UAV Autonomous Landing

Team Expeditus

SDSMT MCS

December 10, 2015

Introduction

UAV Autonomous Landing Project

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Sponsor
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Goal

Demonstrate the capability of a UAV to autonomously take-off, navigate through some waypoints, return to the landing pad, and land with a minimum of distance and orientation error.

Requirements

Goal

- receive a set of waypoints
- autonomously take-off
- navigate through waypoints
- return to launch pad
- **land with $\pm$.1m distance and $\pm 15^\circ$ orientation error**

Limitations

- landing platform is a fixed position
- landing platform is a stable, horizontal surface
- environment is ideal(no wind, gps available, no obstacles)

User Stories/Backlog

- **User 1(U-1):**
  As a user, I want to communicate the waypoints to the UAV.
- **Owner 1(O-1):**
  As an owner, I want the UAV to autonomously take-off from the landing pad.
- **Owner 2(O-2):**
  As an owner, I want the UAV to autonomously navigate through a set of waypoints.
- **Owner 3(O-3):**
  As an owner, I want the UAV to autonomously return to the location of the landing pad.
- **Owner 4(O-4):**
  As an owner, I want the UAV to autonomously land on the landing pad without damaging the craft.
- **Owner 5(O-5):**
  As an owner, I want the UAV to autonomously land on the landing pad with the correct orientation.

U-1

As a user, I want to communicate the waypoints to the UAV.

Task No.	Task	Date Completed	Sprint
1	Review previous method/interface for communicating coordinates to UAV.	10/05/15	1
2	Review code that communicates with quadrotor	10/16/15	2
3	Review code that allows a user to input waypoints	10/16/15	2

O-1

As an owner, I want the UAV to autonomously take-off from the landing pad.

Task No.	Task	Date Completed	Sprint
1	Review previous implementation for autonomous take-off.	10/05/15	1
2	Review code that enables the quadrotor to autonomously take-off from landing pad	10/16/15	2

As an owner, I want the UAV to autonomously navigate through a set of waypoints.

Task No.	Task	Date Completed	Sprint
1	Review previous implementation for navigating waypoints.	10/05/15	1
2	Review code that enables the quadrotor to autonomously navigate through a series of way-points	10/16/15	2

As an owner, I want the UAV to autonomously return to the location of the landing pad.

Task No.	Task	Date Completed	Sprint
1	Review previous implementation to autonomously return to location of landing pad	10/05/15	1
2	Review code that allows the autonomous return of the UAV to the landing pad.	10/16/15	2

As an owner, I want the UAV to autonomously land on the landing pad without damaging the craft

Task No.	Task	Date Completed	Sprint
1	Review previous implementation for autonomous landing	10/05/15	1
2	Install previous implementation	10/19/15	2
3	Test previous implementation	10/26/15	2

As an owner, I want the UAV to autonomously land on the landing pad with the correct orientation.

Task No.	Task	Date Completed	Sprint
1	Review previous implementation for autonomous landing	10/05/15	1
2	Install previous implementation	10/19/15	2
3	Test previous implementation	10/26/15	2

Initial Common Tasks

Task No.	Task	Date Completed	Sprint
1	Install Ubuntu 14.04 or some other ROS Indigo/Jade distro compliant OS.	09/25/15	1
2	Setup Gazebo 6.+	09/25/15	1
3	Download Rviz package	09/25/15	1
4	Setup Simulation Environment	11/02/15	2

C Continued

Initial Common Tasks

Task No.	Task	Date Completed	Sprint
5	Review previous iteration of project documentation	09/25/15	1
6	Inspect current quadrotor configuration	09/28/2015	2
7	Identify parts needed for quadrotor	11/02/2015	2
8	Acquire parts needed for hexrotor	12/01/2015	3

Sprint 1

Sprint 1 - Successes

- Revised project scope
- Product Backlog - User Stories
- Setup Development Environment
- Review previous years hardware and software

Sprint 1 - Setbacks

- Previous years UAV unusable
- Previous years flight code unusable

Sprint 2

Sprint 2 - Successes

- Visual Homography Code repurposed
- Created simulation environment
- Ordered parts for new Hex-copter

