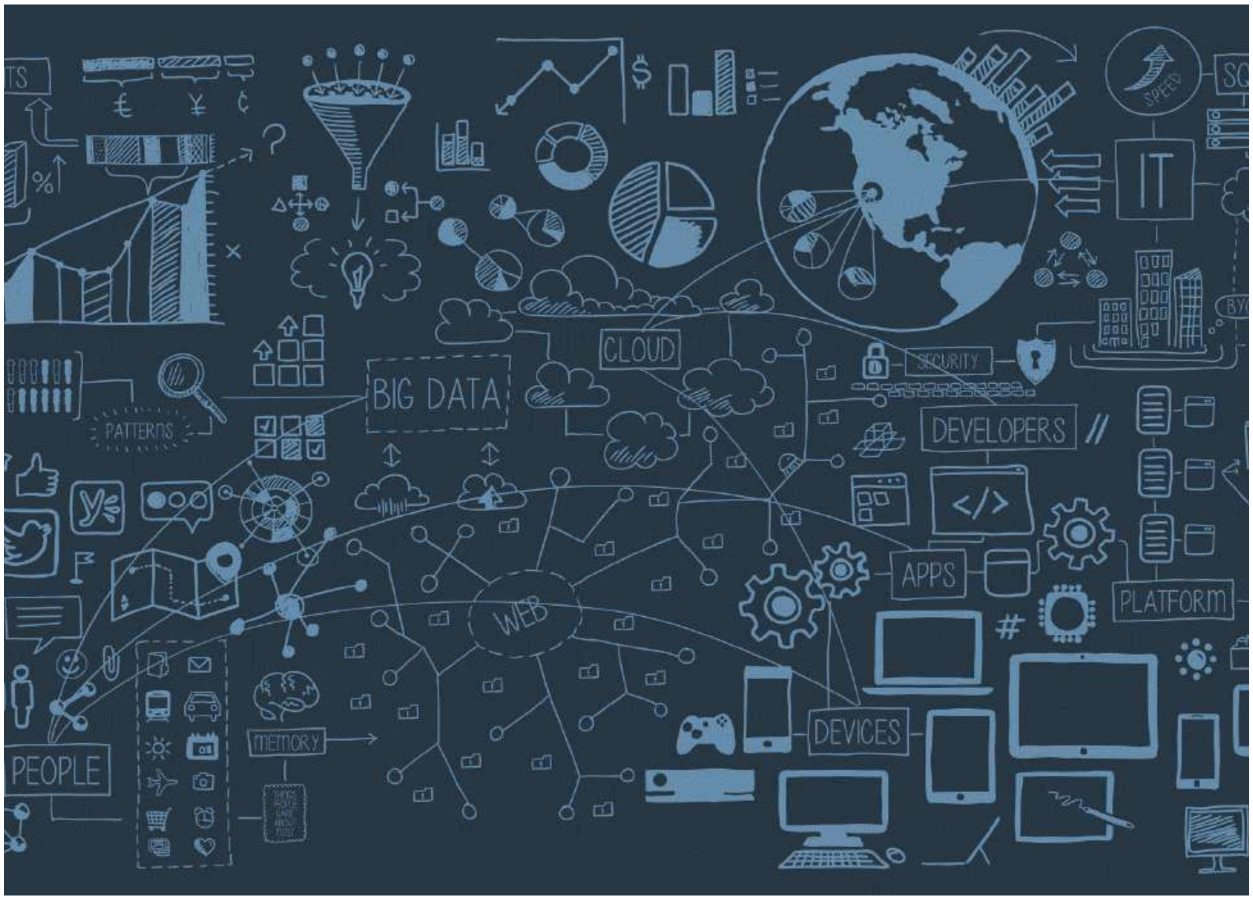
CSE2040 L13-L14

Drone Applications, Components & Assembly (Experiment 6)

Abdul Aziz A.B 20BRS1185



Introduction

Program to take off the drone and land in new location

PREREQUISITES:

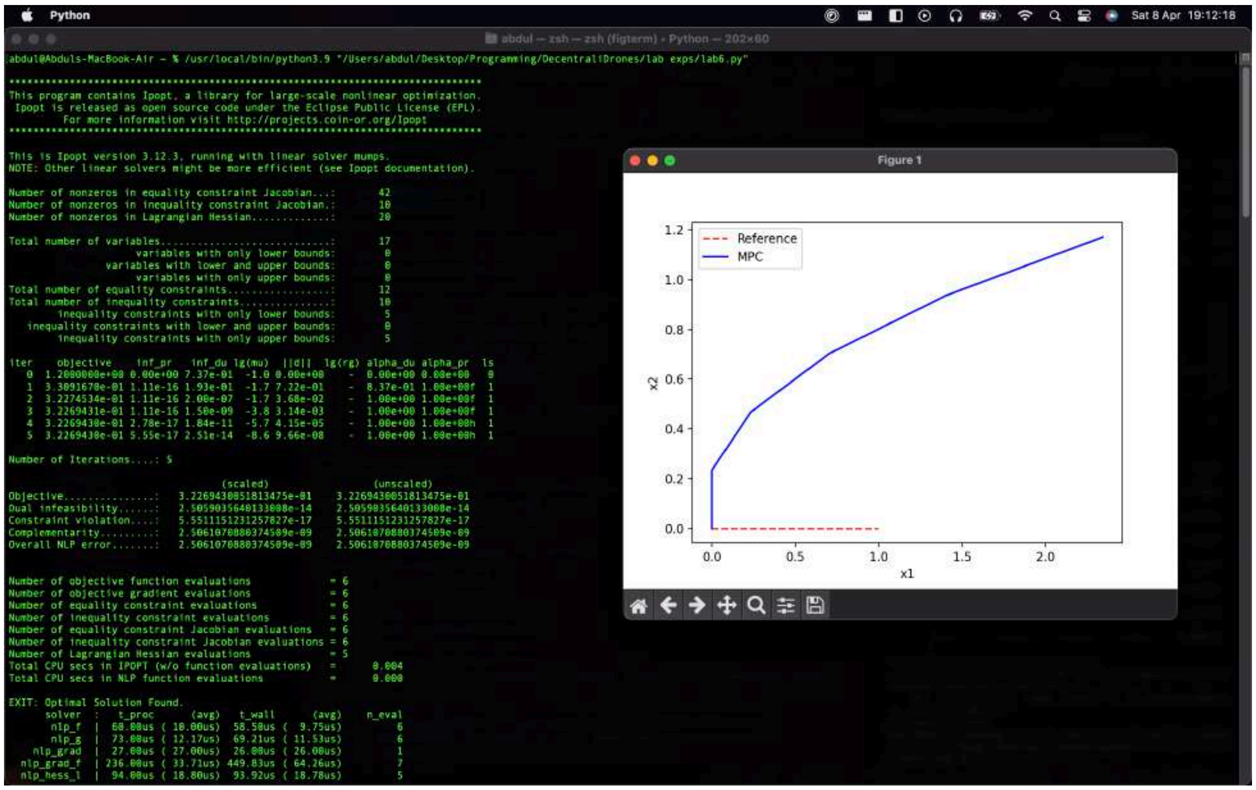
- Mission Planner
- PX4 Autopilot SITL
- Unix based OS (eg. Ubuntu, MacOS)

Python program for Model Predictive Control (MPC) using CasADi library:

