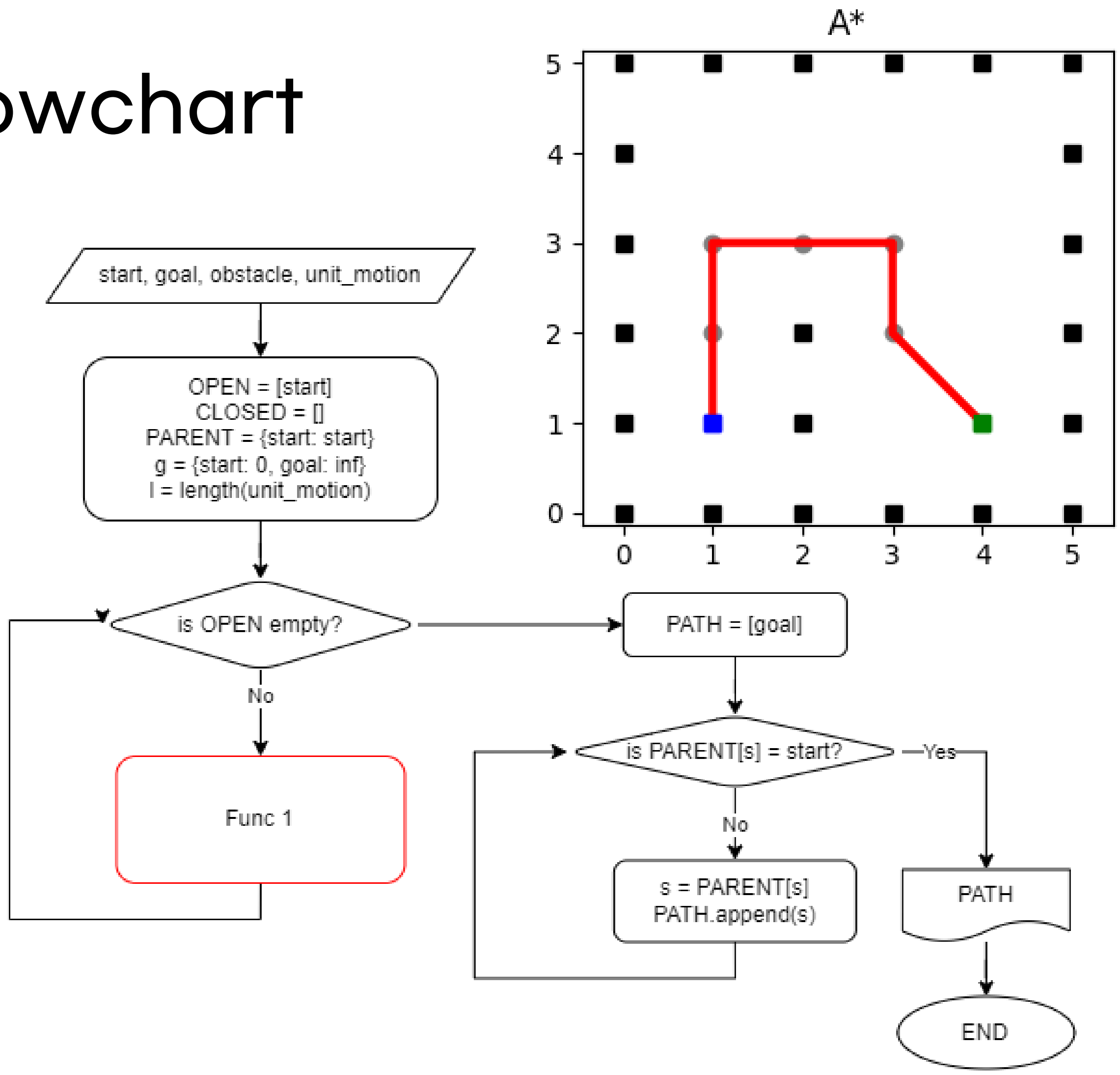
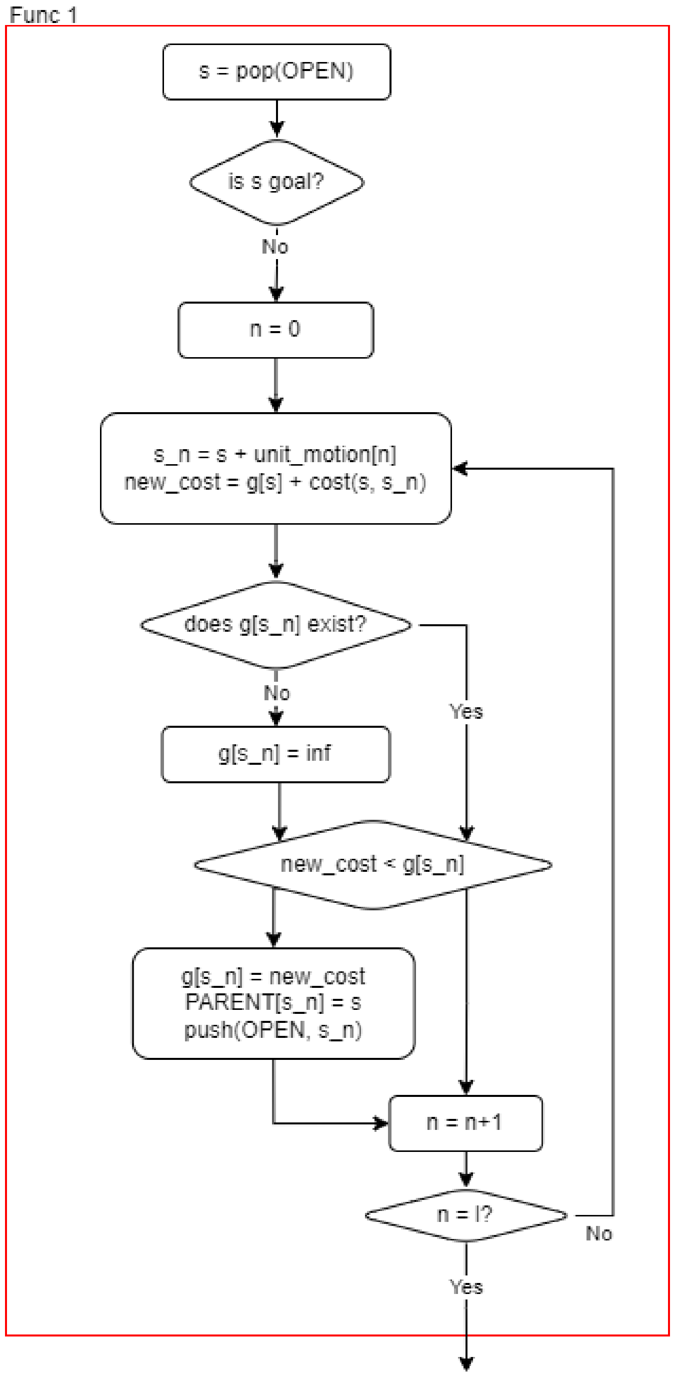
- Flowchart





2022/11/29

D* Algorithm

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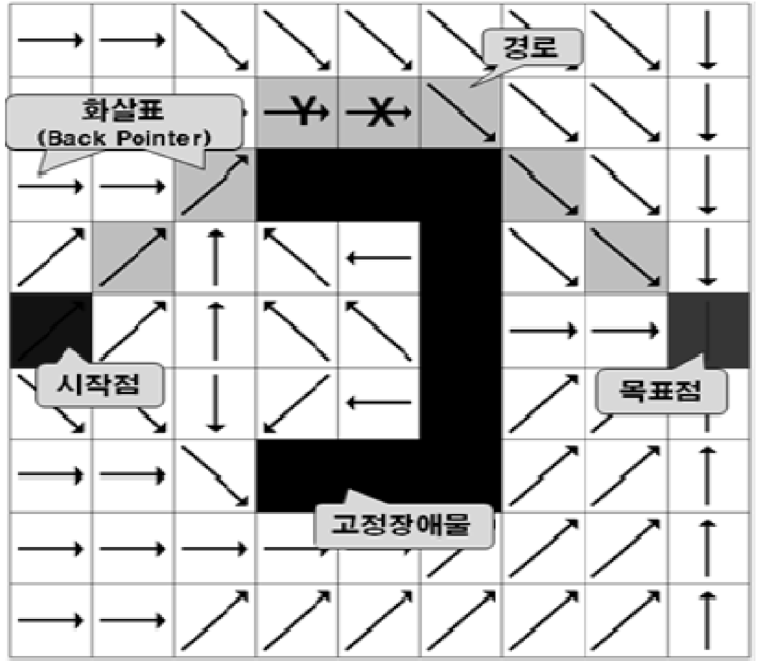
- Search-based algorithm
- Dynamic A*
- Backward searching
- Pre-mapped global map
- Bigger memory required

- Cost function : f(n) = g(n) + h(n)