Sprint 2 - Setbacks

- Simulation only supports manual control

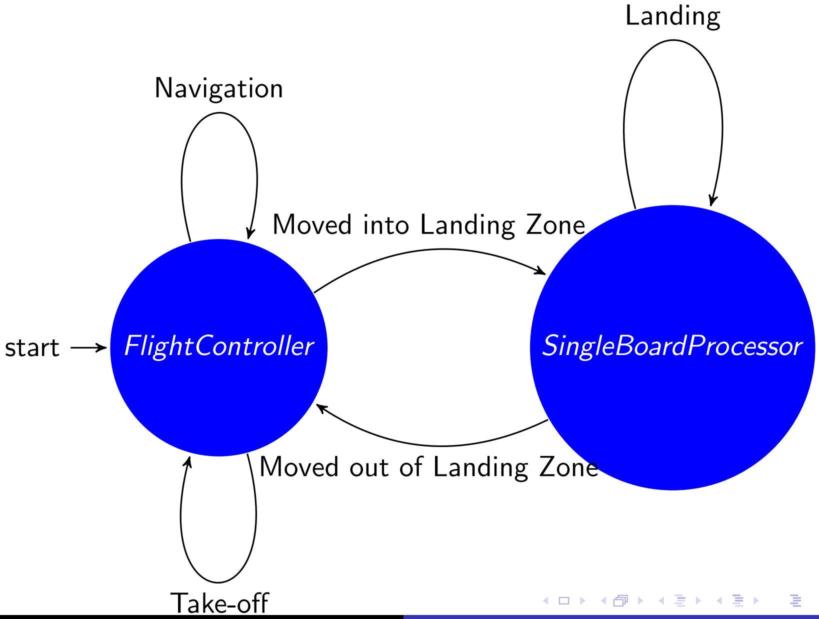
Sprint 3 - Successes

- Assembled Frame, Motors, ESC's
- Many SITL simulations
- Waypoint Publisher publishes mavros commands
- Working image homography code
- Becoming familiar with python openCV libraries

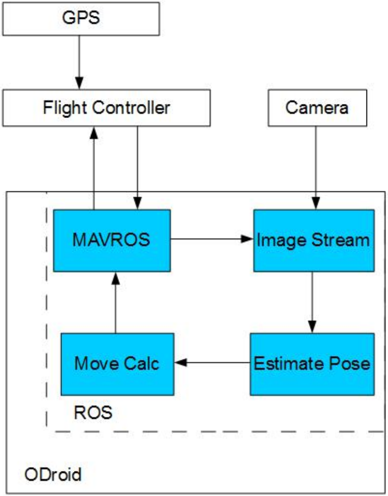
Sprint 3 - Setbacks

- Pixhawk delayed 2 weeks, build not completed
- SITL simulations rejected waypoint files
- SITL simulations rejected mavros commands

Design


Landing
Navigation
Moved into Landing Zone
start
FlightController
SingleBoardProcessor
Moved out of Landing Zone
Take-off

Architecture



Hardware Requirements

- ODroid XU4
- Pixhawk Flight Controller
- GPS peripheral
- Camera
- Battery
- UAV(Frame, Motors, ESCs, Power Distribution Board)

Software Requirements

- Mavlink
- Python
- OpenCV
- Robot Operating System(ROS) Indigo/Jade Distro
- Ubuntu 14.04

UAV Design & Tech Specs

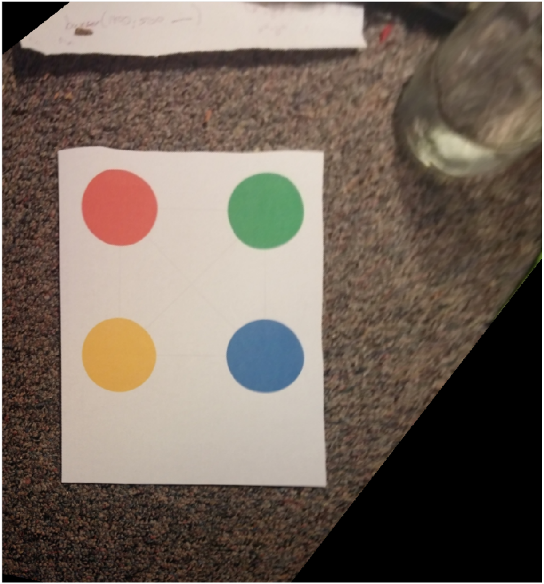
Physical design of the hex-copter is the **Turnigy Talon Hexcopter**