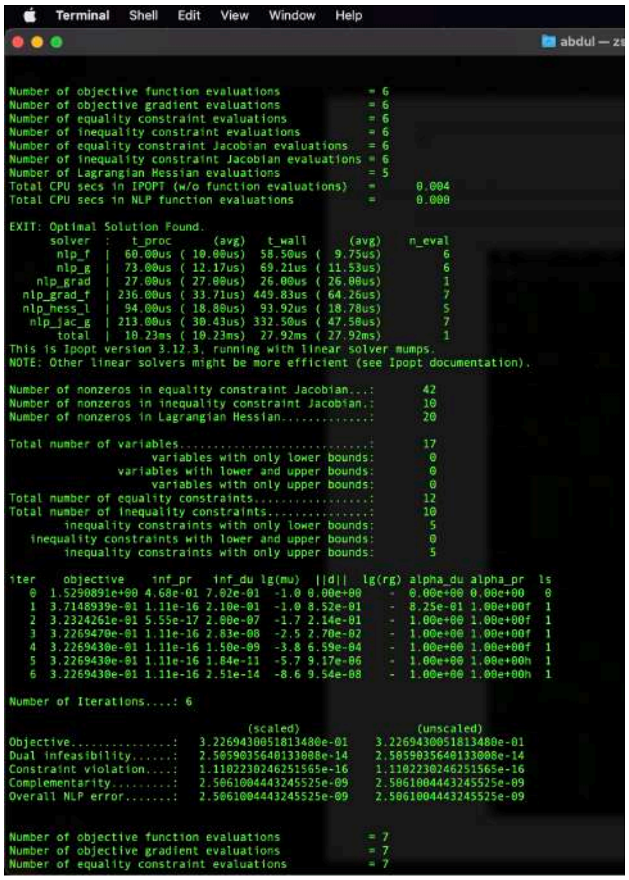
```
import casadi as cs
import numpy as np
import matplotlib.pyplot as plt

# Define the system dynamics
A = np.array([[1, 1], [0, 1]])
B = np.array([[0], [1]])
C = np.array([[1, 0], [0, 1]])
D = np.array([[0], [0]])

# Define the MPC parameters
N = 5
dt = 0.1
Q = np.diag([1, 1])
R = np.array([[1]])

# Define the optimization problem
opti = cs.Opti()

# Define the state variables
x = opti.variable(2, N+1)
x0 = opti.parameter(2, 1)

# Define the control variables
u = opti.variable(1, N)

# Define the reference trajectory
x_ref = opti.parameter(2, N+1)
u_ref = opti.parameter(1, N)
```

```
# Define the initial state constraint
opti.subject_to(x[:,0] == x0)

# Define the dynamic constraints
for k in range(N):
    x_next = cs.mtimes(A, x[:,k]) + cs.mtimes(B, u[:,k])
    opti.subject_to(x[:,k+1] == x_next)

# Define the cost function
J = 0
for k in range(N):
    J += cs.mtimes([(x[:,k] - x_ref[:,k]).T, Q, (x[:,k] -
x_ref[:,k])])
    J += cs.mtimes([(u[:,k] - u_ref[:,k]).T, R, (u[:,k] -
u_ref[:,k])])
opti.minimize(J)

# Define the control constraints
opti.subject_to(u <= 1)
opti.subject_to(u >= -1)

# Set the initial state parameter
x0_val = np.array([[0], [0]])
opti.set_value(x0, x0_val)

# Define the reference trajectory and control inputs
x_ref_val = np.zeros((2, N+1))
x_ref_val[0,:] = np.linspace(0, 1, N+1)
u_ref_val = np.zeros((1, N))
opti.set_value(x_ref, x_ref_val)
opti.set_value(u_ref, u_ref_val)

# Simulate the system and plot the results
x_val = np.zeros((2, N+1))
u_val = np.zeros((1, N))

for i in range(N):
    # Update the optimization problem with the current state
    opti.set_initial(u, u_val)
    opti.set_initial(x, x_val)

    # Solve the optimization problem
    opti.solver('ipopt')
    sol = opti.solve()
    # Extract the control input
    u_val = opti.value(u[:,0])

    # Update the system state
    x_val[:,i+1] = np.squeeze(cs.mtimes(A, x_val[:,i]) +
cs.mtimes(B, u_val))

# Plot the results
plt.plot(x_ref_val[0,:], x_ref_val[1,:], 'r--',
label='Reference')
plt.plot(x_val[0,:], x_val[1,:], 'b', label='MPC')
plt.legend()
plt.xlabel('x1')
plt.ylabel('x2')
plt.show()
```

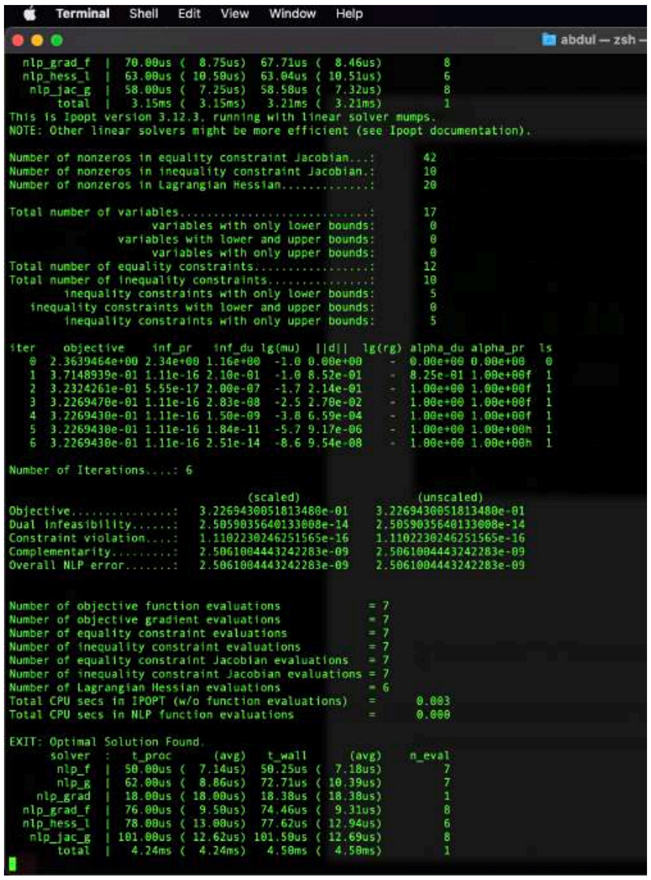
Output:



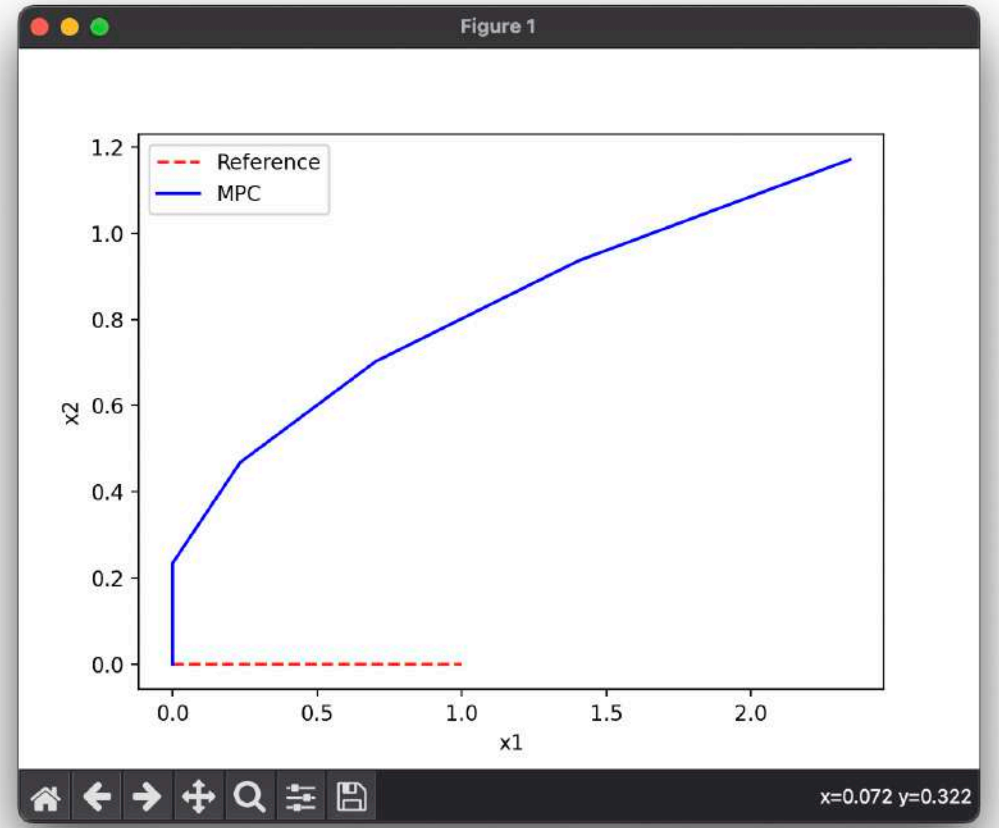
```
abdul@Abduls-MacBook-Air ~ % /usr/local/bin/python3.9 "/Users/abdul/Desktop/Programming/DecentralDrones/lab exps/lab6.py"

******************************************************************************
This program contains Ipopt, a library for large-scale nonlinear optimization.
 Ipopt is released as open source code under the Eclipse Public License (EPL).
         For more information visit http://projects.coin-or.org/Ipopt
******************************************************************************

This is Ipopt version 3.12.3, running with linear solver mumps.
NOTE: Other linear solvers might be more efficient (see Ipopt documentation).

Number of nonzeros in equality constraint Jacobian...:       42
Number of nonzeros in inequality constraint Jacobian.:       10
Number of nonzeros in Lagrangian Hessian.............:       20

Total number of variables............................:       17
                     variables with only lower bounds:        0
                variables with lower and upper bounds:        0
                     variables with only upper bounds:        0
Total number of equality constraints.................:       12
Total number of inequality constraints...............:       10
        inequality constraints with only lower bounds:        5
   inequality constraints with lower and upper bounds:        0
        inequality constraints with only upper bounds:        5

iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du alpha_pr  ls
   0  1.2080000e+00 0.00e+00 7.37e-01  -1.0 0.00e+00    -  0.00e+00 0.00e+00   0
   1  3.3091670e-01 1.11e-16 1.93e-01  -1.7 7.22e-01    -  8.37e-01 1.00e+00f  1
   2  3.2274534e-01 1.11e-16 2.00e-07  -1.7 3.68e-02    -  1.00e+00 1.00e+00f  1
   3  3.2269431e-01 1.11e-16 1.50e-09  -3.8 3.14e-03    -  1.00e+00 1.00e+00f  1
   4  3.2269430e-01 2.78e-17 1.84e-11  -5.7 4.15e-05    -  1.00e+00 1.00e+00h  1
   5  3.2269430e-01 5.55e-17 2.51e-14  -8.6 9.66e-08    -  1.00e+00 1.00e+00h  1

Number of Iterations....: 5

                                   (scaled)                 (unscaled)
Objective...............:   3.2269430051813475e-01    3.2269430051813475e-01
Dual infeasibility......:   2.5059035640133008e-14    2.5059035640133008e-14
Constraint violation....:   5.5511151231257827e-17    5.5511151231257827e-17
Complementarity.........:   2.5061070880374509e-09    2.5061070880374509e-09
Overall NLP error.......:   2.5061070880374509e-09    2.5061070880374509e-09


Number of objective function evaluations             = 6
Number of objective gradient evaluations             = 6
Number of equality constraint evaluations            = 6
Number of inequality constraint evaluations          = 6
Number of equality constraint Jacobian evaluations   = 6
Number of inequality constraint Jacobian evaluations = 6
Number of Lagrangian Hessian evaluations             = 5
Total CPU secs in IPOPT (w/o function evaluations)   =      0.004
Total CPU secs in NLP function evaluations           =      0.000

EXIT: Optimal Solution Found.
      solver  :   t_proc      (avg)   t_wall      (avg)    n_eval
       nlp_f  |  60.00us ( 10.00us)  58.50us (  9.75us)         6
       nlp_g  |  73.00us ( 12.17us)  69.21us ( 11.53us)         6
    nlp_grad  |  27.00us ( 27.00us)  26.00us ( 26.00us)         1
  nlp_grad_f  | 236.00us ( 33.71us) 449.83us ( 64.26us)         7
  nlp_hess_l  |  94.00us ( 18.80us)  93.92us ( 18.78us)         5
```



```
Number of objective function evaluations             = 6
Number of objective gradient evaluations             = 6
Number of equality constraint evaluations            = 6
Number of inequality constraint evaluations          = 6
Number of equality constraint Jacobian evaluations   = 6
Number of inequality constraint Jacobian evaluations = 6
Number of Lagrangian Hessian evaluations             = 5
Total CPU secs in IPOPT (w/o function evaluations)   =      0.004
Total CPU secs in NLP function evaluations           =      0.000

EXIT: Optimal Solution Found.
      solver  :   t_proc      (avg)   t_wall      (avg)    n_eval
       nlp_f  |  60.00us ( 10.00us)  58.50us (  9.75us)         6
       nlp_g  |  73.00us ( 12.17us)  69.21us ( 11.53us)         6
    nlp_grad  |  27.00us ( 27.00us)  26.00us ( 26.00us)         1
  nlp_grad_f  | 236.00us ( 33.71us) 449.83us ( 64.26us)         7
  nlp_hess_l  |  94.00us ( 18.80us)  93.92us ( 18.78us)         5
   nlp_jac_g  | 213.00us ( 30.43us) 332.50us ( 47.50us)         7
       total  |  10.23ms ( 10.23ms)  27.92ms ( 27.92ms)         1
This is Ipopt version 3.12.3, running with linear solver mumps.
NOTE: Other linear solvers might be more efficient (see Ipopt documentation).

Number of nonzeros in equality constraint Jacobian...:       42
Number of nonzeros in inequality constraint Jacobian.:       10
Number of nonzeros in Lagrangian Hessian.............:       20

Total number of variables............................:       17
                     variables with only lower bounds:        0
                variables with lower and upper bounds:        0
                     variables with only upper bounds:        0
Total number of equality constraints.................:       12
Total number of inequality constraints...............:       10
        inequality constraints with only lower bounds:        5
   inequality constraints with lower and upper bounds:        0
        inequality constraints with only upper bounds:        5

iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du alpha_pr  ls
   0  1.5290891e+00 4.68e-01 7.02e-01  -1.0 0.00e+00    -  0.00e+00 0.00e+00   0
   1  3.7148939e-01 1.11e-16 2.10e-01  -1.0 8.52e-01    -  8.25e-01 1.00e+00f  1
   2  3.2324261e-01 5.55e-17 2.00e-07  -1.7 2.14e-01    -  1.00e+00 1.00e+00f  1
   3  3.2269470e-01 1.11e-16 2.83e-08  -2.5 2.70e-02    -  1.00e+00 1.00e+00f  1
   4  3.2269430e-01 1.11e-16 1.50e-09  -3.8 6.59e-04    -  1.00e+00 1.00e+00f  1
   5  3.2269430e-01 1.11e-16 1.84e-11  -5.7 9.17e-06    -  1.00e+00 1.00e+00h  1
   6  3.2269430e-01 1.11e-16 2.51e-14  -8.6 9.54e-08    -  1.00e+00 1.00e+00h  1

Number of Iterations....: 6

                                   (scaled)                 (unscaled)
Objective...............:   3.2269430051813480e-01    3.2269430051813480e-01
Dual infeasibility......:   2.5059035640133008e-14    2.5059035640133008e-14
Constraint violation....:   1.1102230246251565e-16    1.1102230246251565e-16
Complementarity.........:   2.5061004443245525e-09    2.5061004443245525e-09
Overall NLP error.......:   2.5061004443245525e-09    2.5061004443245525e-09


Number of objective function evaluations             = 7
Number of objective gradient evaluations             = 7
Number of equality constraint evaluations            = 7
```



