Team Daphne: Amphibian Quadcopter

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Problem Statement

Nowadays, drones can only operate in the one dimensional space of the sky. It makes a lot of places inaccessible due to the fact that most drones aren't waterproof or not dexterous underwater. Waterproof quadcopter can be applied to geological surveys or military use.

Motivation And Scope

We want to break the boundary of the operational space of the drone. In this sense, we can expand a vast possibilities of the applications of drones

Detail Context / Related Works

- Drone failure under water

https://www.youtube.com/watch?v=4OKXSjkbJwg

From the video, we can see that even top-class drone made by DJI will experience malfunction underwater.

- Underwater drone by Rutgers University

https://www.youtube.com/watch?v=FC9EJhs0pc0

It is the only research that we can find online involving development of underwater quadcopter, meaning underwater quadcopter it is still a new area in the field of robotics. The difference between our proposal and their project is that we can to implement the quadcopter system in a wireless fashion, using WiFi for connections. Furthermore, we are planning to install a camera onto the drone allowing pilot to manipulate the quadcopter even without seeing the quadcopter itself. In addition, a camera will give the system for potential in performing tasks in different fields.

Task Breakdown With Particular Challenges

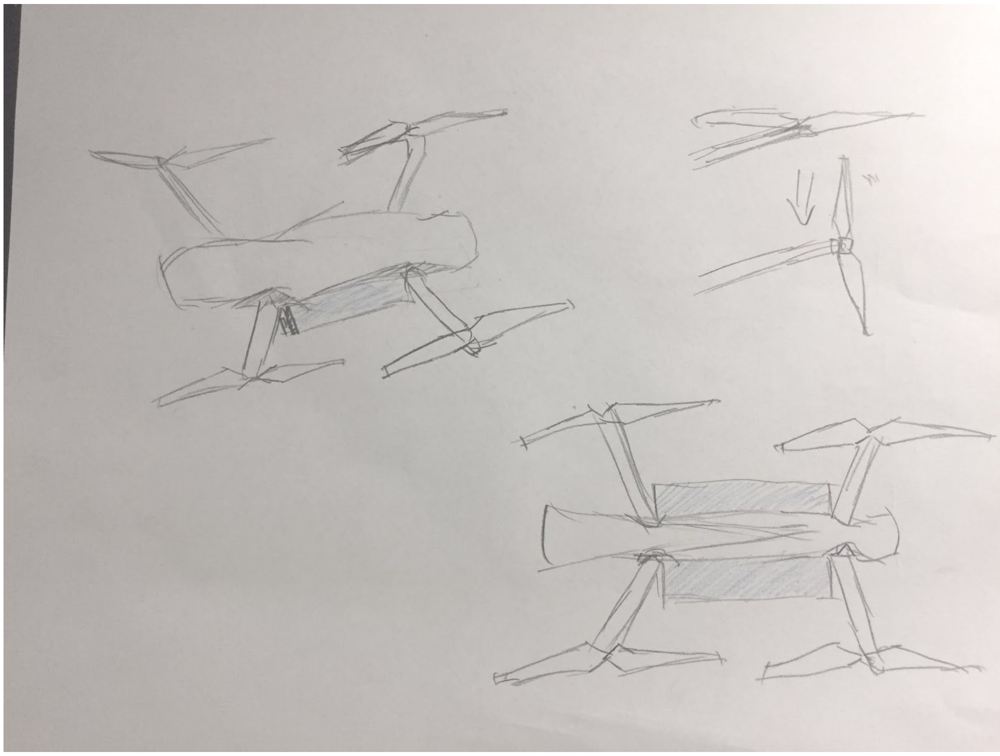
- Different types of propulsions in air and underwater
- Control of the drone, and how to make it level in the water
- Waterproof components and floating challenges

a. Waterproof motors

Underwater motors made by JFEC are used for driving quadcopter both in air and underwater. Motors take input voltage of 11.1V and can provide 250G thrust under the driving current of 2A. The motor is a 2212 KV960 model, 2212 indicates the size of the coil inside of the motor and KV960 means the motor speed will raise 960 rpm for 1V increase of the input voltage. This model is a quite common configuration for quadcopter motors, therefore it is compatible with most quadcopter frames in the market. We will try different size of motor blades to determine which size can meet our requirement. Finally, each motor has weight of 65g which is acceptable comparing to the thrust it provides.