Visual Homography Design & Tech Specs

- Blob detection is used to detect colored circles
- For each color we are looking for, look for a group of pixels over a certain size
- that is considered a "blob"

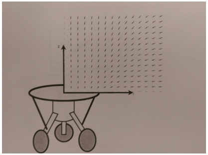
Homography

Homography



Design & Tech

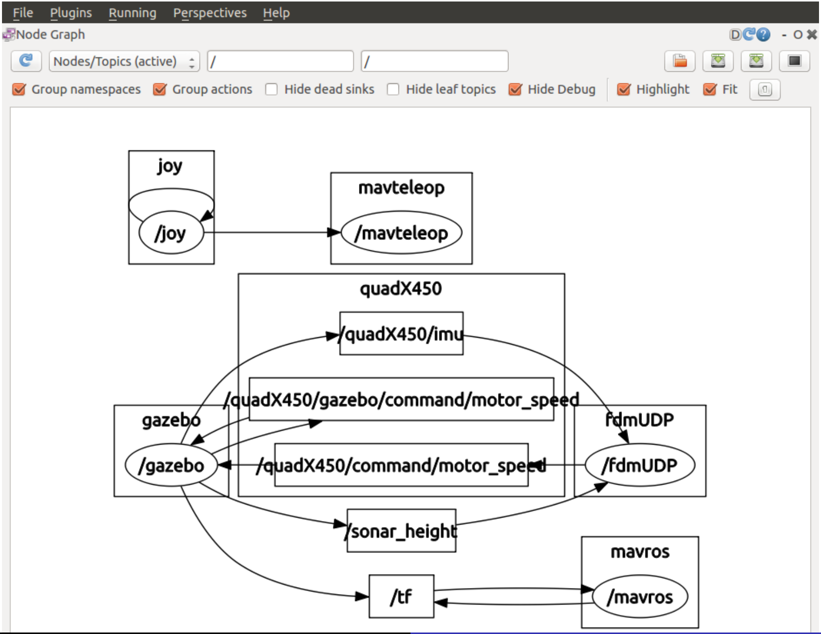
- Linear, gradient-decent sarsa
- 2D State Space
- 3D State Space



Setbacks

- Research and familiarizing
- Simulation Environment

Simulation Design & Tech Specs



UAV Testing - O-1

As an owner, I want the UAV to autonomously take-off from the landing pad.

Task No.	Task	Testing
1	Review previous implementation for autonomous take-off.	Send mission containing takeoff followed by hover command in simulation.
2	Review code that enables the quadrotor to autonomously take-off from landing pad	Upload code to physical UAV and send mission containing takeoff followed by hover command with manual override enabled.

UAV Testing - O-2

As an owner, I want the UAV to autonomously navigate through a set of waypoints.

Task No.	Task	Test
1	Review previous implementation for navigating waypoints.	Send mission containing takeoff followed by way-points and once the last waypoint is reached a hover command all in simulation.
2	Review code that enables the quadrotor to autonomously navigate through a series of way-points	Upload code to physical UAV and send mission again with manual over-ride enabled

UAV Testing - O-3

As an owner, I want the UAV to autonomously return to the location of the landing pad.

Task No.	Task	Test
1	Review previous implementation to autonomously return to location of landing pad	The last waypoint from the previous test should be the landing pad but to verify a image match will be used in simulation that will verify that the UAV is in fact above the landing pad.
2	Review code that allows the autonomous return of the UAV to the landing pad.	The physical UAV will match what it sees with its camera to a image it has stored of the landing pad at multiple heights.

As an owner, I want the UAV to autonomously land on the landing pad without damaging the craft

Task No.	Task	Test
1	Review previous implementation for autonomous landing	The UAV should be able to detect the landing pad
2	Install previous implementation	The UAV should be able to begin to lower onto the pad
3	Test previous implementation	The UAV should land gently on the pad

Visual Homography Landing Testing - O-5

As an owner, I want the UAV to autonomously land on the landing pad with the correct orientation.