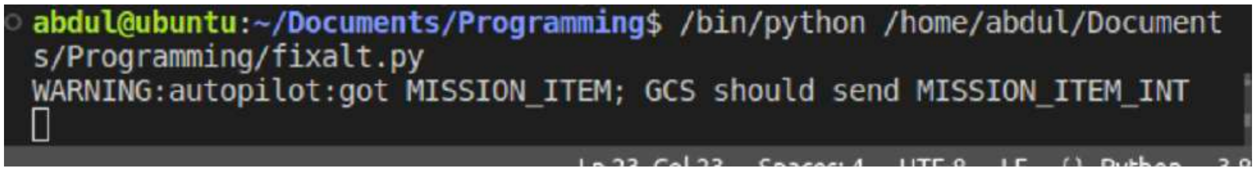
```
  nlp_grad_f  |  70.00us (  8.75us)  67.71us (  8.46us)         8
  nlp_hess_l  |  63.00us ( 10.50us)  63.04us ( 10.51us)         6
   nlp_jac_g  |  58.00us (  7.25us)  58.58us (  7.32us)         8
       total  |   3.15ms (  3.15ms)   3.21ms (  3.21ms)         1
This is Ipopt version 3.12.3, running with linear solver mumps.
NOTE: Other linear solvers might be more efficient (see Ipopt documentation).

Number of nonzeros in equality constraint Jacobian...:       42
Number of nonzeros in inequality constraint Jacobian.:       10
Number of nonzeros in Lagrangian Hessian.............:       20

Total number of variables............................:       17
                     variables with only lower bounds:        0
                variables with lower and upper bounds:        0
                     variables with only upper bounds:        0
Total number of equality constraints.................:       12
Total number of inequality constraints...............:       10
        inequality constraints with only lower bounds:        5
   inequality constraints with lower and upper bounds:        0
        inequality constraints with only upper bounds:        5

iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du alpha_pr  ls
   0  2.3639464e+00 2.34e+00 1.16e+00  -1.0 0.00e+00    -  0.00e+00 0.00e+00   0
   1  3.7148939e-01 1.11e-16 2.10e-01  -1.0 8.52e-01    -  8.25e-01 1.00e+00f  1
   2  3.2324261e-01 5.55e-17 2.00e-07  -1.7 2.14e-01    -  1.00e+00 1.00e+00f  1
   3  3.2269470e-01 1.11e-16 2.83e-08  -2.5 2.70e-02    -  1.00e+00 1.00e+00f  1
   4  3.2269430e-01 1.11e-16 1.50e-09  -3.8 6.59e-04    -  1.00e+00 1.00e+00f  1
   5  3.2269430e-01 1.11e-16 1.84e-11  -5.7 9.17e-06    -  1.00e+00 1.00e+00h  1
   6  3.2269430e-01 1.11e-16 2.51e-14  -8.6 9.54e-08    -  1.00e+00 1.00e+00h  1

Number of Iterations....: 6

                                   (scaled)                 (unscaled)
Objective...............:   3.2269430051813480e-01    3.2269430051813480e-01
Dual infeasibility......:   2.5059035640133008e-14    2.5059035640133008e-14
Constraint violation....:   1.1102230246251565e-16    1.1102230246251565e-16
Complementarity.........:   2.5061004443242283e-09    2.5061004443242283e-09
Overall NLP error.......:   2.5061004443242283e-09    2.5061004443242283e-09


Number of objective function evaluations             = 7
Number of objective gradient evaluations             = 7
Number of equality constraint evaluations            = 7
Number of inequality constraint evaluations          = 7
Number of equality constraint Jacobian evaluations   = 7
Number of inequality constraint Jacobian evaluations = 7
Number of Lagrangian Hessian evaluations             = 6
Total CPU secs in IPOPT (w/o function evaluations)   =      0.003
Total CPU secs in NLP function evaluations           =      0.000

EXIT: Optimal Solution Found.
      solver  :   t_proc      (avg)   t_wall      (avg)    n_eval
       nlp_f  |  50.00us (  7.14us)  50.25us (  7.18us)         7
       nlp_g  |  62.00us (  8.86us)  72.71us ( 10.39us)         7
    nlp_grad  |  18.00us ( 18.00us)  18.38us ( 18.38us)         1
  nlp_grad_f  |  76.00us (  9.50us)  74.46us (  9.31us)         8
  nlp_hess_l  |  78.00us ( 13.00us)  77.62us ( 12.94us)         6
   nlp_jac_g  | 101.00us ( 12.62us) 101.50us ( 12.69us)         8
       total  |   4.24ms (  4.24ms)   4.50ms (  4.50ms)         1
```