b. How to make it float and sink

Inspired by submarines, having 2 or 4 tanks attached to the bottom of the drone, as illustrated below:



Pros:

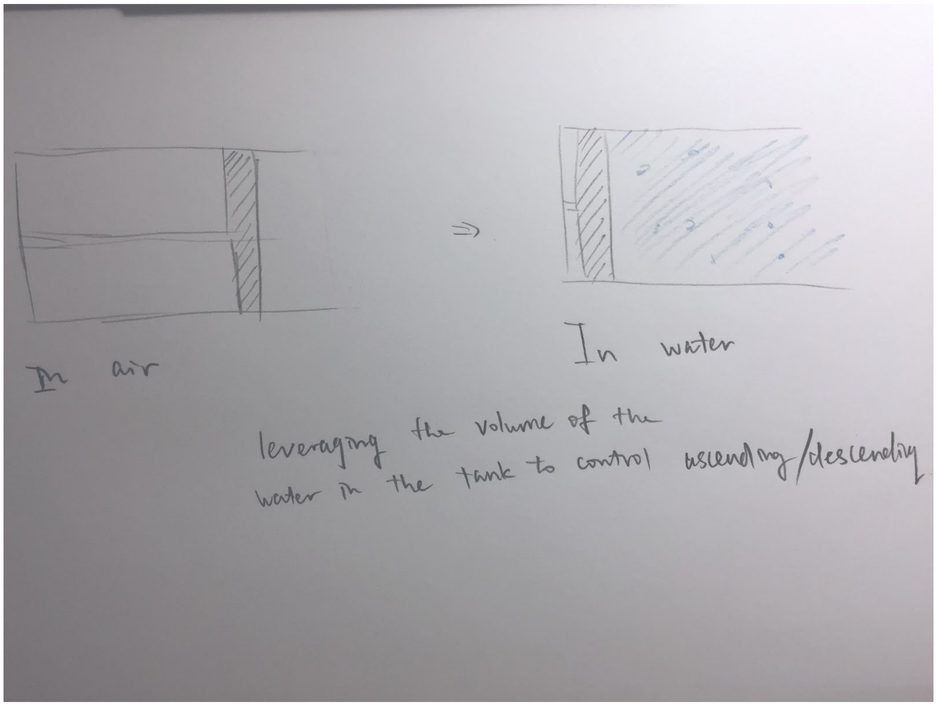
1. Easy to implement
2. Acts as buffer when the drone lands on land or water

Cons:

1. Extra payload
2. More controls and motors to control of the volume of the water inside the tank

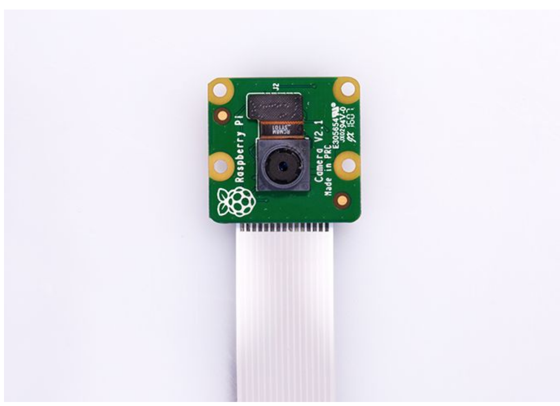
c. *Water volume control*

We can implement a piston-like mechanics that extends while the drone is in air. When we want to keep the drone sink in the water with its bodyweight, we can gradually release the piston to let the water in. Note that it requires a large power from the piston since the tube would be vacuum when it extends under the water.



d. Live camera streaming from quadcopter to laptop

We use Raspberry Pi(a small Linux based computer) and its own own camera module for streaming video to laptop or take pictures.



The camera module has a Sony 8-megapixel sensor for high-definition video as well as still photography.