Task No.	Task	Test
1	Review previous implementation for autonomous landing	The UAV should be able to calculate its angle wrt the pad
2	Install previous implementation	The UAV should be able to rotate to match the pad
3	Test previous implementation	UAV should maintain orientation throughout descent

As a user, I want to communicate the waypoints to the UAV.

Task No.	Task	Test
1	Review previous method/interface for communicating coordinates to UAV.	Connect GPS to pixhawk and verify it recieves a connection and in Mavros verify we can retrieve gps coordinates from gps in ROS.
2	Review code that communicates with quadrotor	Verify that all commands in Mavros can be sent to and accepted by the Pixhawk and it acts appropiately
3	Review code that allows a user to input waypoints	Verify that user entered waypoints can be uploaded into Pixhawk Successfully with mavros.

Remaining Backlog

- **User 1(U-1)**
- **Owner 1(O-1)**
- **Owner 2(O-2)**
- **Owner 3(O-3)**
- **Owner 4(O-4)**
- **Owner 5(O-5)**
- **Common**

Revised Goals

- Project Goals remain fixed

Risk Analysis

- Simulation: SITL has proven to be problematic
- UAV Build: Borrowing items from UAV Team (Radio and Control)
- UAV Build: One UAV for physical testing and demonstration
- Landing Algorithm: Many approaches, we may pick the wrong one

Risk Mitigation

- Simulation:
  - Attempt HIL as Alternative
- UAV Build(Sharing)
  - Schedule use of tools to prevent conflict
  - Request more funding if schedule is untenable
- UAV Build(One Shot)
  - Integrate manual control override
  - Validate solutions through simulation

Timeline

Sprint 3.5 12/16/15 to 1/10/16

- Finish UAV Build(C)
- Manual Flight of UAV(C)
- Autonomous Flight of UAV(C,U-1,O-1,O-2,O-3)
- Resolve Simulation Issues(C)

At the end of break, 3 backlog items will have been completed

Sprint 4 1/18/16 2/5/16

- Finish Landing Algorithm Simulations(O-4,O-5)

At the end of sprint 4, we should have a landing approach validated by simulation.

Timeline...continued

Sprint 5 2/15/16 3/4/16

- Integration of Landing Autonomy on UAV(O-4,O-5)

At the end of sprint 5, we should have completed the remainder of backlog items.

Sprint 6 3/21/16 4/15/16

- Refinement

At the end of sprint 6, project will be complete

Budget

Item	Qty	Price	Total
Frame	1	$79.99	$79.99
Motors	8	$23.99	$191.92
ESCs	8	$17.78	$142.24
Pixhawk	1	$199.99	$199.99
Power Distribution	1	$19.99	$19.99
GPS Mast	2	$10.00	$20.00
GPS	2	$89.99	$179.98
Power Module	1	$24.99	$24.99
Odroid XU4	1	$75.95	$75.95
Props(set of 4)	3	$7.55	$22.65
TOTAL			$957.70

IP & Licensing

Intellectual Property:
Project is owned by SDSMT

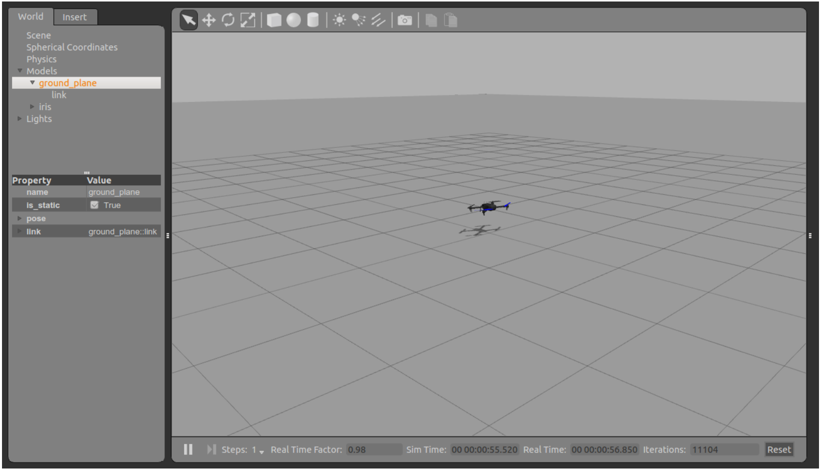
Licensing for Dependencies:

- OpenCV: BSD
- ROS: BSD
- Mavlink: LGPL version 3
- QGroundControl: GPL version 3

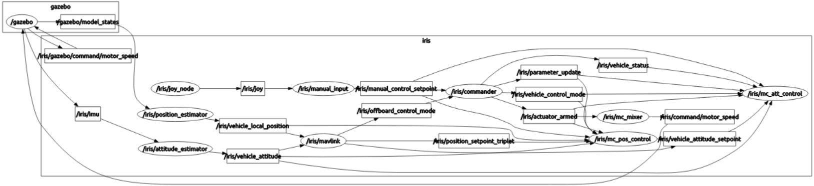
Demos

- PX4 ROS SITL
- Ground Control Station
- Visual Homography

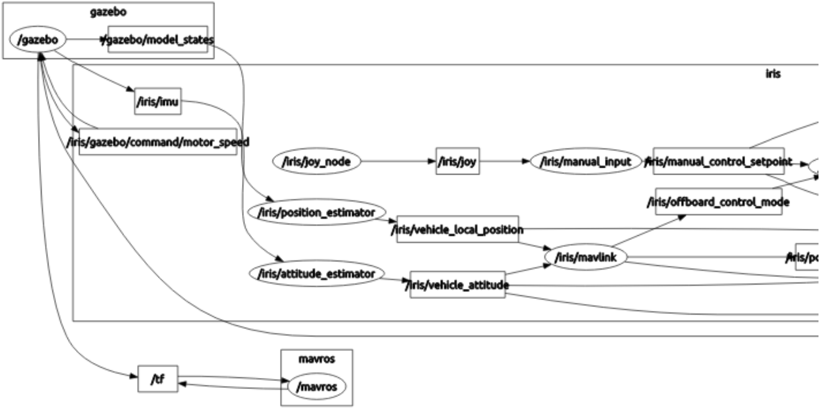
Simulation - PX4 ROS SITL



PX4 ROS SITL...continued



PX4 ROS SITL...continued



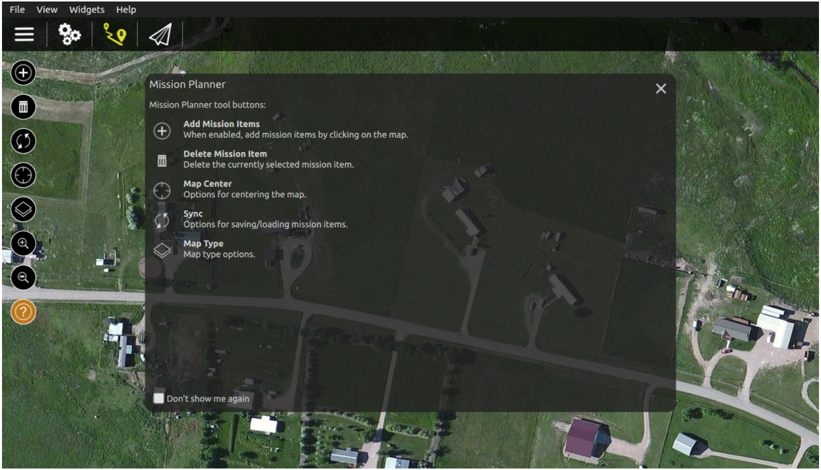
PX4 ROS SITL...continued

```
rvice [/rosout] found
[mavros-1]: started with pid [5760]
 [1449625813.107703184]: FCU URL: udp://localhost:14560@localhost:14565
 [1449625813.108111698]: udp0: Bind address: 127.0.0.1:14560
 [1449625813.108231677]: udp0: Remote address: 127.0.0.1:14565
 [1449625813.108390158]: GCS bridge disabled
 [1449625813.111757989]: udp0: Remote address: 127.0.0.1:14565
 [1449625813.246282225, 415.735000000]: Plugin 3dr_radio loaded and initi

 [1449625813.264741115, 415.755000000]: Plugin actuator_control loaded an
alized
 [1449625813.427370113, 415.905000000]: Plugin cam_imu_sync loaded and in
ed
 [1449625813.446682768, 415.925000000]: Plugin command loaded and initial

 [1449625813.446866194, 415.925000000]: Plugin distance_sensor blackliste
```