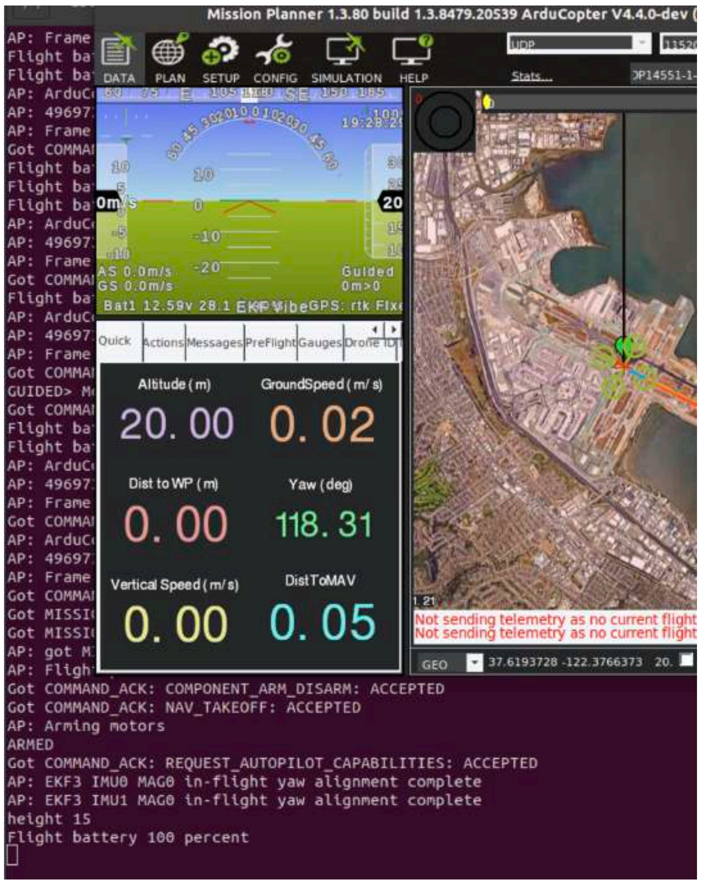
Python program for setting the drone altitude fixed at 20:

```
from dronekit import connect, VehicleMode, Command
from pymavlink import mavutil
import time

# Set up connection to vehicle
vehicle = connect('udp:127.0.0.1:14550')

# Set vehicle mode to GUIDED
vehicle.mode = VehicleMode("GUIDED")

# Set fixed altitude of 20 meters for all waypoints
ground_altitude = vehicle.location.global_frame.alt
target_altitude = 20.0
altitude = ground_altitude + target_altitude

# Set up mission with RTL mode
cmds = vehicle.commands
cmds.clear()

# Add waypoints
wp1 = vehicle.location.global_frame
wp1.alt = altitude
wp2 = vehicle.location.global_frame
wp2.lat += 0.0001
wp2.lon += 0.0001
wp2.alt = altitude
wp3 = vehicle.location.global_frame
wp3.lat += 0.0001
wp3.lon -= 0.0001
wp3.alt = altitude

# Create RTL command
cmd = Command(0, 0, 0,
mavutil.mavlink.MAV_FRAME_GLOBAL_RELATIVE_ALT,
              mavutil.mavlink.MAV_CMD_NAV_RETURN_TO_LAUNCH, 0,
0, 0, 0, 0, 0,
              0, 0, 0)

# Add RTL command to mission
cmds.add(cmd)

# Upload mission to vehicle
cmds.upload()
```

```python
# Arm and takeoff
vehicle.armed = True
vehicle.simple_takeoff(target_altitude)

# Wait for takeoff to complete
while True:
    if abs(vehicle.location.global_relative_frame.alt -
altitude) < 1.0:
        print("Reached target altitude")
        break
    time.sleep(1)

# Set mode to AUTO and start mission
vehicle.mode = VehicleMode("AUTO")
print("Starting mission")
vehicle.commands.next = 0

# Monitor mission execution
while True:
    nextwaypoint = vehicle.commands.next
    if nextwaypoint == len(vehicle.commands):
        print("Mission complete")
        vehicle.mode = VehicleMode("RTL")
        break
    time.sleep(1)

# Wait for vehicle to return to launch point and land
while True:
    if vehicle.mode.name == "RTL":
        print("Vehicle returning to launch point")
        break
    time.sleep(1)

while True:
    if vehicle.mode.name == "LAND":
        print("Vehicle landed")
        break
    time.sleep(1)

# Close connection to vehicle
vehicle.close()
```



```
abdul@ubuntu:~/Documents/Programming$ /bin/python /home/abdul/Document
s/Programming/fixalt.py
WARNING:autopilot:got MISSION_ITEM; GCS should send MISSION_ITEM_INT
```

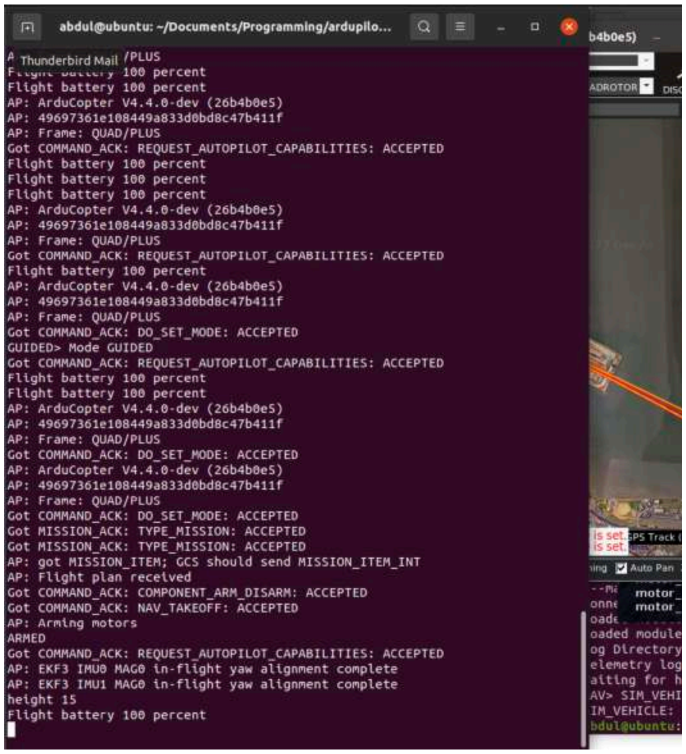


Altitude (m)	GroundSpeed (m/s)
20.00	0.02
Dist to WP (m)	**Yaw (deg)**
0.00	118.31
Vertical Speed (m/s)	**DistToMAV**
0.00	0.05

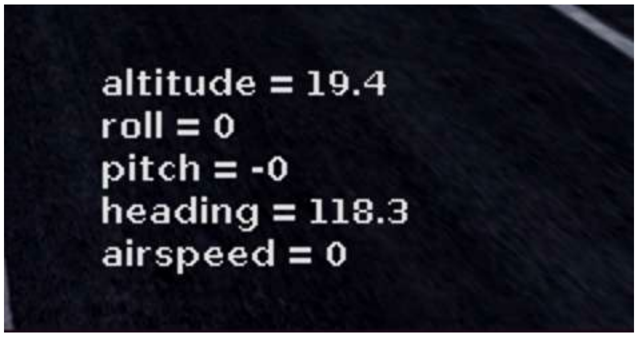
Not sending telemetry as no current flight
Not sending telemetry as no current flight

37.6193728 -122.3766373 20.

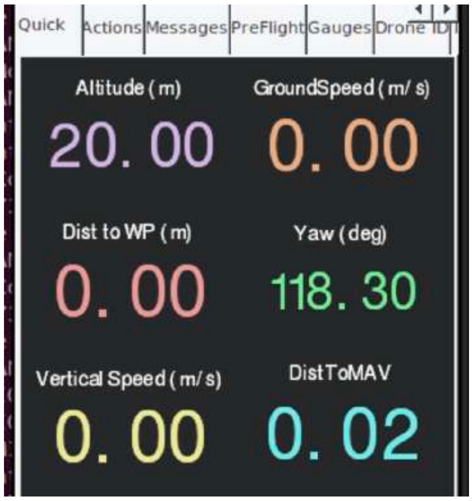
```
Got COMMAND_ACK: COMPONENT_ARM_DISARM: ACCEPTED
Got COMMAND_ACK: NAV_TAKEOFF: ACCEPTED
AP: Arming motors
ARMED
Got COMMAND_ACK: REQUEST_AUTOPILOT_CAPABILITIES: ACCEPTED
AP: EKF3 IMU0 MAG0 in-flight yaw alignment complete
AP: EKF3 IMU1 MAG0 in-flight yaw alignment complete
height 15
Flight battery 100 percent
```


abdul@ubuntu: ~/Documents/Programming/ardupilo...