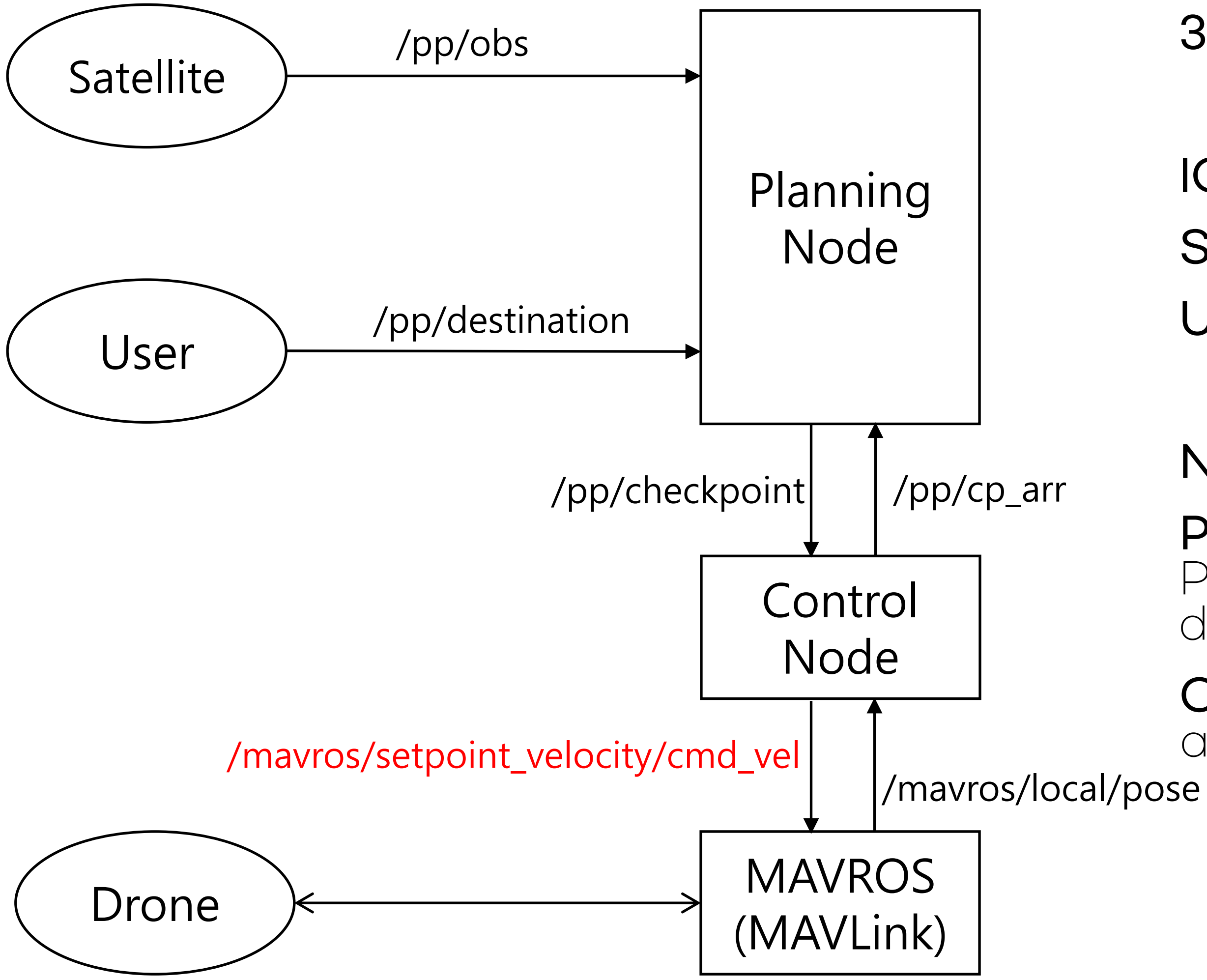
g(n) : 현재 node까지의 cost

h(n) : 현재 node부터 목표 node
까지의 heuristic cost



Development of a Navigation Control Algorithm
for Mobile Robots Using D* Search and Fuzzy Algorithm
Yun-Ha Jung, Hyo-Woon Park, Sang-Jin Lee and Moon-Cheol Won

Schematic



3 IOs / 3 Nodes / 6 Topics

IOs:

Satellite: Detect and manage obstacles

User: Set destination point

Nodes:

Planning Node: Make map with obstacle. Path planning with current position, destination and map

Control Node: Transfer control signals and arrived trigger

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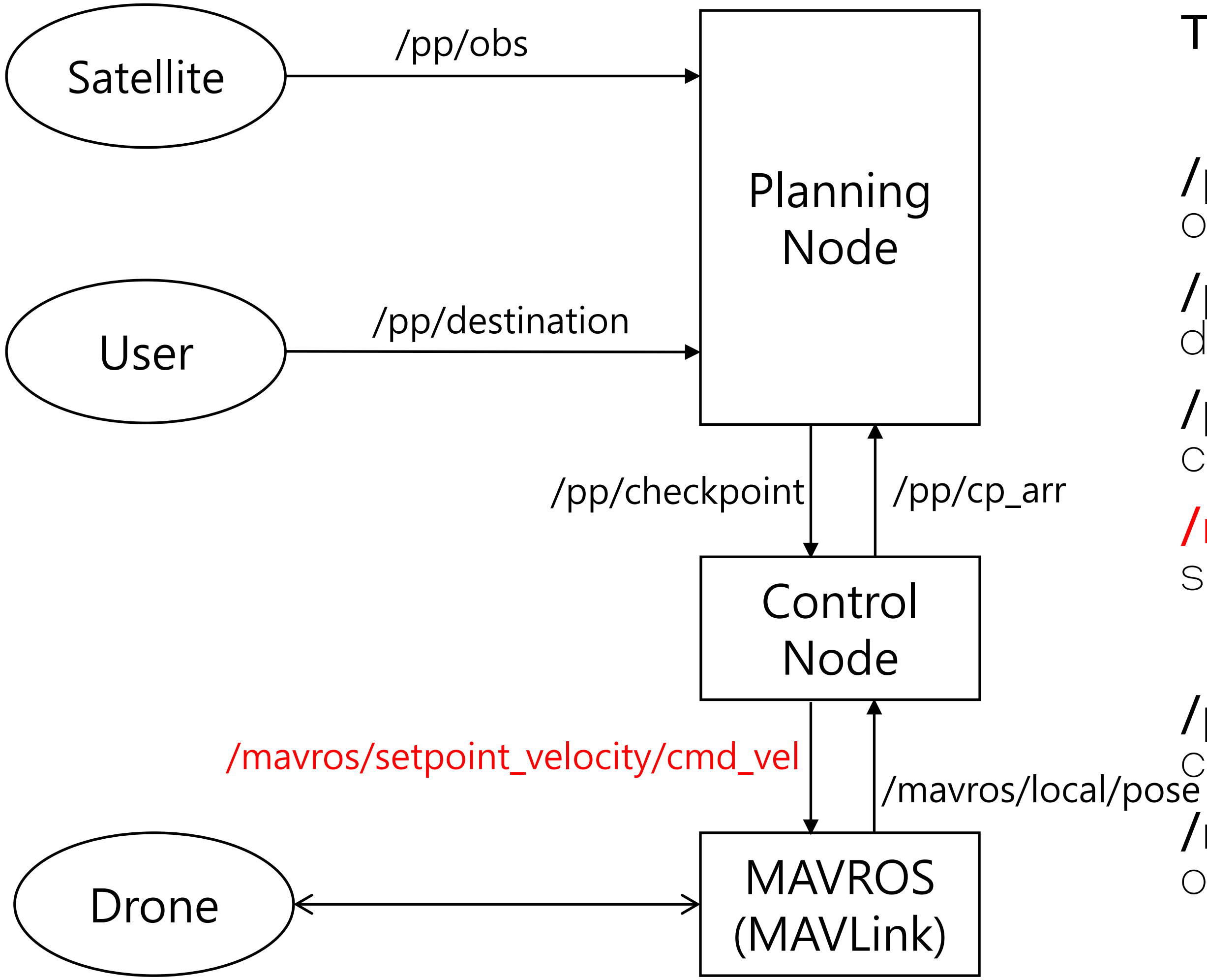
Schematic



Topics:

/pp/obs: contains array of xyz coordinates of obstacle

/pp/destination: contains xyz coordinates of destination

/pp/checkpoint: contains xyz coordinates of checkpoint, way to destination

/mavros/setpoint_velocity/cmd_vel: contain s xyz velocity signal to checkpoint

/pp/cp_arr: contains bool if drone arrived checkpoint

/mavros/local/pose: contains xyz coordinates of drone's local position

Simulation(problem)

