Sheet 1
Models and Robot Odometry

Group 3
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Exercise 1

a) What is the state space of the quadrocopter?

$$\vec{x} = \begin{pmatrix} x \\ y \\ z \\ \phi \\ \theta \\ \psi \end{pmatrix}$$

x, y, z are the 3D position, and ϕ, θ, ψ are the orientation of the quadrocopter.

b) Define the odometry vector of the (AR.Drone) quadrocopter.

$$\vec{u_t} = \begin{pmatrix} v_x \\ v_y \\ z \\ \phi \\ \theta \\ \psi \end{pmatrix}$$

v_x, v_y are the velocities in the x and y direction referring to the quadrocopter's local frame; z is its distance to the ground.[1]
ϕ, θ, ψ are the orientation of the quadrocopter referring to the global frame.

c) Specify the odometry model

The update function:

$$\vec{x_t} = \begin{pmatrix} x_t \\ y_t \\ z_t \\ \phi_t \\ \theta_t \\ \psi_t \end{pmatrix} = \begin{pmatrix} x_{t-1} + v_{global\_x} * \Delta t \\ y_{t-1} + v_{global\_y} * \Delta t \\ z_t \\ \phi_t \\ \theta_t \\ \psi_t \end{pmatrix}, \begin{pmatrix} v_{global\_x} \\ v_{global\_y} \\ v_{global\_z} \end{pmatrix} = R(\phi_t, \theta_t, \psi_t) \begin{pmatrix} v_x \\ v_y \\ v_z \end{pmatrix}$$

Δt is the time period between two time steps. $R(\phi_t, \theta_t, \psi_t)$ is the rotation matrix calculated from yaw, pitch and roll.

Exercise 2

b) Replay the bag files and inspect the topics.

Which topics are there?

/ardrone/camera_info
/ardrone/image_raw
/ardrone/navdata
/clock
/cmd_vel
/rosout

[1] Precisely spreaking, the measurement we get directly from the ultrasound sensor is the distance from the quadrocopter to the ground along its yaw-axis. There is normally a small angle between the yaw-axis and the global z-axis. Since the angle has to be very small, otherwise the quadrocopter will fall, we can ignore it, and take the measured distance (which is "altd" in the "navdata" message) as the distance from quadrocopter to the ground along the global z-axis.

/rosout_agg
/visualization_marker_array

What data does the "/cmd_vel " and the "/ardrone/navdata" topics contain?

Topic constance showed at a random time step
"/cmd_vel" :

```
linear:
  x: -0.0
  y: -0.0
  z: -0.0
angular:
  x: 0.0
  y: 0.0
  z: -0.0
```

They are the linear velocities along the x,y,z axis and angular velocities around the x,y,z axis of the steering commands.

"/ardrone/navdata" :

```
header:
  seq: 92877
  stamp:
    secs: 1366712135
    nsecs: 747363018
  frame_id: ardrone_base_link
batteryPercent: 61.0
state: 6
magX: 19
magY: 51
magZ: 95
pressure: 96551
temp: 412
```

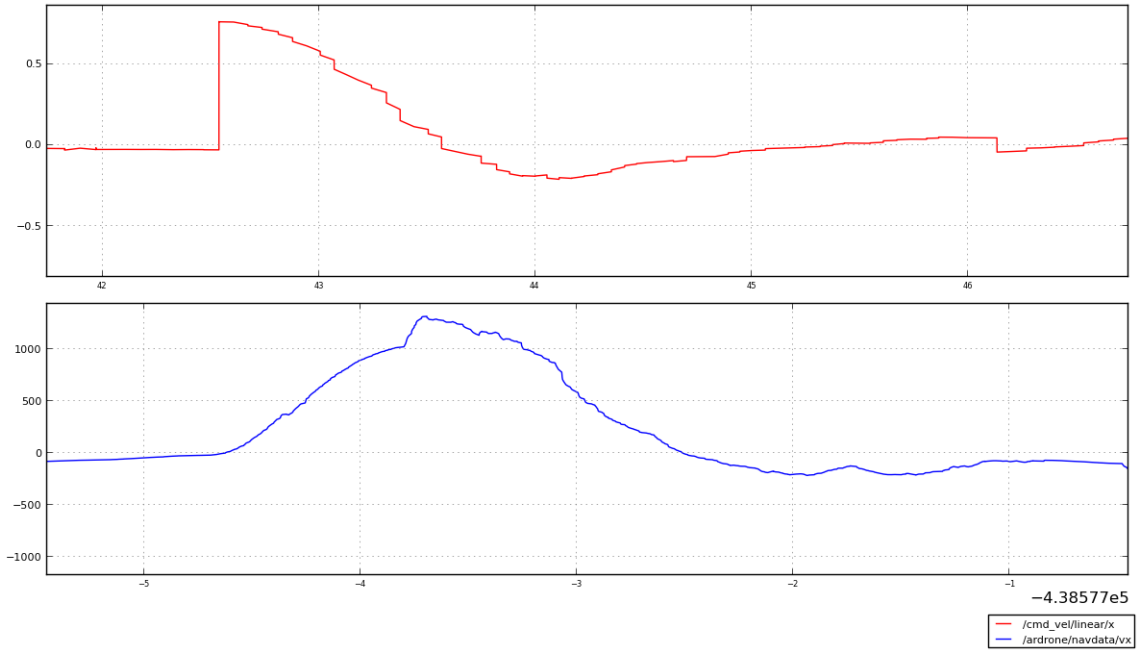
```
wind_speed: 0.0504936724901
wind_angle: 11.7192182541
wind_comp_angle: 0.0
rotX: -1.15799999237
rotY: 0.801999986172
rotZ: 133.697998047
altd: 793
vx: 85.3681182861
vy: -210.962188721
vz: -0.0
ax: -0.0213275831193
ay: 0.0328969322145
az: 0.571606338024
motor1: 124
motor2: 133
motor3: 128
motor4: 132
tags_count: 0
tags_type: []
tags_xc: []
tags_yc: []
tags_width: []
tags_height: []
tags_orientation: []
tags_distance: []
tm: 1509097088.0
```