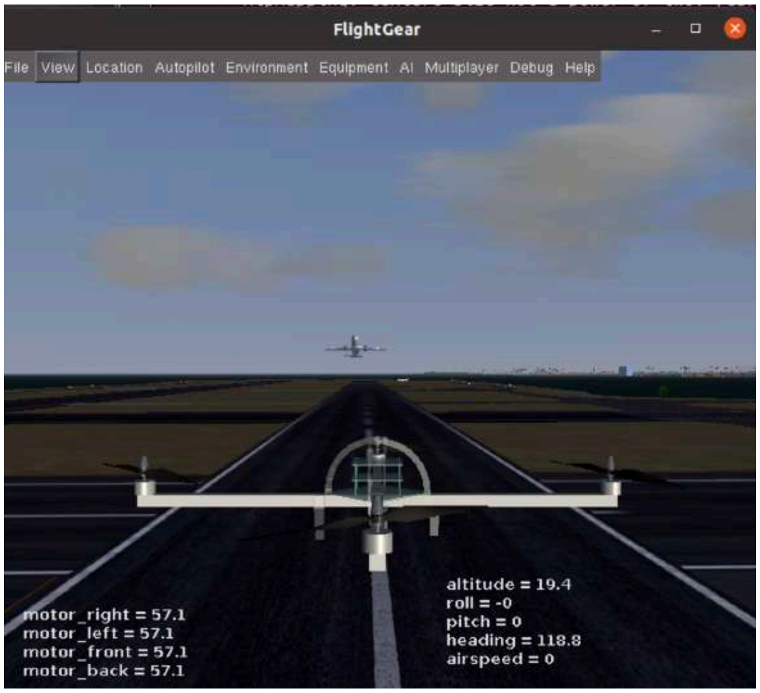
```
/PLUS
Flight battery 100 percent
Flight battery 100 percent
AP: ArduCopter V4.4.0-dev (26b4b0e5)
AP: 49697361e108449a833d0bd8c47b411f
AP: Frame: QUAD/PLUS
Got COMMAND_ACK: REQUEST_AUTOPILOT_CAPABILITIES: ACCEPTED
Flight battery 100 percent
Flight battery 100 percent
Flight battery 100 percent
AP: ArduCopter V4.4.0-dev (26b4b0e5)
AP: 49697361e108449a833d0bd8c47b411f
AP: Frame: QUAD/PLUS
Got COMMAND_ACK: REQUEST_AUTOPILOT_CAPABILITIES: ACCEPTED
Flight battery 100 percent
AP: ArduCopter V4.4.0-dev (26b4b0e5)
AP: 49697361e108449a833d0bd8c47b411f
AP: Frame: QUAD/PLUS
Got COMMAND_ACK: DO_SET_MODE: ACCEPTED
GUIDED> Mode GUIDED
Got COMMAND_ACK: REQUEST_AUTOPILOT_CAPABILITIES: ACCEPTED
Flight battery 100 percent
Flight battery 100 percent
AP: ArduCopter V4.4.0-dev (26b4b0e5)
AP: 49697361e108449a833d0bd8c47b411f
AP: Frame: QUAD/PLUS
Got COMMAND_ACK: DO_SET_MODE: ACCEPTED
AP: ArduCopter V4.4.0-dev (26b4b0e5)
AP: 49697361e108449a833d0bd8c47b411f
AP: Frame: QUAD/PLUS
Got COMMAND_ACK: DO_SET_MODE: ACCEPTED
Got MISSION_ACK: TYPE_MISSION: ACCEPTED
Got MISSION_ACK: TYPE_MISSION: ACCEPTED
AP: got MISSION_ITEM; GCS should send MISSION_ITEM_INT
AP: Flight plan received
Got COMMAND_ACK: COMPONENT_ARM_DISARM: ACCEPTED
Got COMMAND_ACK: NAV_TAKEOFF: ACCEPTED
AP: Arming motors
ARMED
Got COMMAND_ACK: REQUEST_AUTOPILOT_CAPABILITIES: ACCEPTED
AP: EKF3 IMU0 MAG0 in-flight yaw alignment complete
AP: EKF3 IMU1 MAG0 in-flight yaw alignment complete
height 15
Flight battery 100 percent
```



```
altitude = 19.4
roll = 0
pitch = -0
heading = 118.3
airspeed = 0
```



Altitude (m)	GroundSpeed (m/s)
20.00	0.00
Dist to WP (m)	**Yaw (deg)**
0.00	118.30
Vertical Speed (m/s)	**DistToMAV**
0.00	0.02



```
motor_right = 57.1
motor_left = 57.1
motor_front = 57.1
motor_back = 57.1
```

```
altitude = 19.4
roll = -0
pitch = 0
heading = 118.8
airspeed = 0
```

Procedure:

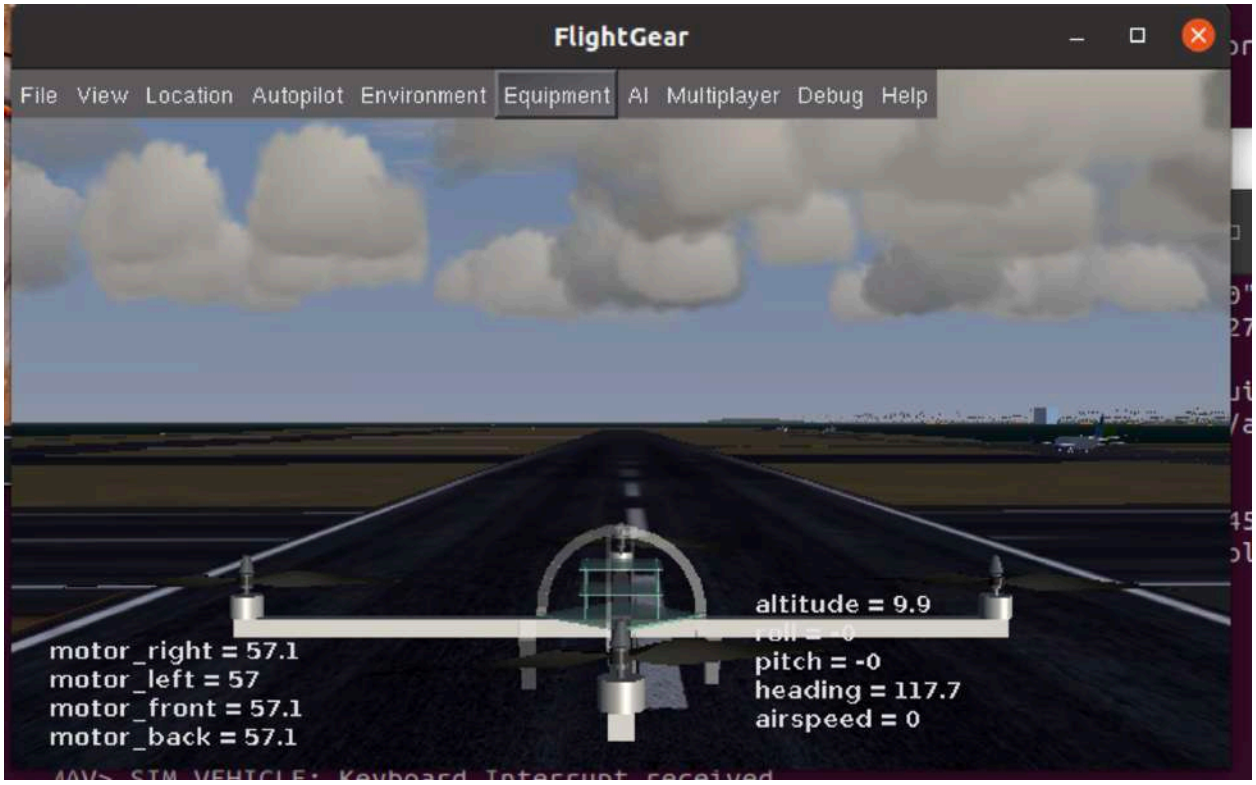
- Launch Mission Planner (same procs as lab 5)

- Launch FlightGear (same procs as lab 5)

- Write the code in an IDE like Vscode and run it. (same procs as lab 5)

Python program for having the drone fly at varying altitudes at different waypoints:

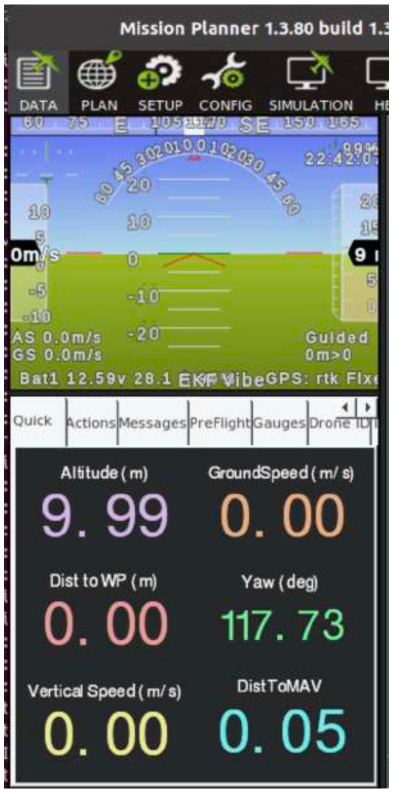
```python
from dronekit import connect, VehicleMode, 
LocationGlobalRelative, Command
from pymavlink import mavutil
import time

# Set up connection to vehicle
vehicle = connect('udp:127.0.0.1:14550')

# Set vehicle mode to GUIDED
vehicle.mode = VehicleMode("GUIDED")

# Define waypoints with varying altitude
waypoints = [
    LocationGlobalRelative(37.6205, -122.3880, 10), # altitude 
of 10 meters
    LocationGlobalRelative(37.6215, -122.3860, 20), # altitude 
of 20 meters
    LocationGlobalRelative(37.6210, -122.3840, 30), # altitude 
of 30 meters (this is the max threshold, the drone maintains 
below this)
]

# Set up mission
cmds = vehicle.commands
cmds.clear()
# Add waypoints to mission
for i, wp in enumerate(waypoints):
    cmd = Command(0, 0, 0, 
mavutil.mavlink.MAV_FRAME_GLOBAL_RELATIVE_ALT,
                  mavutil.mavlink.MAV_CMD_NAV_WAYPOINT, 0, 0, 0, 
0, 0, 0,
                  wp.lat, wp.lon, wp.alt)
    cmds.add(cmd)

# Upload mission to vehicle
cmds.upload()

# Arm and takeoff
vehicle.armed = True
vehicle.simple_takeoff(waypoints[0].alt)

# Wait for takeoff to complete
while True:
    if abs(vehicle.location.global_relative_frame.alt -
waypoints[0].alt) < 1.0:
        print("Reached target altitude")
        break
    time.sleep(1)

# Set mode to AUTO and start mission
vehicle.mode = VehicleMode("AUTO")
print("Starting mission")
vehicle.commands.next = 0

# Monitor mission execution
while True:
    nextwaypoint = vehicle.commands.next
    if nextwaypoint == len(vehicle.commands):
        print("Mission complete")
        vehicle.mode = VehicleMode("RTL")
        break
    time.sleep(1)

# Wait for vehicle to return to launch point and land
while True:
    if vehicle.mode.name == "RTL":
        print("Vehicle returning to launch point")
        break
    time.sleep(1)

while True:
    if vehicle.mode.name == "LAND":
        print("Vehicle landed")
        break
    time.sleep(1)

# Close connection to vehicle
vehicle.close()
```


FlightGear
File View Location Autopilot Environment Equipment AI Multiplayer Debug Help

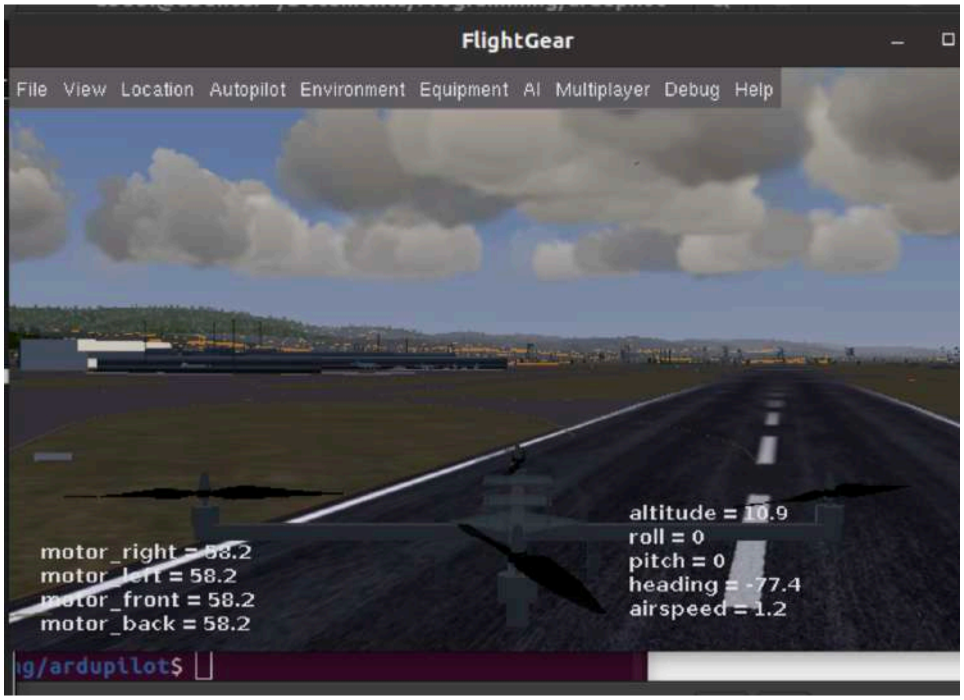
```
motor_right = 57.1
motor_left = 57
motor_front = 57.1
motor_back = 57.1
```

```
altitude = 9.9
roll = -0
pitch = -0
heading = 117.7
airspeed = 0
```

```
MAV> SIM_VEHICLE: Keyboard Interrupt received
```


Mission Planner 1.3.80 build 1.3
DATA PLAN SETUP CONFIG SIMULATION
AS 0.0m/s
GS 0.0m/s
Guided
Bat1 12.59v 28.1 EKF Vibe GPS: rtk Fixed
Quick Actions Messages PreFlight Gauges Drone ID

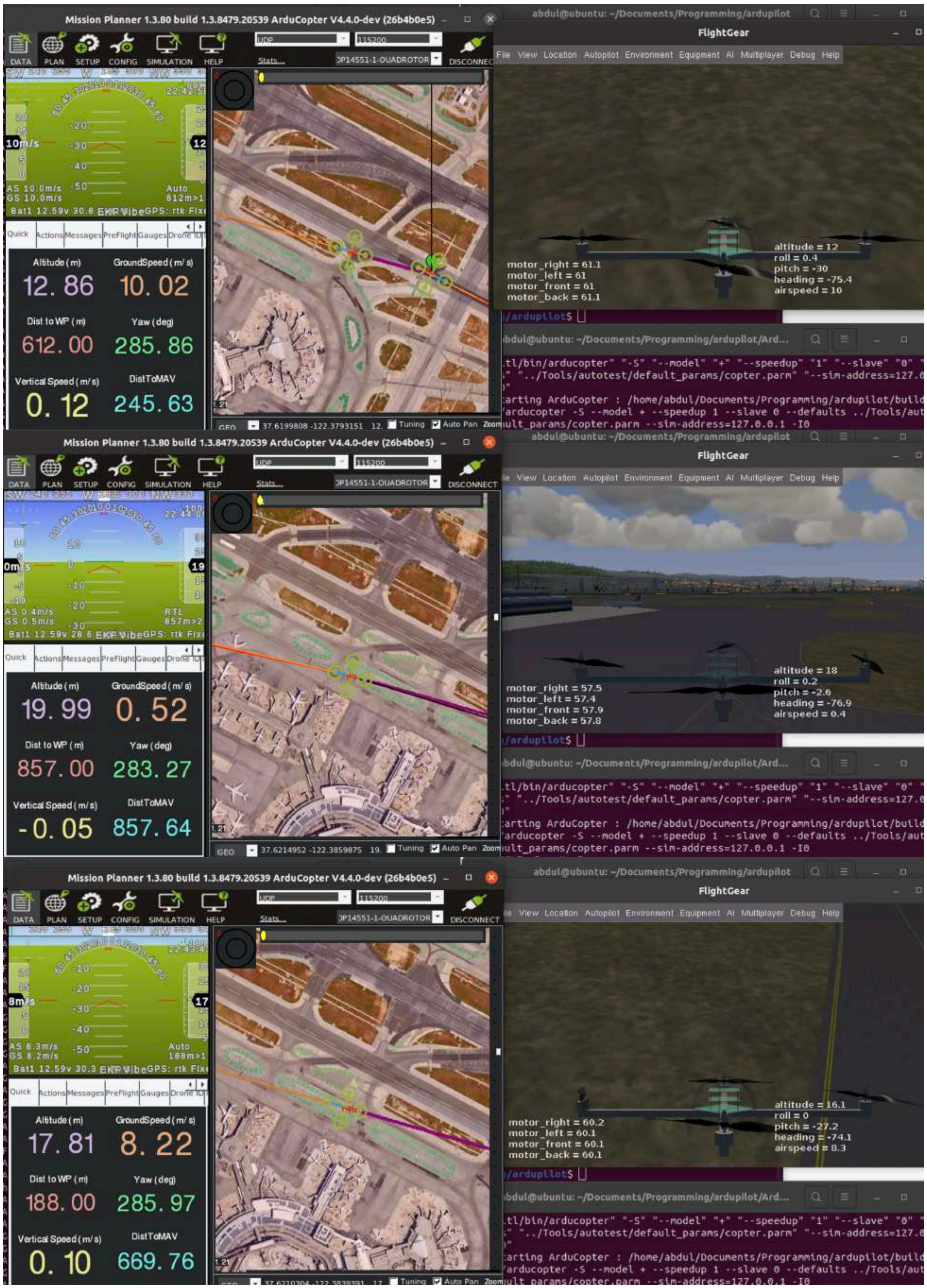
Altitude (m)	GroundSpeed (m/s)
9.99	0.00
Dist to WP (m)	Yaw (deg)
0.00	117.73
Vertical Speed (m/s)	DistToMAV
0.00	0.05


FlightGear
File View Location Autopilot Environment Equipment AI Multiplayer Debug Help

```
motor_right = 58.2
motor_left = 58.2
motor_front = 58.2
motor_back = 58.2
```

```
altitude = 10.9
roll = 0
pitch = 0
heading = -77.4
airspeed = 1.2
```

```
g/ardupilot$
```



Mission Planner 1.3.80 build 1.3.8479.20539 ArduCopter V4.4.0-dev (26b4b0e5)

abdul@ubuntu: ~/Documents/Programming/ardupilot

```
AS 10.0m/s
GS 10.0m/s
Bat1 12.59v 30.8 EKF Vibe GPS: rtk Fix
Auto
612m>1
```