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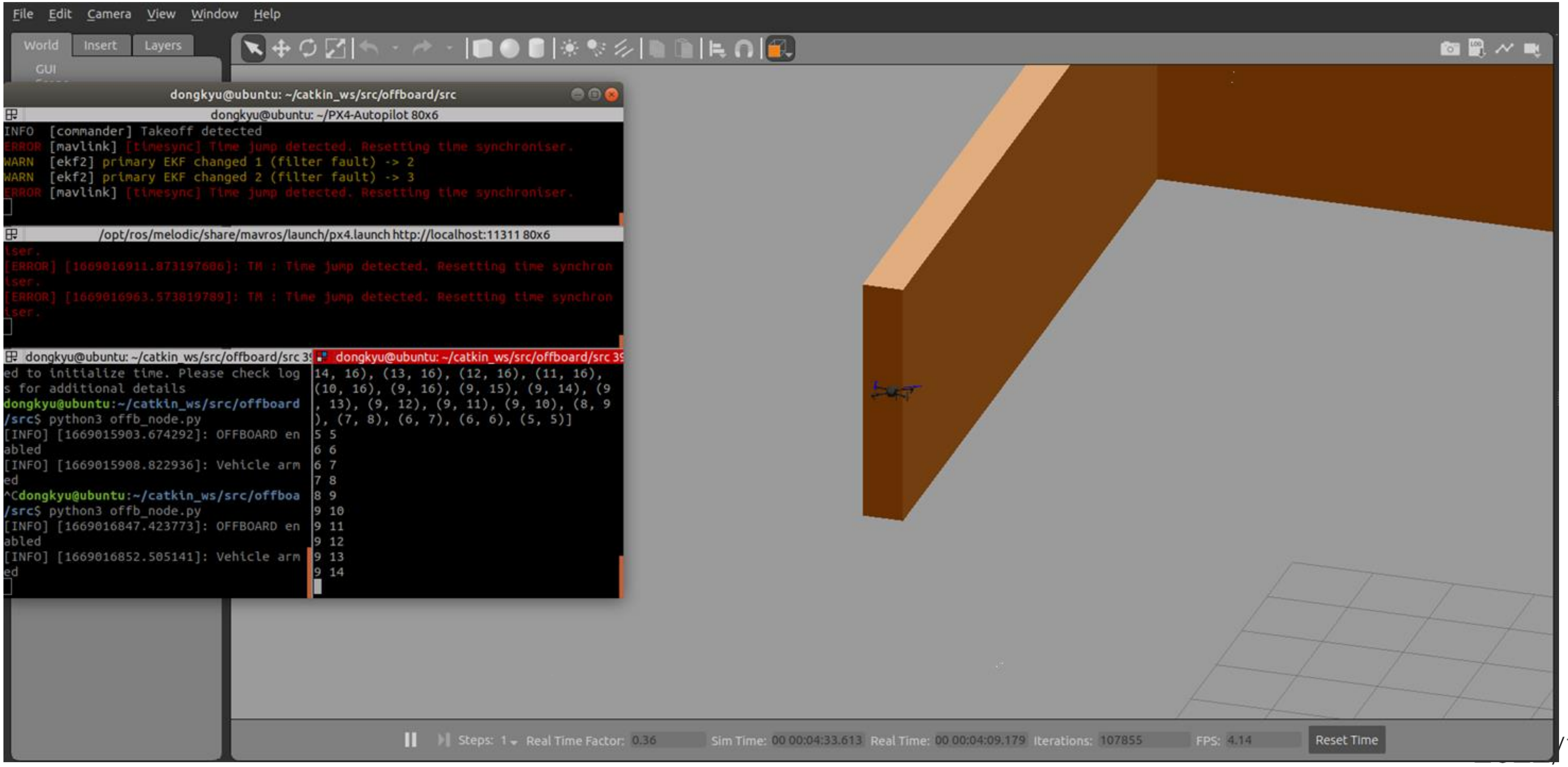
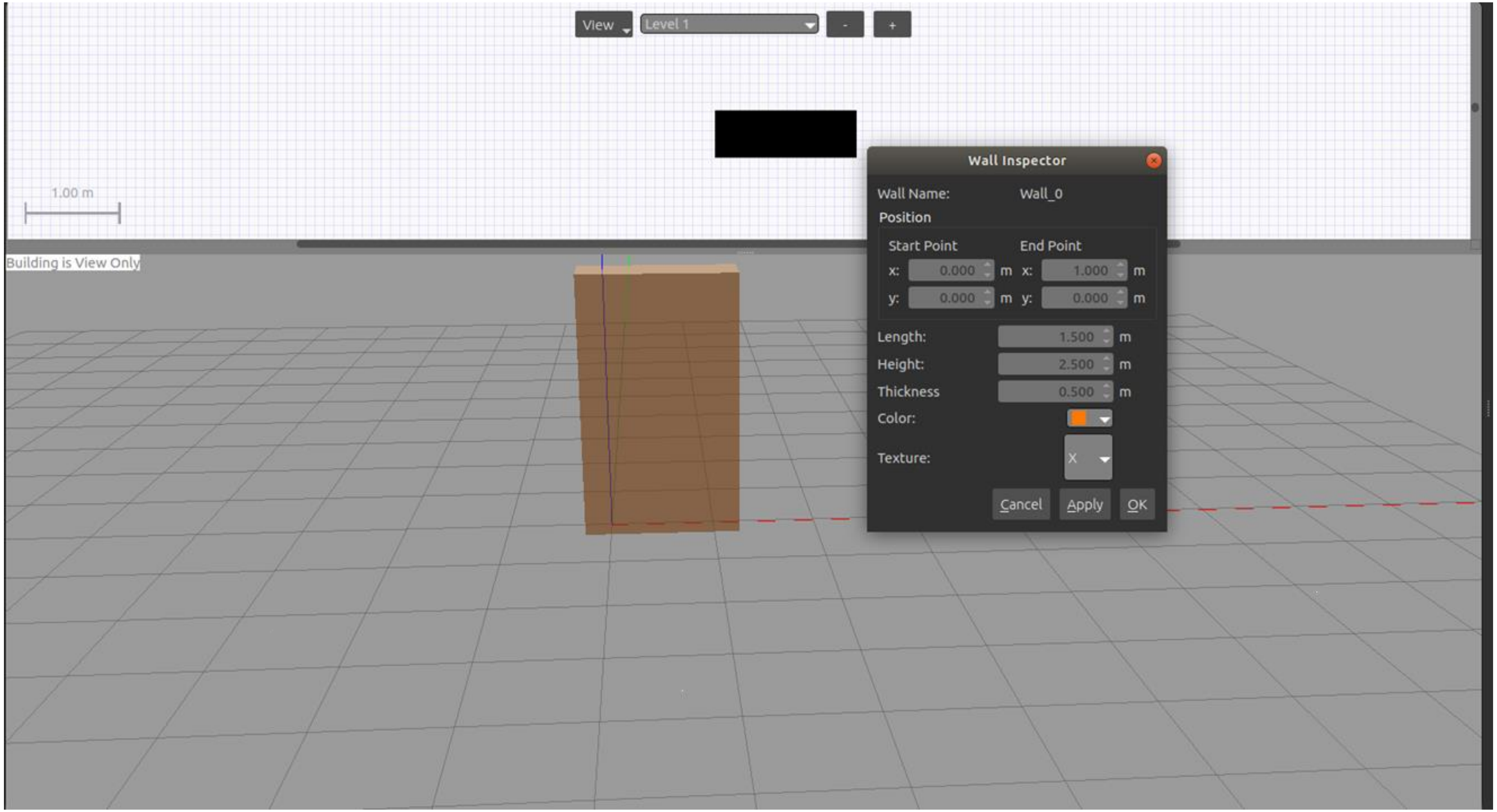
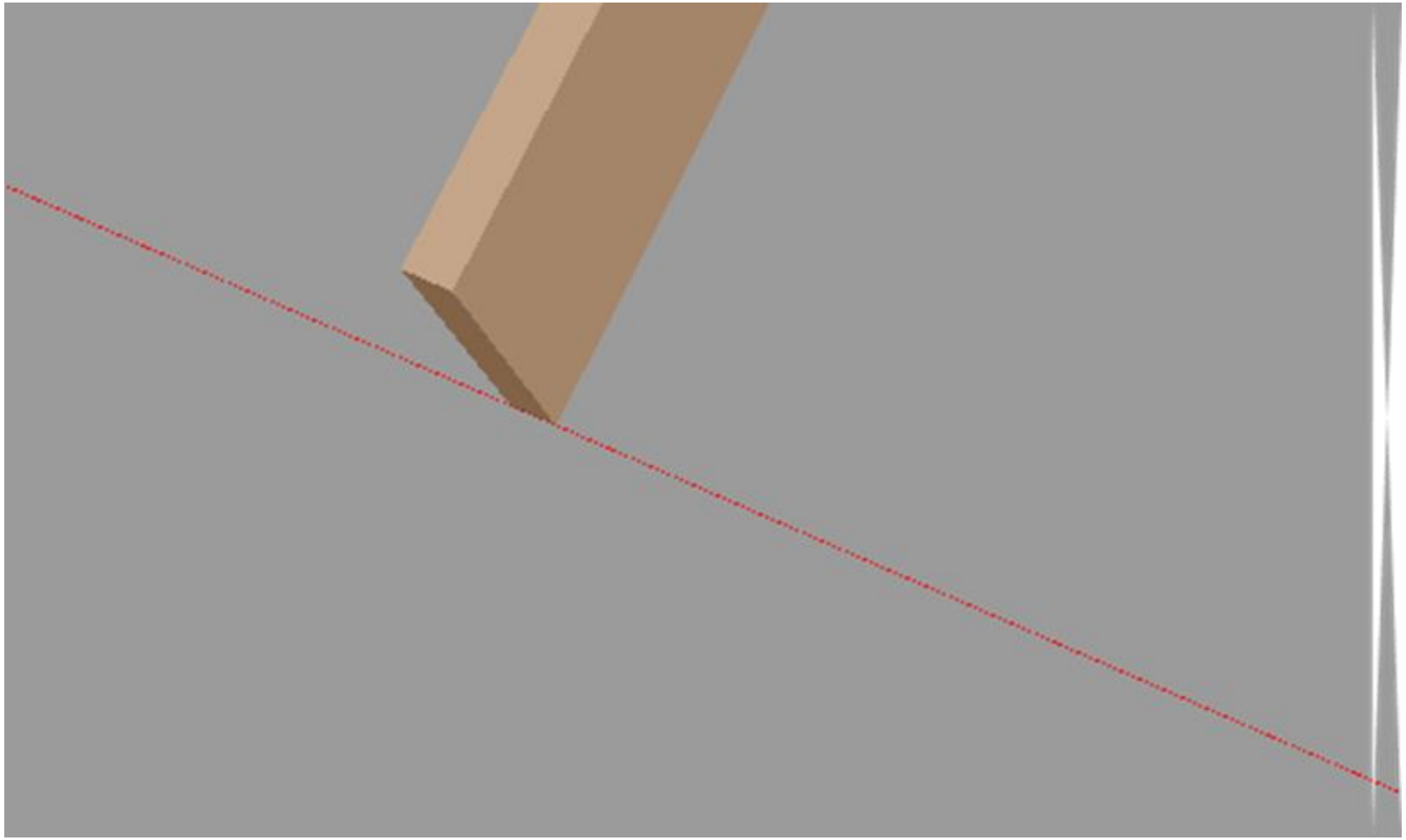