They are some basic information returned from the quadrocopter sensors. Some of the useful variables for this exercise are e.g. vx, vy, vz (the measured linear velocities); rotX, rotY, rotZ (the measured yaw, pitch, roll angles) and altd (the measured height to the ground).

c) Use rxplot to visualize vx and vy

What is the relation between "/cmd_vel/linear/x" and "/ardrone/-navdata/vx"?

The "/cmd_vel/linear/x" is the linear velocity of x-axis from the steering command and the "/ardrone/navdata/vx" is the measured linear velocity of x-axis from the sensor. So there is a delay between the command was sent and the quadrocopter really abtained the velocity. Using rxplot to visualize this two topic, see figure1(a), we can roughly measure the delay as roughly 1 sec.[2]



(a) rxplot to compare /cmd_vel/linear/x and /ardrone/navdata/vx

f) x,y velocities, yaw angle and height

In which coordinate system are these values given?

In the local quadrocopter coordinate system.

[2]The range of the x-axis in the graph is 5 sec. The two peaks can be compared, which takes roughly 1/5 of the whole range. So the time delay is as 1 sec approximated.

What are their units?

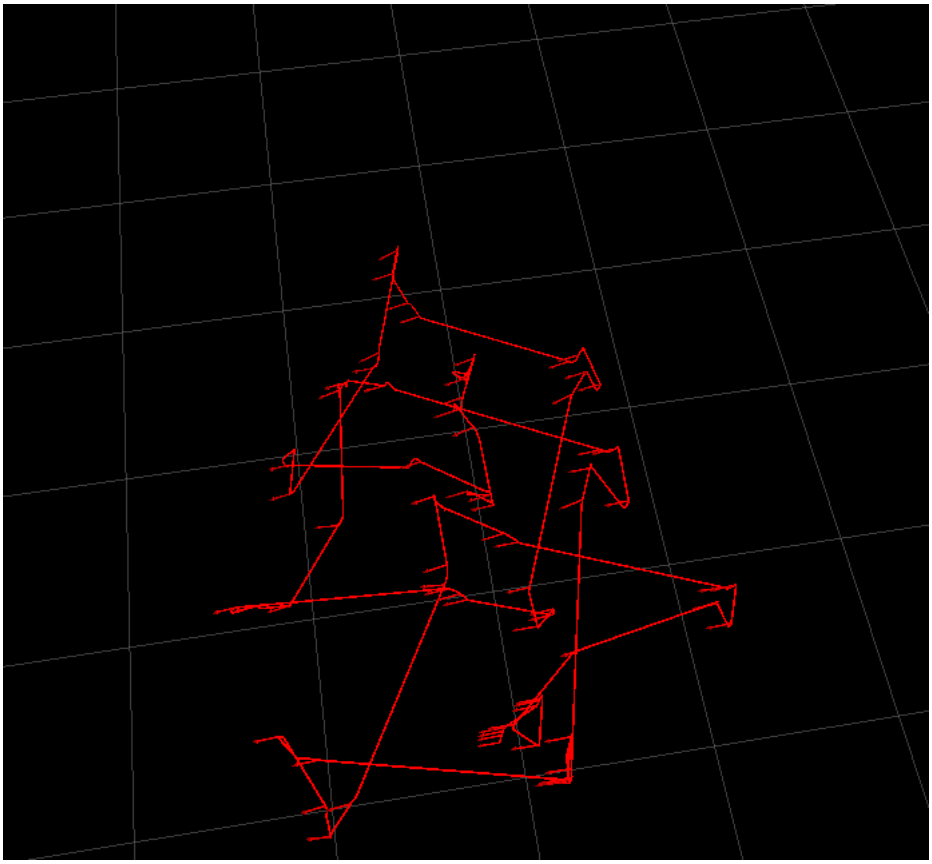
x, y: mm

yaw: degree

height: mm

h) Visualization in RVIZ

The following picture shows the first round of the total three square manoeuvre from the quadrocopter. The line in the middle is part of the second square, since they are shifted.



(b) MarkerArray of flight_square.bag in rviz

i) Distance traveled and mean height

The related code is handed in. Here is the result.
The distance traveled[3] by the quadrocopter for flight_manual.bag: 41.822 m.
The mean height for flight_z.bag: 1.246 m.

[3]We ran each of the bag files 5 times. The results are by taking the average values.