Altitude (m)	GroundSpeed (m/s)
12.86	10.02
Dist to WP (m)	**Yaw (deg)**
612.00	285.86
Vertical Speed (m/s)	**DistToMAV**
0.12	245.63

```
motor_right = 61.1
motor_left = 61
motor_front = 61
motor_back = 61.1
```

```
altitude = 12
roll = 0.4
pitch = -30
heading = -75.4
airspeed = 10
```

```
/ardupilot$
```

abdul@ubuntu: ~/Documents/Programming/ardupilot/Ard...

```
tl/bin/arducopter" "-S" "--model" "+" "--speedup" "1" "--slave" "0" "
" "../Tools/autotest/default_params/copter.parm" "--sim-address=127.0
"
tarting ArduCopter : /home/abdul/Documents/Programming/ardupilot/build
arducopter -S --model + --speedup 1 --slave 0 --defaults ../Tools/aut
ult_params/copter.parm --sim-address=127.0.0.1 -I0
```

```
GEO 37.6199808 -122.3793151 12. Tuning Auto Pan Zoom
```

Mission Planner 1.3.80 build 1.3.8479.20539 ArduCopter V4.4.0-dev (26b4b0e5)

abdul@ubuntu: ~/Documents/Programming/ardupilot

```
AS 0.4m/s
GS 0.5m/s
Bat1 12.59v 28.6 EKF Vibe GPS: rtk Fix
RTL
857m>2
```

Altitude (m)	GroundSpeed (m/s)
19.99	0.52
Dist to WP (m)	**Yaw (deg)**
857.00	283.27
Vertical Speed (m/s)	**DistToMAV**
-0.05	857.64

```
motor_right = 57.5
motor_left = 57.4
motor_front = 57.9
motor_back = 57.8
```

```
altitude = 18
roll = 0.2
pitch = -2.6
heading = -76.9
airspeed = 0.4
```

```
/ardupilot$
```

abdul@ubuntu: ~/Documents/Programming/ardupilot/Ard...

```
tl/bin/arducopter" "-S" "--model" "+" "--speedup" "1" "--slave" "0" "
" "../Tools/autotest/default_params/copter.parm" "--sim-address=127.0
"
tarting ArduCopter : /home/abdul/Documents/Programming/ardupilot/build
arducopter -S --model + --speedup 1 --slave 0 --defaults ../Tools/aut
ult_params/copter.parm --sim-address=127.0.0.1 -I0
```

```
GEO 37.6214952 -122.3859875 19. Tuning Auto Pan Zoom
```

Mission Planner 1.3.80 build 1.3.8479.20539 ArduCopter V4.4.0-dev (26b4b0e5)

abdul@ubuntu: ~/Documents/Programming/ardupilot

```
AS 6.3m/s
GS 8.2m/s
Bat1 12.59v 30.3 EKF Vibe GPS: rtk Fix
Auto
188m>1
```

Altitude (m)	GroundSpeed (m/s)
17.81	8.22
Dist to WP (m)	**Yaw (deg)**
188.00	285.97
Vertical Speed (m/s)	**DistToMAV**
0.10	669.76

```
motor_right = 60.2
motor_left = 60.1
motor_front = 60.1
motor_back = 60.1
```

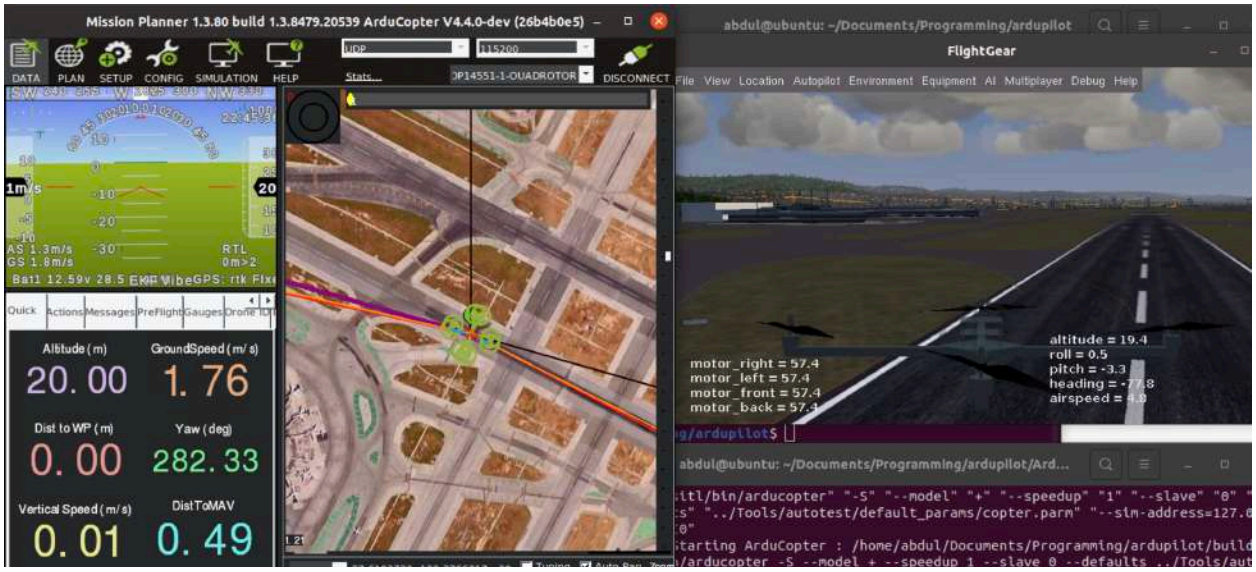
```
altitude = 16.1
roll = 0
pitch = -27.2
heading = -74.1
airspeed = 8.3
```

```
/ardupilot$
```

abdul@ubuntu: ~/Documents/Programming/ardupilot/Ard...

```
tl/bin/arducopter" "-S" "--model" "+" "--speedup" "1" "--slave" "0" "
" "../Tools/autotest/default_params/copter.parm" "--sim-address=127.0
"
tarting ArduCopter : /home/abdul/Documents/Programming/ardupilot/build
arducopter -S --model + --speedup 1 --slave 0 --defaults ../Tools/aut
ult_params/copter.parm --sim-address=127.0.0.1 -I0
```

```
GEO 37.6210304 -122.3839391 17. Tuning Auto Pan Zoom
```

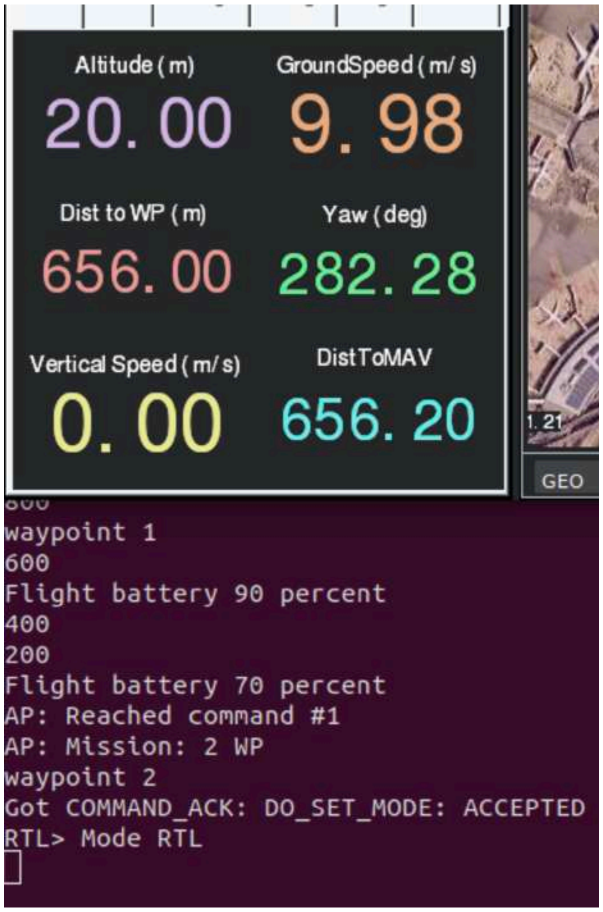

Mission Planner 1.3.80 build 1.3.8479.20539 ArduCopter V4.4.0-dev (26b4b0e5)
DATA
PLAN
SETUP
CONFIG
SIMULATION
HELP
DISCONNECT
Quick
Actions
Messages
PreFlight
Gauges
Drone
abdul@ubuntu: ~/Documents/Programming/ardupilot
FlightGear
File View Location Autopilot Environment Equipment AI Multiplayer Debug Help

Altitude (m) 20.00
GroundSpeed (m/s) 1.76
Dist to WP (m) 0.00
Yaw (deg) 282.33
Vertical Speed (m/s) 0.01
DistToMAV 0.49

```
motor_right = 57.4
motor_left = 57.4
motor_front = 57.4
motor_back = 57.4
```