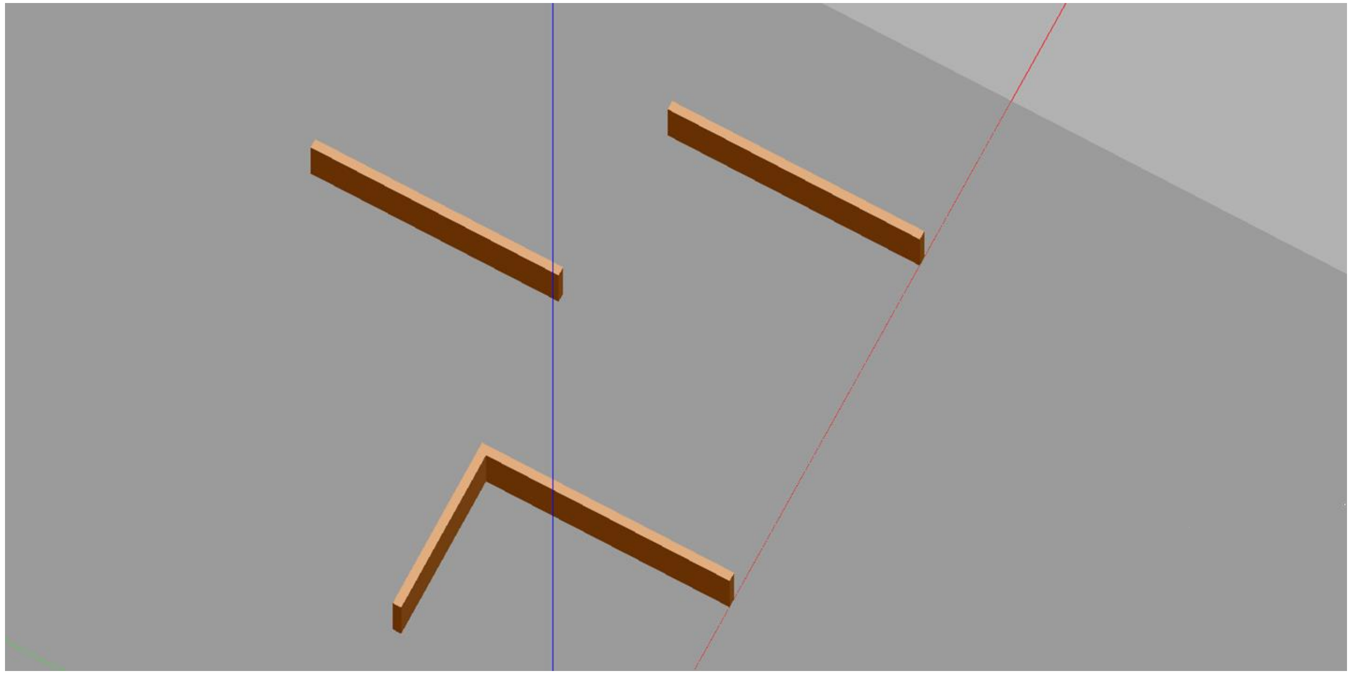
Simulation

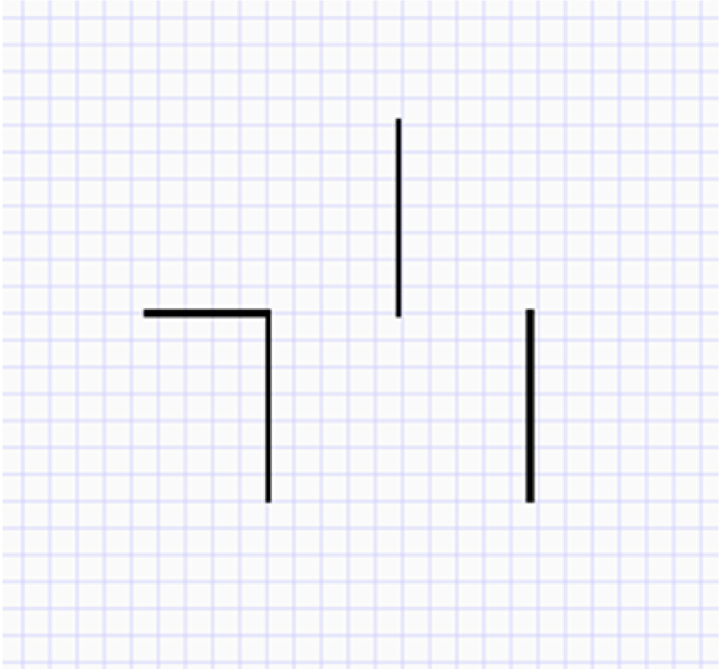

View
Level 1
-
+
1.00 m
Building is View Only
Wall Inspector
Wall Name: Wall_0
Position
Start Point
End Point
x: 0.000 m
y: 0.000 m
x: 1.000 m
y: 0.000 m
Length: 1.500 m
Height: 2.500 m
Thickness 0.500 m
Color:
Texture:
Cancel
Apply
OK