At least two potential methods can be used for streaming video:

1. VLC: stable, easy to implement, but latency around 1s

2. V4L2: may not as stable as VLC, latency about 0.1s

All video streaming are transmitted using WiFi. In addition, the cable connecting camera module and Raspberry Pi is waterproofing , so it won't affect the quality of the streaming.

e. Control Hardware

A printed circuit board (PCB) will be used for implementing the circuit required for state sensing, motor control and wireless communication. Microcontroller chip, IMU, WiFi module and motor control circuit(half bridge motor driver) will be soldered on the board.

Pros:

1. Lighter/smaller board and more stable(permanent) connections

Cons:

1. Hard to replace components and debugging
2. May take some take for ordering the board and delivery

As for plan B, we can use an Arduino Development Board with WiFi Module and configure all the components on a perfboard/breadboard for control, sensing and wireless communication.

Pros:

1. Easier for debugging and replace components

Cons:

1. Have loose connections and take more space
2. Soldering that much components on perf board can be messy and time-consuming

f. Powering the system

We will use a 11.1V 2200mAh Lipo battery to power the system including all boards and motors. We Choose 11.1V because it's the minimal required voltage for the motors. In

addition, we choose Lipo battery due to the reason that Lipo battery are the lightest for the same capacity. The battery is 2200 mAh and rechargable give us enough battery life for testing the system and also save our budget(double battery capacities will double battery price).
Microcontroller and Raspberry Pi have required input voltage of 5V. Hence a regulated 5V voltage will be provided to two boards, and 11.1V will be directly provided to each motor.

g. Mounting for the system

Mounting electronics: All electronics (microcontroller, Raspberry Pi) goes into a waterproof electronic project box(158 x 90 x 60mm), which is large enough for holding all the components.

Holes will be drilled on the sides of the box, allowing cables for motor control and camera to come out. In additions, liquid rubber coating will be used for drilled holes to prevent water leakage.

For camera mounting, we will use liquid rubber to seal a pre-made camera case and screw it onto the electronic project box.

Mounting motors:

FY450 quadcopter is chosen for mounting the whole system because it is compatible with the underwater motor we choose and it is low-priced. Motors will be screwed on the arms of the frame. Holes will be drilled at the bottom of the electronic box, and the box will be screwed on the middle of the frame. Liquid rubber will be used for sealing the gaps between electronic box and outside. The arms of the frame are not made of metal, reducing weight of the frame and also preventing rust.

h. Part choice

Oscillator: the MCU needs an external clock to keep track of time, which is provided by the oscillator. In this case, we chose a 8MHz Ceramic Resonator. It is cheap and easy to assembly, and its precision is good enough for MCUs.

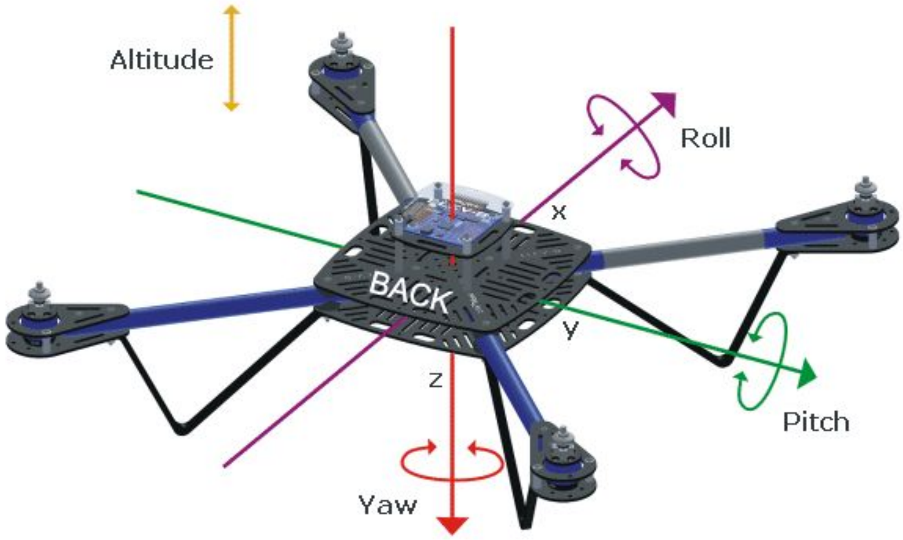
Voltage Regulator: We will use the voltage regulator MIC5219-3.3YM5-TR. This voltage regulator can take in input up to 12V and output 3.3V, which is compatible with the battery voltage. It also has good dropout voltage and current capability.