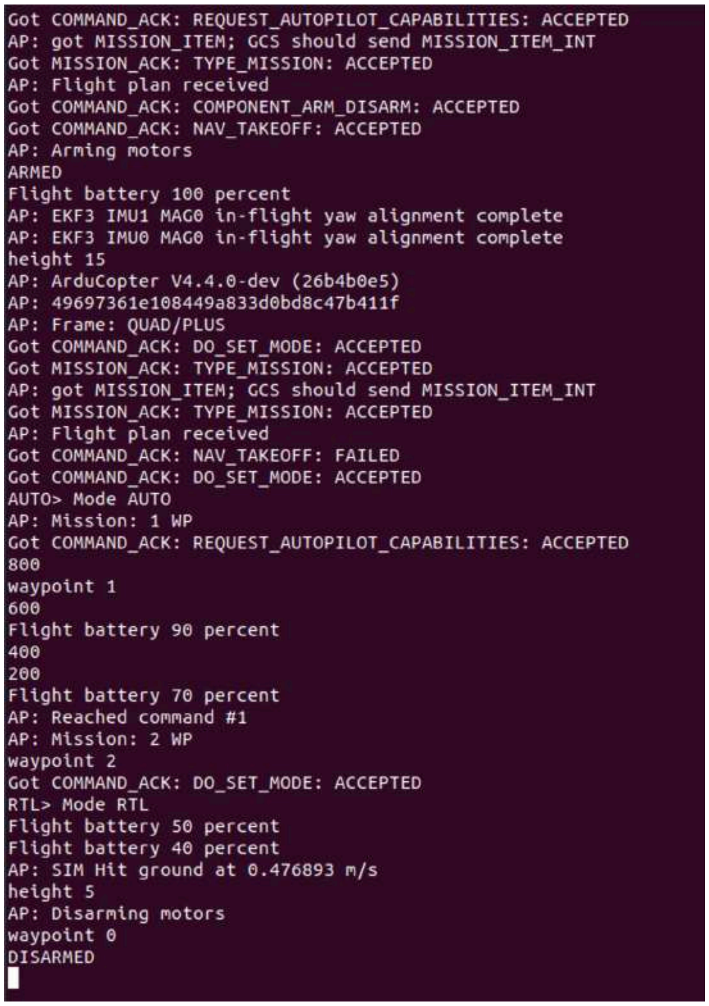
```
altitude = 19.4
roll = 0.5
pitch = -3.3
heading = -77.8
airspeed = 4.0
```

```
abdul@ubuntu: ~/Documents/Programming/ardupilot/Ard...
itl/bin/arducopter" "-S" "--model" "+" "--speedup" "1" "--slave" "0" "
s" "../Tools/autotest/default_params/copter.parm" "--sim-address=127.0
0"
tarting ArduCopter : /home/abdul/Documents/Programming/ardupilot/build
/arducopter -S --model + --speedup 1 --slave 0 --defaults ../Tools/aut
```



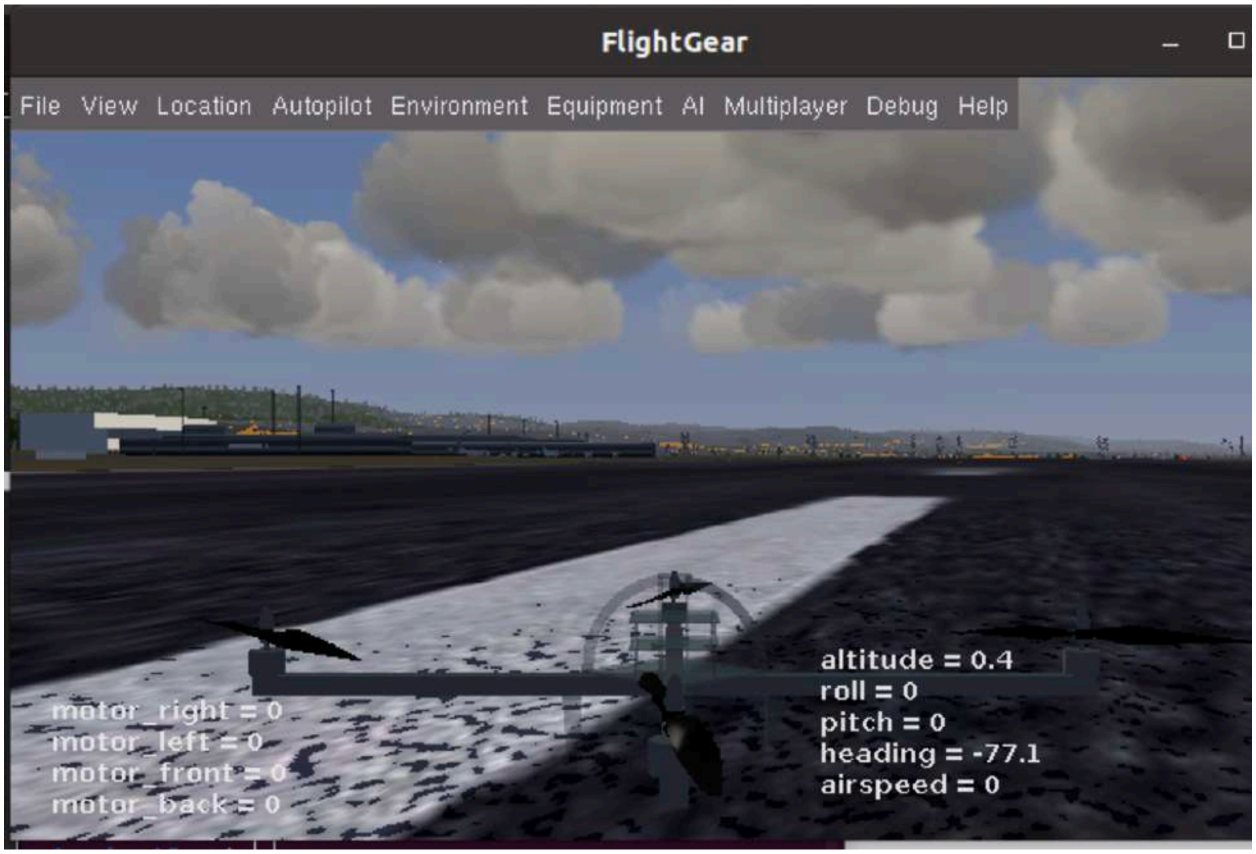
Altitude (m) 20.00
GroundSpeed (m/s) 9.98
Dist to WP (m) 656.00
Yaw (deg) 282.28
Vertical Speed (m/s) 0.00
DistToMAV 656.20

```
800
waypoint 1
600
Flight battery 90 percent
400
200
Flight battery 70 percent
AP: Reached command #1
AP: Mission: 2 WP
waypoint 2
Got COMMAND_ACK: DO_SET_MODE: ACCEPTED
RTL> Mode RTL
```



```
Got COMMAND_ACK: REQUEST_AUTOPILOT_CAPABILITIES: ACCEPTED
AP: got MISSION_ITEM; GCS should send MISSION_ITEM_INT
Got MISSION_ACK: TYPE_MISSION: ACCEPTED
AP: Flight plan received
Got COMMAND_ACK: COMPONENT_ARM_DISARM: ACCEPTED
Got COMMAND_ACK: NAV_TAKEOFF: ACCEPTED
AP: Arming motors
ARMED
Flight battery 100 percent
AP: EKF3 IMU1 MAG0 in-flight yaw alignment complete
AP: EKF3 IMU0 MAG0 in-flight yaw alignment complete
height 15
AP: ArduCopter V4.4.0-dev (26b4b0e5)
AP: 49697361e108449a833d0bd8c47b411f
AP: Frame: QUAD/PLUS
Got COMMAND_ACK: DO_SET_MODE: ACCEPTED
Got MISSION_ACK: TYPE_MISSION: ACCEPTED
AP: got MISSION_ITEM; GCS should send MISSION_ITEM_INT
Got MISSION_ACK: TYPE_MISSION: ACCEPTED
AP: Flight plan received
Got COMMAND_ACK: NAV_TAKEOFF: FAILED
Got COMMAND_ACK: DO_SET_MODE: ACCEPTED
AUTO> Mode AUTO
AP: Mission: 1 WP
Got COMMAND_ACK: REQUEST_AUTOPILOT_CAPABILITIES: ACCEPTED
800
waypoint 1
600
Flight battery 90 percent
400
200
Flight battery 70 percent
AP: Reached command #1
AP: Mission: 2 WP
waypoint 2
Got COMMAND_ACK: DO_SET_MODE: ACCEPTED
RTL> Mode RTL
Flight battery 50 percent
Flight battery 40 percent
AP: SIM Hit ground at 0.476893 m/s
height 5
AP: Disarming motors
waypoint 0
DISARMED
```

The drone flies over a range of 0-30, according to the code, however, it doesn't hit the 30 mark due to a failsafe mechanism that keeps it 10 units below the specified altitude. Hence, we are getting 10m on the first waypoint and further, 20 after reaching the second way point, which is then fixed at 20 while the third waypoint is reached and the drone returns back to spawn with the same altitude.


FlightGear
File View Location Autopilot Environment Equipment AI Multiplayer Debug Help

```
motor_right = 0
motor_left = 0
motor_front = 0
motor_back = 0
```

```
altitude = 0.4
roll = 0
pitch = 0
heading = -77.1
airspeed = 0
```

Return to home and land

Conclusion

In conclusion, we have successfully simulated flight missions using ardupilot.

Overall, this experiment has demonstrated the power and flexibility of ardupilot simulation, and how it can be used to accelerate the development and testing of robotics systems.

Thank you! >.<

Abdul Aziz A.B (20BRS1185)