Simulation

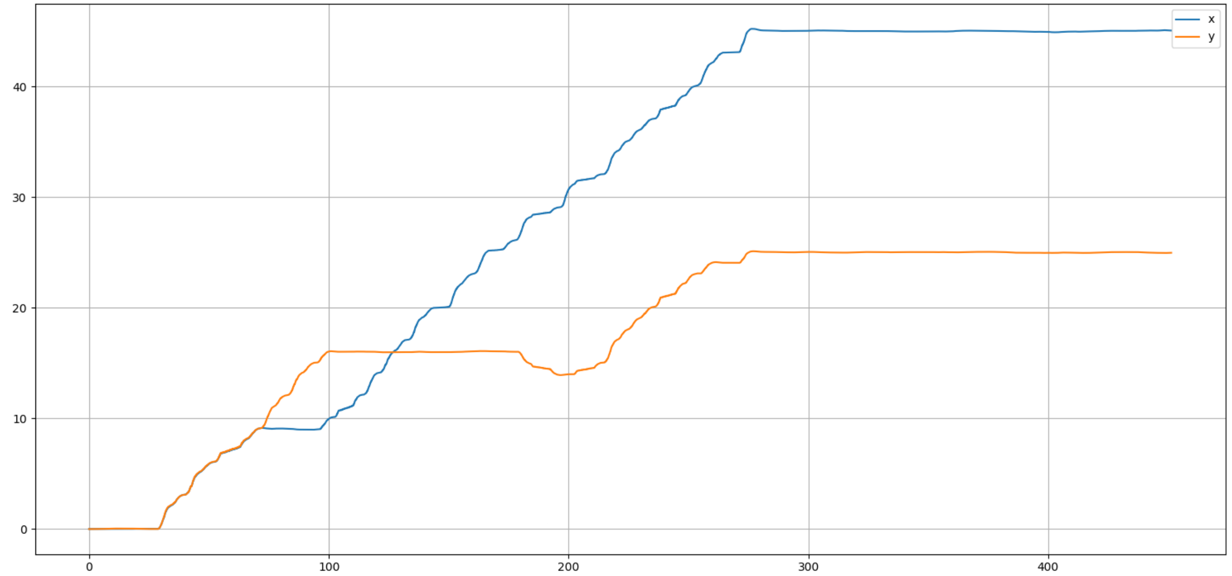


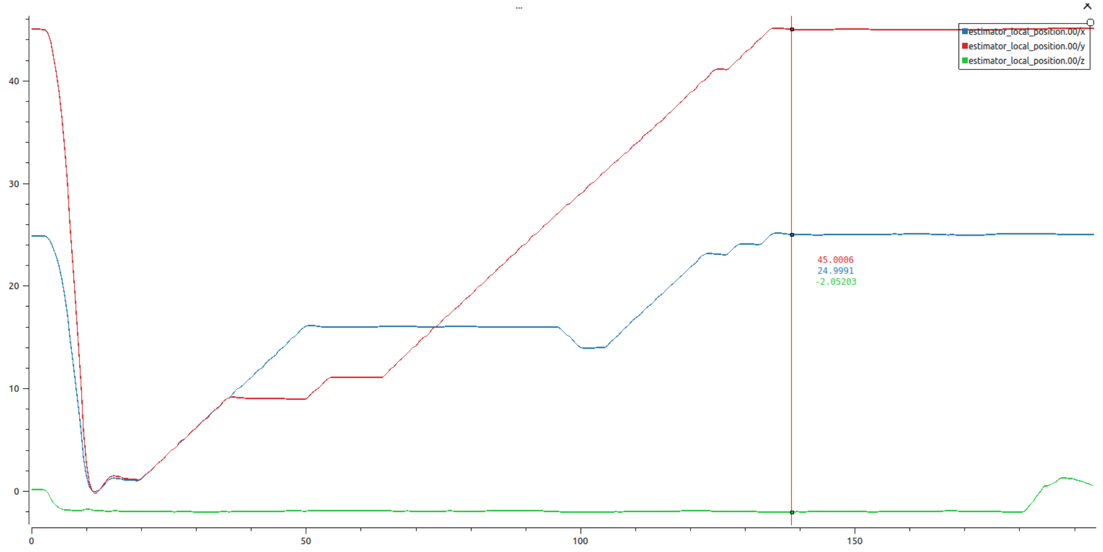
Simulation



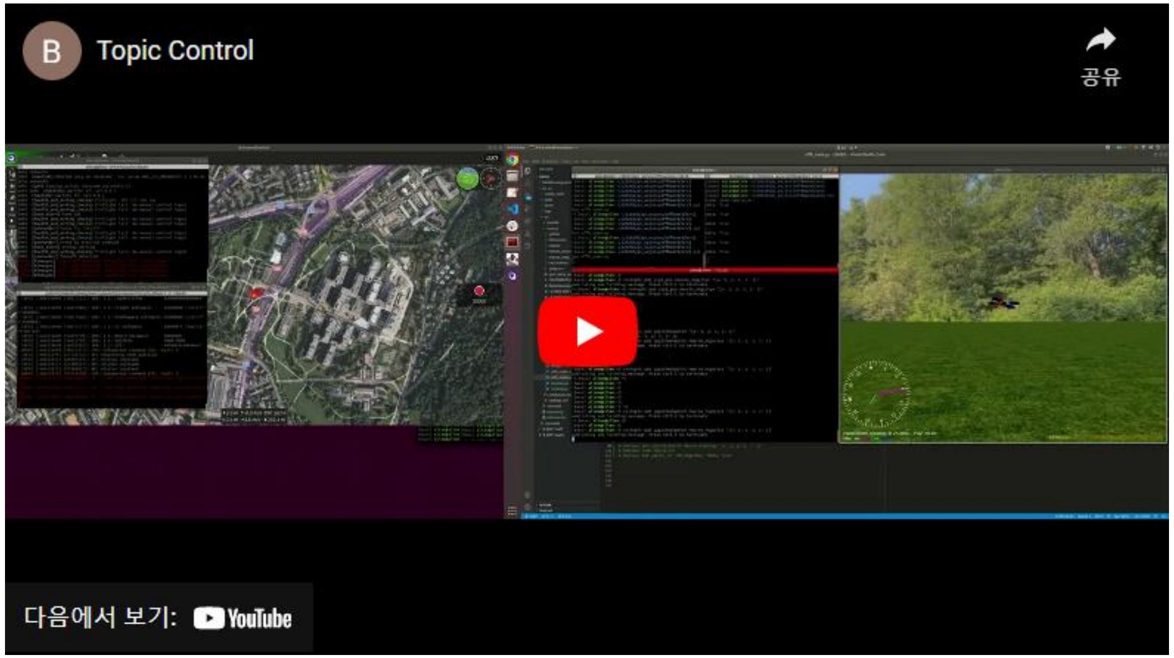


Simulation(result)





Control



Achievements:

PD control implemented:

- input : checkpoint, local position
- output : arrived signal, velocity

ROS embedded:

- Works with ROS embedded planning node
- input : /mavros/local/pose, /pp/checkpoint
- output : /mavros/setpoint_velocity/cmd_vel, /pp/cp_arr

Drone controllable via planning node

Sends /pp/cp_arr

- True if distance between checkpoint and current position is under particular distance

Prevent overshooting

- PD-control with x, y velocity

Control(Overshooting)

Solutions:

1. Step position input(default)
2. Sigmoid position input
3. Velocity control, P-control
4. Velocity control, PD-control

Keypoints:

1. Faster response
2. Reduce overshoot (≈0%)
3. Reduce stuttering
4. Minimize acceleration

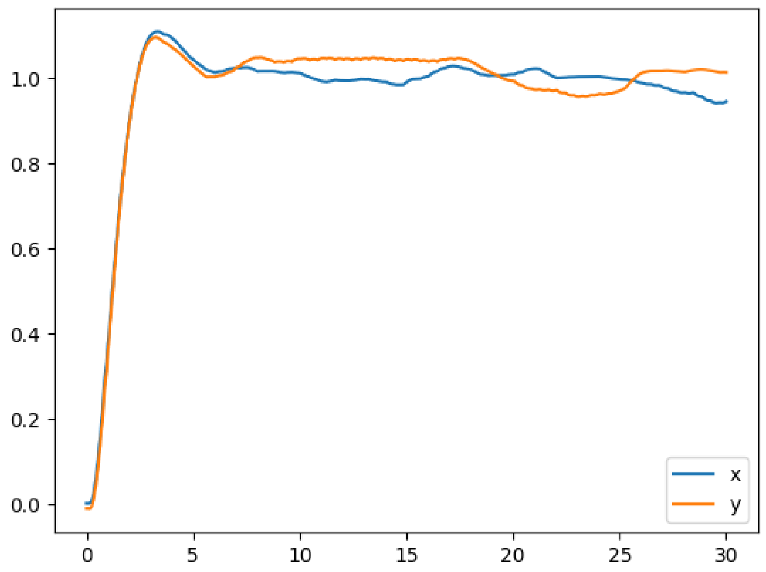
Control(Overshooting - default step position input)

1. Step position input(default)

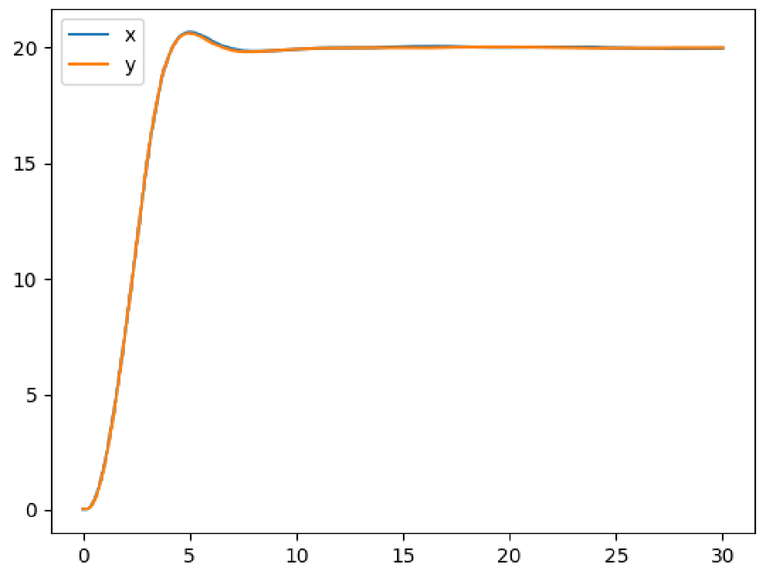
About 15% overshoot occurs in unit step input.

About 10% overshoot occurs in 20 step input.

Settling time: about 7s



Step input, x, y=1

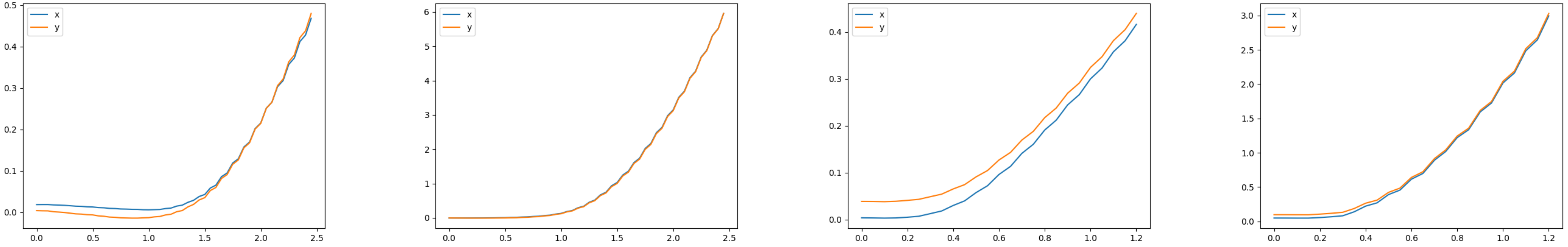


Step input, x, y=20

Control(Overshooting - sigmoid position input)

2. Sigmoid position input(logistic function)

Response time with logistic position input is too long



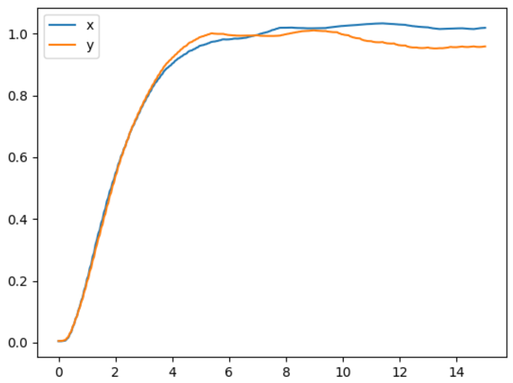
Control(Overshooting - P-controlled velocity)