MOSFET: since we use low side switching to control motors, we will need to have N-channel MOSFETs. The one that we chose has low Rds(on), so it won't heat up a lot when huge amount of current passes through it. Vds(max) of this MOSFET is 20V which is big enough for our battery.

IMU: We will use MPU6050 as IMU for the device. It's a six-axis gyro + accelerator that can provide acceleration and angular velocity data. The voltage supply range is 2.375V-3.46V, and we can use a 3.3V voltage regulator to power it. We used MPU6050 in lab4 and the interface with arduino is relatively easy so we choose this device to measure the kinematic data of the quadcopter. What's more, the MPU6050 chip also has a built-in Digital Motion Processing Unit, which we can use to combine the readings of accelerometer and gyroscope to calculate the yaw, pitch and roll of the system.

WiFi Module: We plan to use nRF24L01, a single chip 2.4GHz Transceiver as Wifi Module between the MCU on the quadcopter and the computer. It operates at worldwide 2.4GHz ISM band, allows 250kbps, 1Mbps and 2Mbps on air data rates, and has ultra low power operation. It is also powered by a 3.3V voltage regulator.

i. Control for quadcopter



There are three axes for the quadcopter: roll, pitch and yaw, and the motion of the quadcopter will be described with respect to these axes. By sending different PWM signals to the motors, we are able to change the angular velocity on the respective axes.

To control the quadcopter, generally we use a feedback control system. The MCU sets a reference point, combine it with the feedback signals to generate actuating signals (in this case, the PWM signal that controls the current through motors). The motors will in turn affect the angle and angular velocity of the quadcopter, which we are able to capture via sensors like IMU. The results of the sensor will be sent back to the reference input, and the state is updated. This control loop will be executed very rapidly (several dozen times a second) to achieve stability.

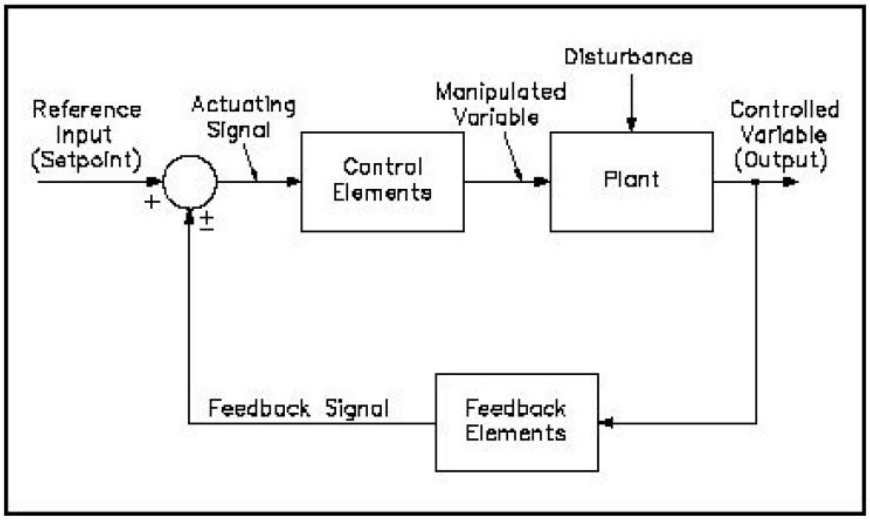
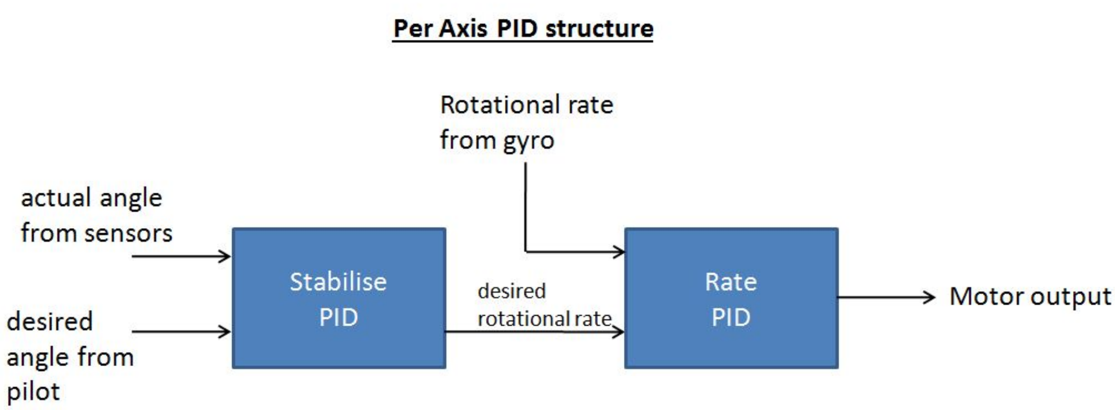