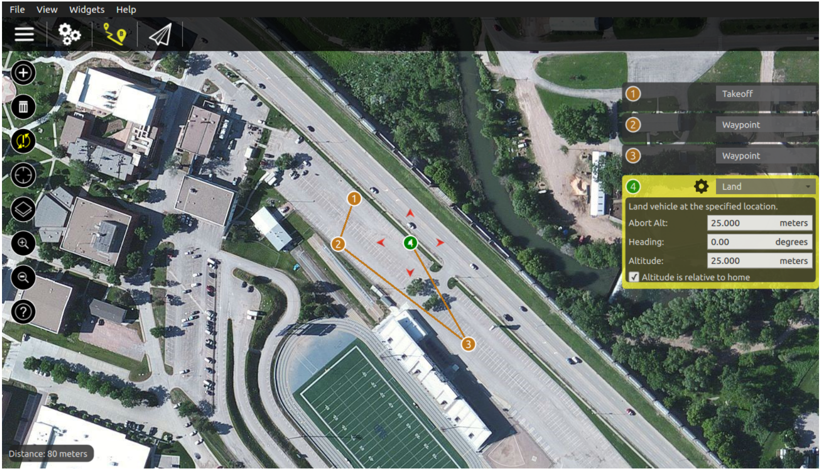
```
/iris/MP_YAW_FF
/iris/MP_YAW_P
/iris/mavlink/mavlink_fcu_url
/iris/mixer
/iris/motor_offset_radps
/iris/motor_scaling_radps
/iris/vehicle_model
/robot_description
/rosdistro
/roslaunch/uris/host_rivercity_lifebook_t725__4524
/rosversion
/run_id
/tf_prefix
/use_sim_time
rivercity@rivercity-LIFEBOOK-T725:~/catkin_ws$ ros
k_fcu_url
udp://localhost:14565@localhost:14560
```

Ground Control Station - QGroundControl

Ground Control Station...continued

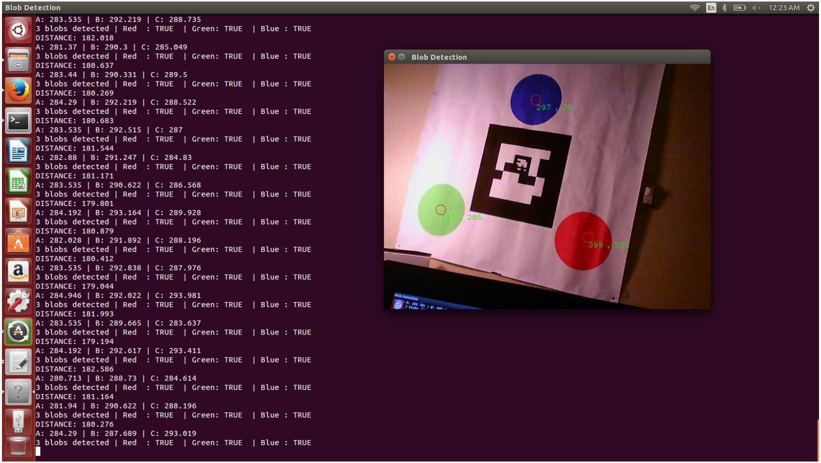


Ground Control Station...continued



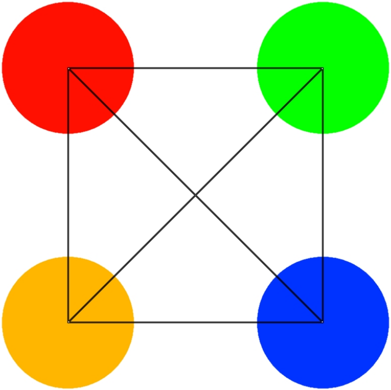
Vision-Based Landing

- Began playing with last year's code
- Able to detect three blobs and distance to target



Vision-Based Landing...continued

- After our computer vision class, we considered adding a fourth circle
- This gives us a square target instead of triangle




frame

END

Questions