3. Velocity control, P-control

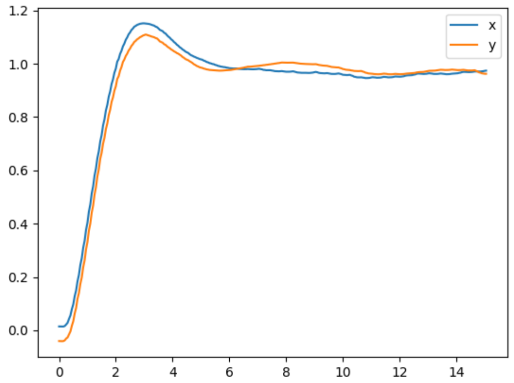
No overshoot occurs with p=0.5

About 15% overshoot occurs with p=1

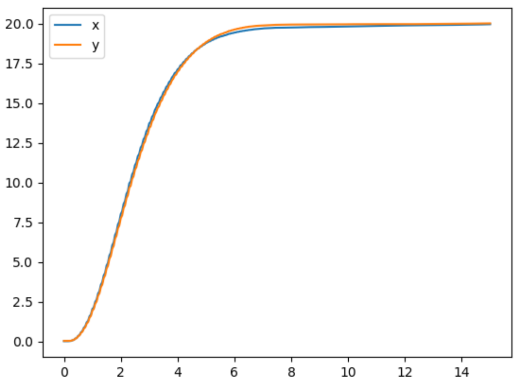
Settling time = 5~6s on both p=0.5 and p=1



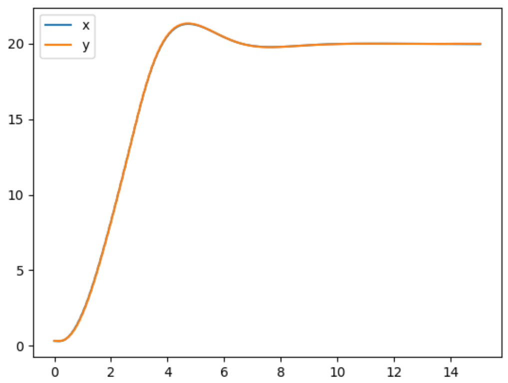
P=0.5, x, y=1



P=1, x, y=1



P=0.5, x, y=20



P=1, x, y=20

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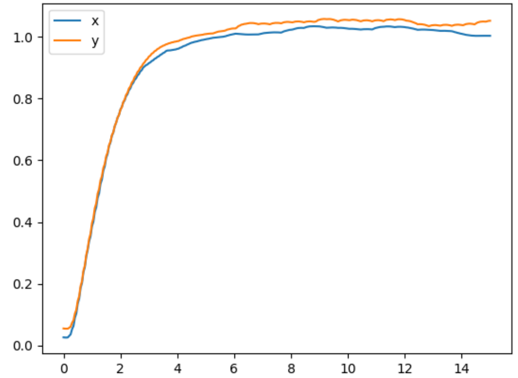
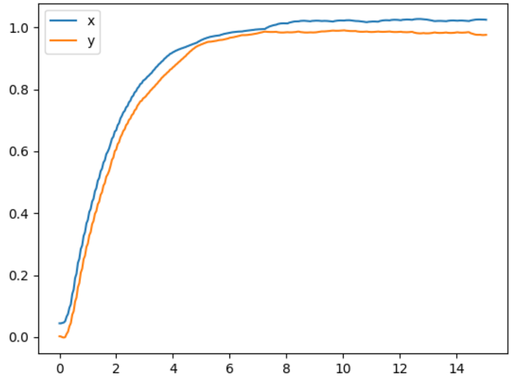
Control(Overshooting - PD-controlled velocity)

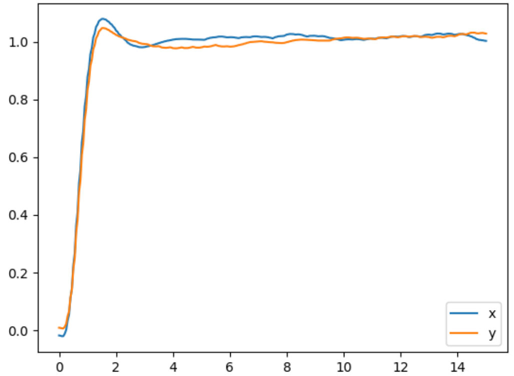
4. Velocity control, PD-control



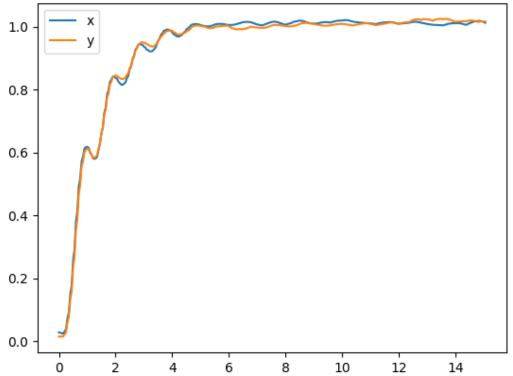
P=1, D=200, (1)



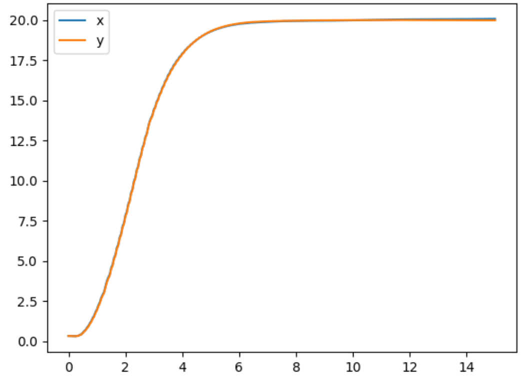
P=1, D=400, (1)



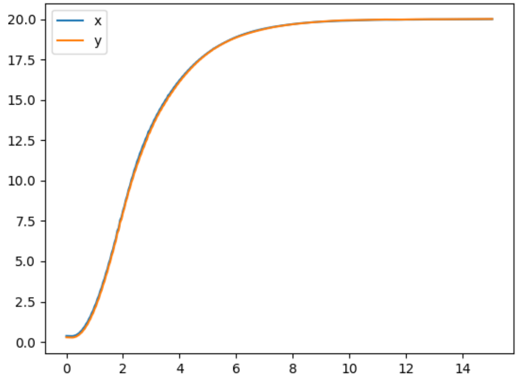
P=3, D=400, (1)



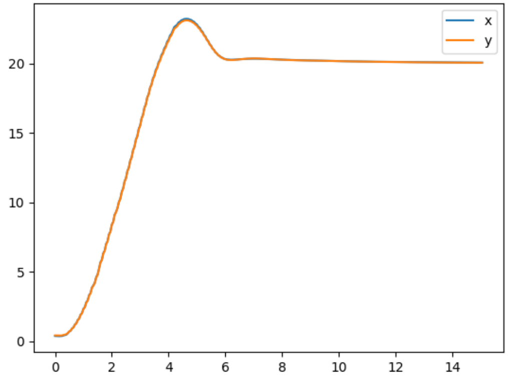
P=3, D=1000, (1)



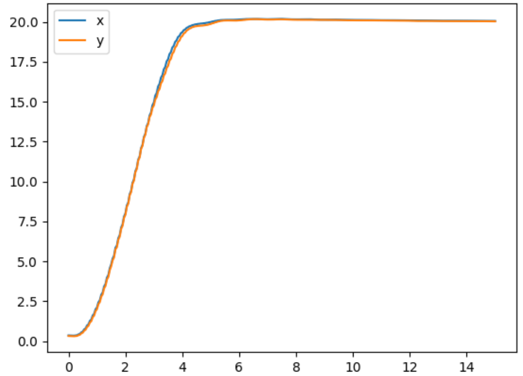
P=1, D=200, (20)



P=1, D=400, (20)



P=3, D=400, (20)



P=3, D=1000, (20)

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Control(Overshooting - PD-controlled velocity)

4. Velocity control, PD-control

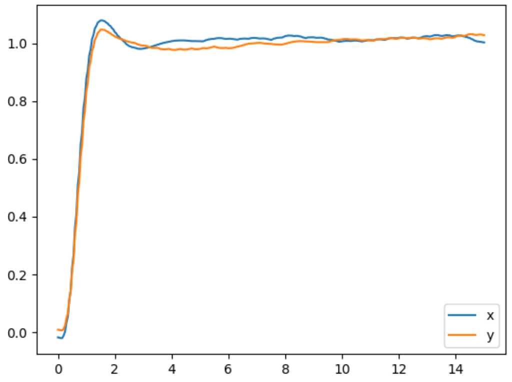
No overshoot occurs with p=1

Faster settling time and response time with p=3

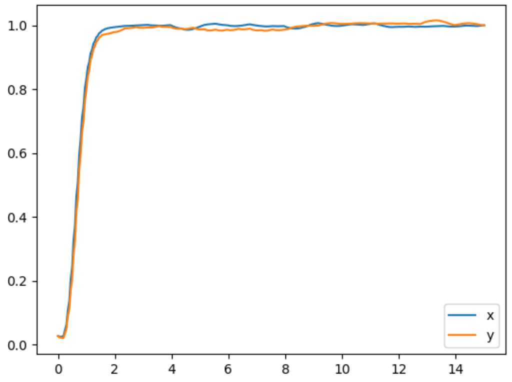
Stuttering occurs with large d(=1000) for small distance

=> p=3, d=1000 shows best performance for large distance

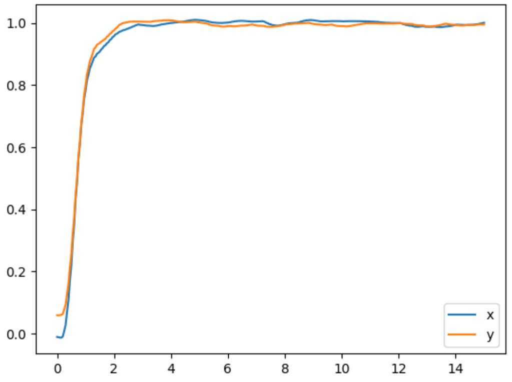
-> find optimal d parameters with p=3 for small distance