Figure 8 Feedback Control System Block Diagram

Specifically, we use PID controller to control the quadcopter. The error is the difference between the desired value and actual value. In rate PID, the value is the angular velocity about a certain axis, and in stabilise PID the value is the angle with respect to the pitch, roll or yaw axis. We use the output of PID to control the PWM signal to the motor.

Aside from proportional control, we can also use the integral part to tune out the constant error (such as disturbance of the environment) and the derivative coefficient to reduce overshoot. The control loop repeats very rapidly (several dozen times a second) to achieve stability.



Bill of Materials

	Manufacturer Part No.	Datasheet Link	Vendor	Description	Vendor Part No.	Qty.	Unit Price	Total Price	Vendor Link	Primary Use	No
Raspberry Pi	Raspberry Pi Model B	http://docs-e	N/A	Raspberry Pi	N/A	1	$19.99	$19.99	https://www.spar	Camera Interfacing	Preown
N/A	N/A	N/A	Ebay	Electronic Project Box	N/A	1	$3.85	$3.85	http://www.ebay.c	Waterproof Casing	
Raspberry Pi	Raspberry Pi Camera Module		Ebay	Raspberry Pi Camera	N/A	1	$9.99	$9.99	http://www.ebay.c	Video Streaming	
JFRC	U2212	N/A	Taobao	Motor	N/A	4	$13.28	$53.12	https://world.taob	Actuators	
Feiyue	FY450 TL2749-05	N/A	Taobao	Quadcoptor Frame	N/A	1	$9.71	$9.71	https://world.taob	Support Motors	
APC	APC 1147	N/A	eBay	Quadcoptor Blade	N/A	2	$4.49	$8.98	http://www.ebay.c	For Motor	
Tenergy	Tenergy 11.1V 2200mAh 25C LIPO	N/A	All-Battery.com	Battery	N/A	1	$19.99	$19.99	http://www.all-bat	Power Supply	
Microchip Technol	MIC5219-3.3YM5-TR	http://ww1.m	Digi-Key	Voltage Regulator	576-1281-1-ND	1	$0.92	$0.92	http://www.digike	Voltage Regulation	
Infineon Technolo	IRLML6244TRPBF	http://www.in	Digi-Key	N-Channel MOSFET	IRLML6244TRPBFCT-ND	5	$0.36	$1.80	http://www.digike	Motor Control	
Murata Electronics	CSTCE8M00G55-R0	http://www.m	Digi-Key	Ceramic Resonator	490-1195-1-ND	1	$0.46	$0.46	http://www.digike	MCU Timing Contro	
Microchip Technol	ATMEGA328P-AUR	http://www.at	Digi-Key	Microcontroller	ATMEGA328P-AURCT-ND	1	$3.81	$3.81	http://www.digike	Microcontroller	
Parasonic Electro	DB2W40300L	http://www.se	Digi-Key	Diode	DB2W40300LCT-ND	4	$0.55	$2.20	http://www.digike	Motor Control	
Bourns Inc	CR0603-FX-1002GLF	http://www.b	Digi-Key	Resistor 10kΩ	CR0603-FX-1002GLFCT-ND	6	$0.10	$0.60	http://www.digike	Motor Control	
Bourns Inc	CR0603-JW-221GLF	http://www.b	Digi-Key	Resistor 220Ω	CR0603-JW-221GLFCT-ND	3	$0.10	$0.30	http://www.digike	LED Circuit	
Bourns Inc	CR0603-JW-183ELF	http://www.b	Digi-Key	Resistor 18kΩ	CR0603-JW-183ELFCT-ND	1	$0.10	$0.10	http://www.digike	Voltage Divider	
Yageo	CC0603ZRY5V9BB104	http://www.ya	Digi-Key	Capacitor 100nF	311-1343-1-ND	5	$0.10	$0.50	http://www.digike	Decoupling Capacit	
Yageo	CC0603KRX7R7BB105	http://www.ya	Digi-Key	Capacitor 1uF	311-1446-1-ND	2	$0.10	$0.20	http://www.digike	For Voltage Regulat	
Yageo	CC0603MRX5R5BB106	http://www.ya	Digi-Key	Capacitor 10uF	311-1448-1-ND	1	$0.21	$0.21	http://www.digike	For Antenna	
KEMET	C1210C107M9PACTU	http://www.ke	Digi-Key	Capacitor 100uF	399-4697-1-ND	4	$1.06	$4.24	http://www.digike	Smooth out motor transient	
RAFI USA	1.14001.5030000	http://media.	Digi-Key	Switch	1715-1032-1-ND	1	$2.34	$2.34	http://www.digike	Reset Button	
Invensense	MPU-6050	https://store.	Invensense Onlir	Gyroscope	MPU-6050	1	$5.45	$5.45	https://store.inver	Measure acceleration, angul	
Nordic Semicondu	nRF24L01	https://www.s	GearBest	Radio Module	nRF24L01	2	$0.93	$1.86	http://www.gearb	Wireless Communication	
								$150.62			