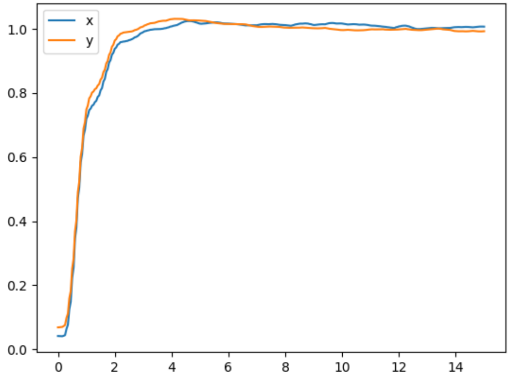
P=3, D=400, (1)



P=3, D=500, (1)



P=3, D=600, (1)



P=3, D=700, (1)

=> p=3, d=500 shows best performance for large distance

Planning

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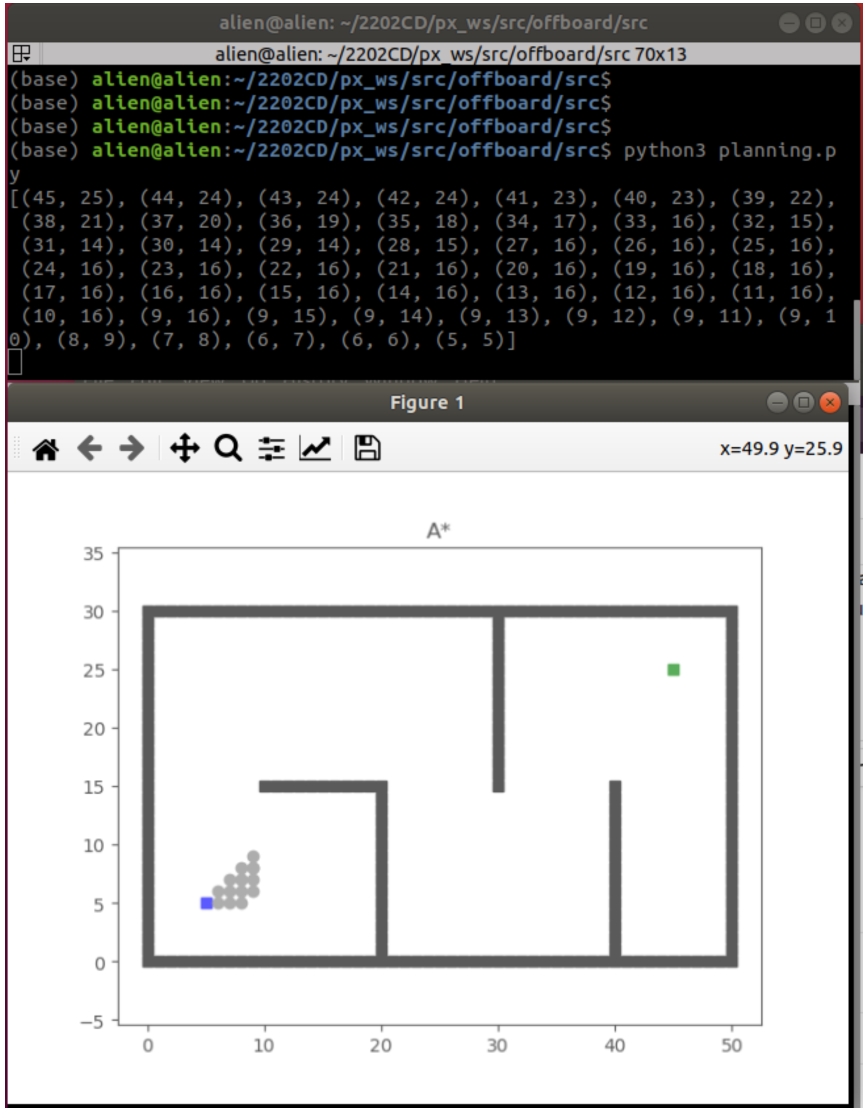


Achievements:

A* algorithm implemented

- input : map, start, destination
- output : route to destination

ROS embedded

- input : /pp/map, /pp/destination, /pp/cp_arr, /pp/obs
- output : /pp/checkpoint

Dynamic mapping(continuous A*)

- Update map with A* when obstacle detected

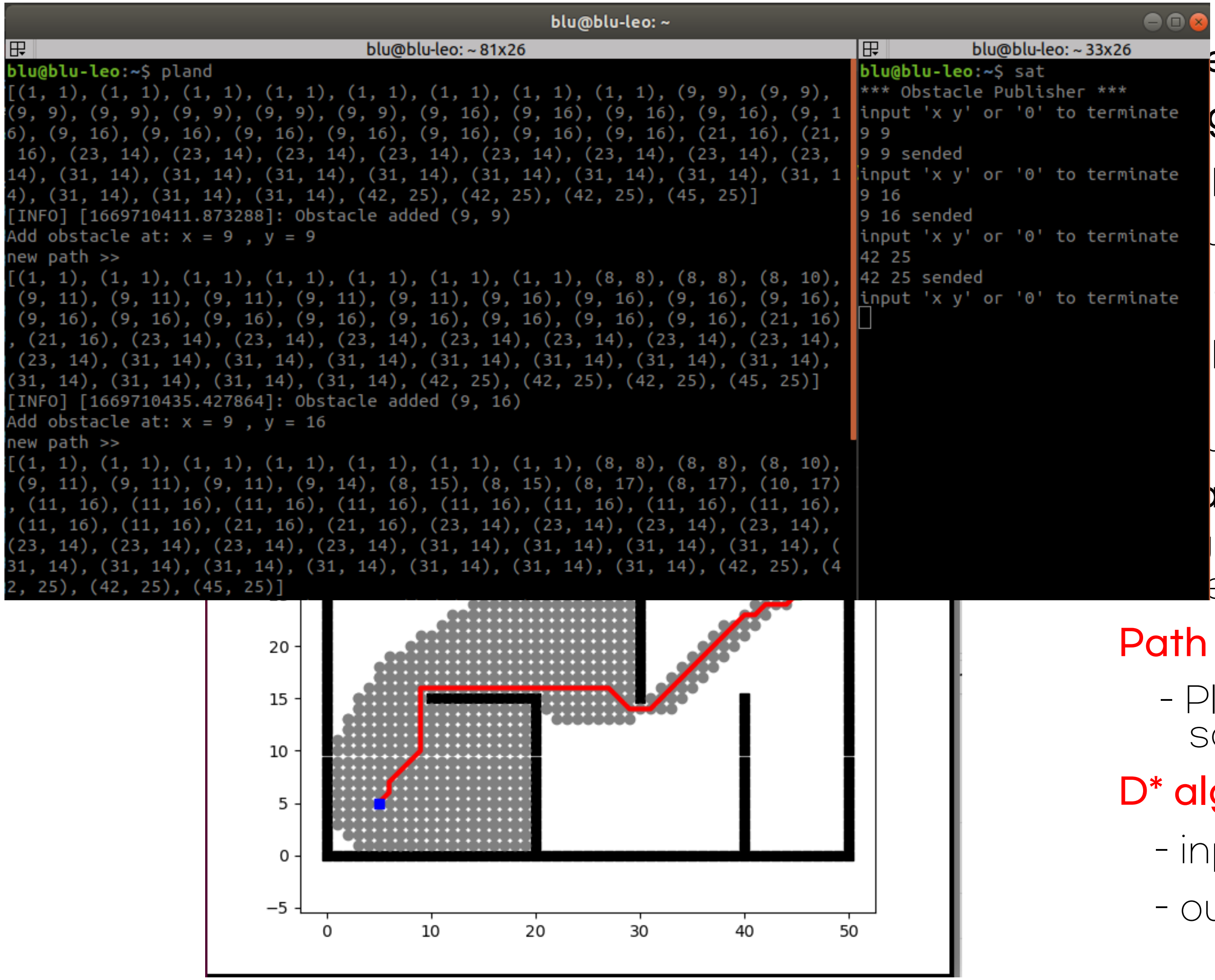
Path simplification

- Planning node simplifies the path along same direction

D* algorithm implemented

- input : map(+obstacles), start, destination
- output : route map to destination

Planning(Dynamic)



evements:

gorithm implemented

put : map, start, destination

utput : route to destination

embedded

put : /pp/map, /pp/destination, /pp/cp_arr, /pp/obs

utput : /pp/checkpoint

amic mapping(continuous A*)

pdate map with A* when obstacle etected

Path simplification

- Planning node simplifies the path along same direction

D* algorithm implemented

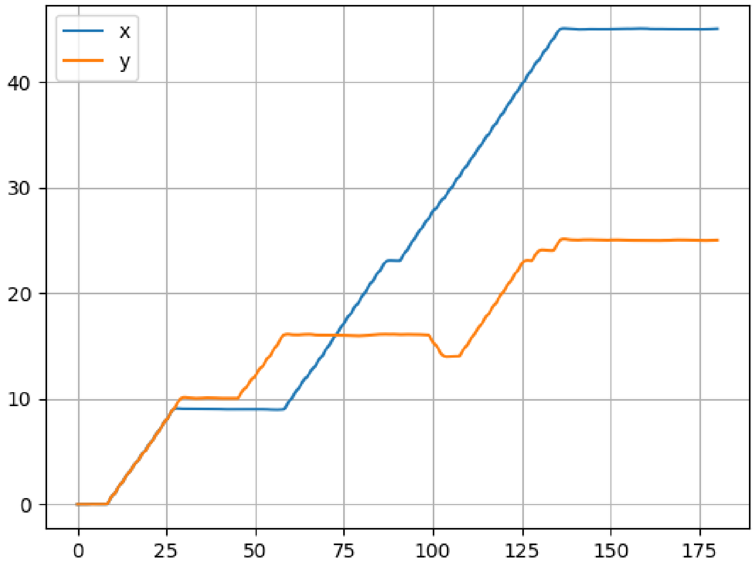
- input : map(+obstacles), start, destination
- output : route map to destination

Planning(Path simplification)

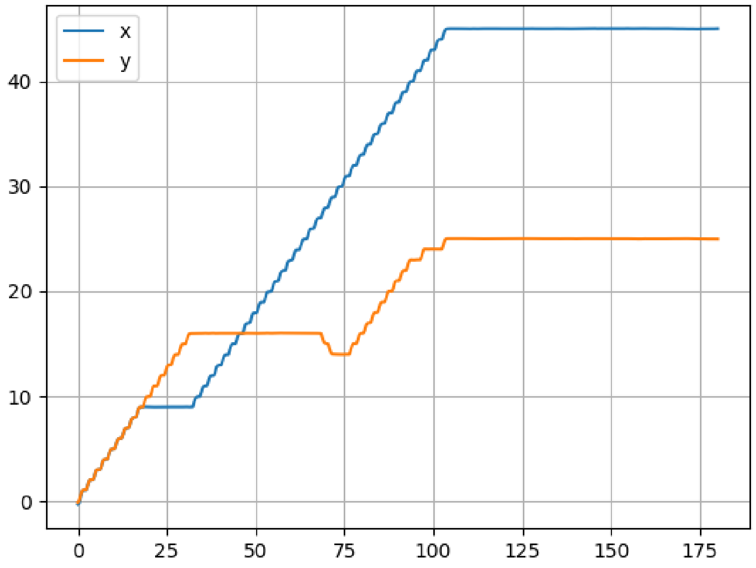
Why is path simplification required?

To prevent overshoot and to improve response time, PD-control applied.

But path with unit length(1 or 1.41) made drone continuously stops on each checkpoints.



Step input(default)



PD-control

-> Response time shortened with PD-control: 130s -> 110s

--> Apply path simplification: Planning node simplifies the path along same direction

Planning(Path simplification)

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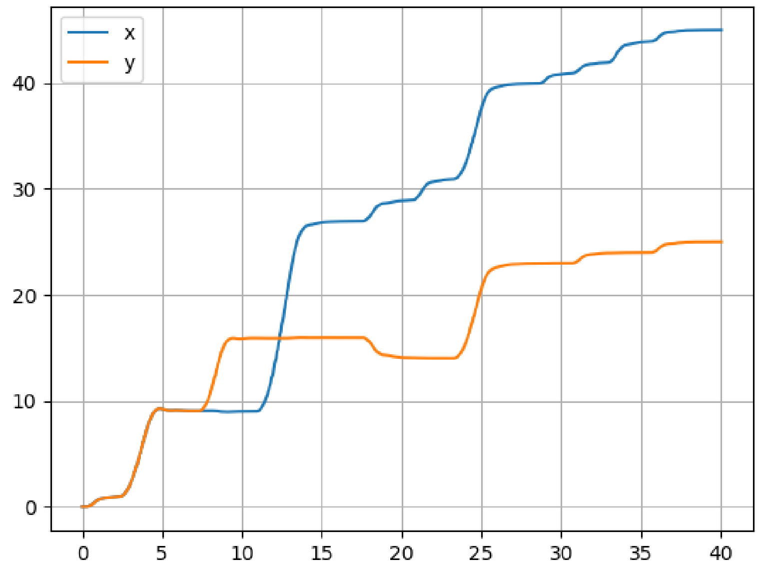
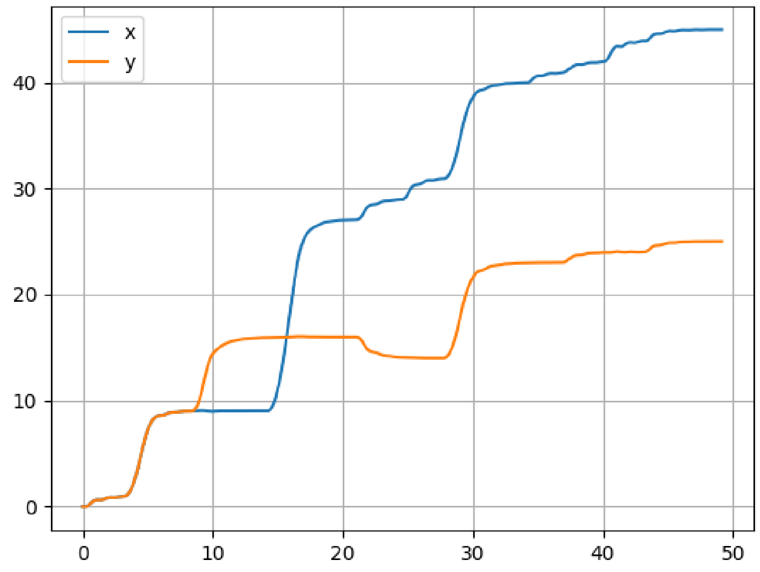
Path simplification made checkpoints with large distance; PD parameters had to changed
P=3, D=700 / P=3, D=1000 showed best performances.



P=3, D=700(simple)
(video)



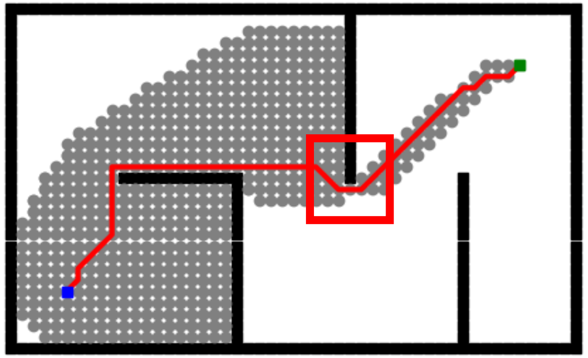
P=3, D=1000(simple)
(video)

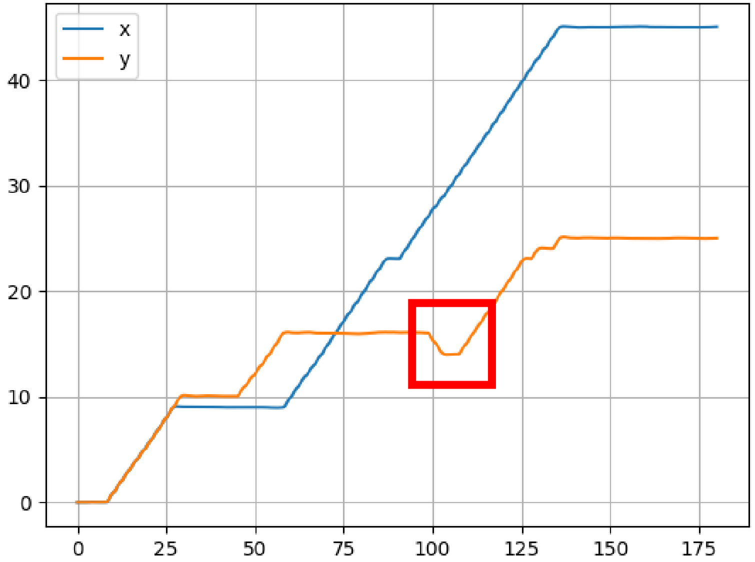
=> Response time shortened with simplification: 110s->37s, 45s

=> No stop-and-go occurred.

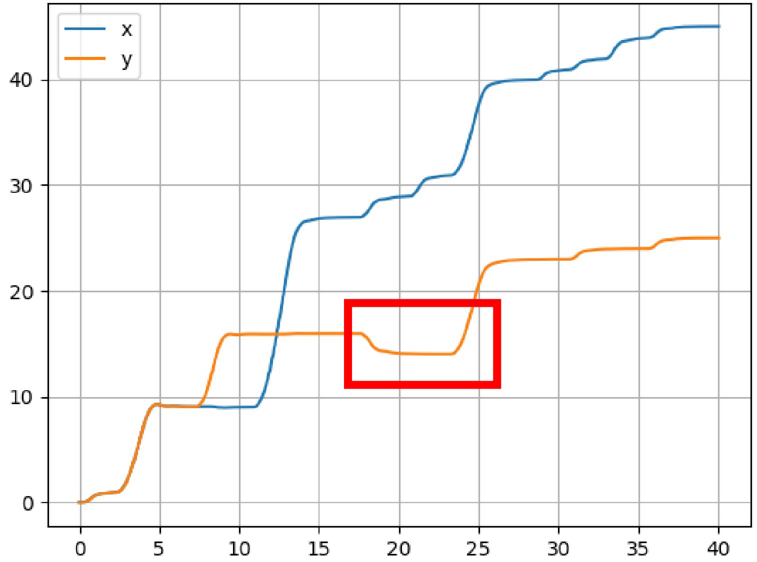
Planning(Path simplification - comparison)

Comparison between step and PD simplified control.





Step input(default)



P=3, D=700(simple)

Linear motion is faster with PD-simplified, zig-zag motion is faster with step position control. .

Demo

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