Google sheet link:

https://docs.google.com/spreadsheets/d/1l4aeeZpLU2HqdHF7owFncWuhiHhhJrN1-ExrxptnZMY/edit#gid=0

Project Plan and Milestones

Week 1- Week 2 : Implement Camera streaming feature/Build Chassis/Solder Control Circuit

Week 3 - Week 5: Quadcopter fully function on land

Week 6 - Week 7: Finish Waterproofing

Week 8: First Underwater Testing

Week 9 - Week 10: On Land/Underwater Testing

Expected Results

Quadcopter able to move smoothly in air and underwater and provide stable camera stream allowing quadcopter to wirelessly control quadcopter.

Tasks Assignments

***Red**: top priority*

***Yellow**: important features*

***Green**: nice-to-have features*

Gray: future features

Kevin

Jerry

Likai

Task	Owner	Status	Notes
Camera Streaming Configuration	*Likai*		
Chassis Building	*Kevin* *Likai* *Jerry*		
Circuit Soldering	*Likai*		
Coding and Adjustment	Kevin *Jerry*		
Waterproof Coating	Kevin		
Underwater Testing	*Kevin* *Likai* *Jerry*		
Air-to-water Landing Test	*Kevin* *Likai* *Jerry*		

Potential Challenges

1. We have no previous experiences with machining, therefore we need to get familiar with UCLA machining resources.

2. We have to do a lot of testing to determine the right PID parameters for running the quadcopter in air and underwater
3. A optimal weight will be determined for allowing our quadcopter moving smoothly in air and not sinking underwater.
4. How can we control the quadcopter to make “water to air” and “air to water” transitions.
5. How are we going to move the system in a stable way underwater
6. How to test our system underwater and how to prevent from water leakage
7. WiFi may not able to work underwater since water will absorb most of 2.4Ghz microwave
    a. *Solution 1:*

        Stay with wireless and test out the functional depth of quadcopter underwater

    b. *Solution 2:*

        Use waterproof wire for Raspberry Pi and Motor Control to implement wired control

    c. *Solution 3:*

        Only goes into shallow water for stable connection

    d. *Solution 4:*

        Install antenna stick out of water surface for signal transmission

    e. *Solution 5:*

        Use WiFi module with lower frequency

References

Quadcopter PID explained and tuning:
https://oscarliang.com/quadcopter-pid-explained-tuning/

Feedback control system block diagram:

https://baniinstind23.wordpress.com/process-controls/control-loops-diagram/feedback-control-system-block-diagram/

RC aircraft ransmitter controls:

http://learn.parallax.com/tutorials/robot/elev-8/multirotor-flying-guide-elev-8-v2/learn-your-transmitter-controls