A Design of an Autonomous Drone for Animal Recognition

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Approval Certificate

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Abstract

The purpose of the research is to design a new drone architecture which will be capable of moving autonomously through most of the environments by interacting with the server itself. The main feature is that it will be able to move through air, land and water. Nowadays various drones are available. But a drone which can move through any environment is never seen before. The main motive is to use the drone in rescue mission and get accuracy in rescue missions in the cases of environmental & natural calamities and make it easier than previous times. Besides this drone will use the environmental data and bio information as a method of communication while interacting with the environment. Environmental data learning can be used to communicate with the nature and gather bio-information and environmental data from the environment and living beings. We hope this drone will be also able to move under water. For communicating with the environment and learning about the environment this drone will use two kinds of database: temporary database and online database. This research paper proposes a new design and modest algorithm which will help to move the drone autonomously avoiding most of the obstacles in its way. By gathering bio-information and environmental data the proposed ALW (Air, Land, and Water) drone will be able to communicate with the environment and adapt the changes in the environment and communicate with the server to act properly to be successful in its rescue mission. In this paper we used R Studio & R programming language to compare the accuracy results among several Machine Learning algorithms for several datasets. Based on the simulation results we can say that the drone will be able to predict the disaster accurately and recognize animal correctly.

Keywords: Drone; Database; AI; Interaction; Algorithm; bio information; Real time communication; Environment; Machine Learning; Disaster prediction; Animal recognition; Autonomous.

Published Papers

Work relating to the research presented in the thesis has been published by the author in the following peer reviewed journals.

1. **ALW drone: A new design and efficient approach** (published by IEEE, ICCIT 2016, Added to IEEE Xplore Digital Library on February 2017)
   Author:
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   Ms. Nusrat Jahan Lisa

   Link:
   https://ieeexplore.ieee.org/search/searchresult.jsp?newsearch=true&queryText=ALW%20Drone

2. **Autonomous drone (ALW): A design and method for disaster prediction and animal recognition** (submitted in Elsevier)

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Last but not the least, I would like to thank my mother who always gives me inspiration and help me to peruse my goal. She is the only family member who stood beside me every time no matter what I decide to do that is not illegal.

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Chapter 1

Introduction

Drones are more commonly known as unmanned aerial vehicles (UAV). Essentially, a drone is a flying robot which can be controlled or can be programmed to run autonomously in general. The aircraft may be remotely controlled or can fly autonomously through software-controlled flight plans in their embedded systems working in conjunction with GPS, Wi-Fi or radio wave generator. But, external components can be added also so that drone may move on land or under water.

Drones are continued being used in various commercial applications, such as journalism, documentary video making, area mapping, surveying, transporting, war, in scientific research and agriculture. In commercial filmmaking, cameras are attached to drones and used to make motion pictures from different angles very easily. In America, the FAA regulations regarding drones used in any commercial application are clearly defined in the American Laws which is pretty strict. Most uses other than recreation or by hobbyists are illegal. Some special limited licenses have been issued at high cost after doing much security check but have regulations within the license itself. Drone used for documentary and filmmaking is largely made by unlicensed individuals. Within certain locations in cities, such as Los Angeles and New York, local government has aggressively interceded to stop drone using due to concerns motivated by terrorism, robbery and personal safety. Film makers use drones because they are less expensive than using helicopters or manned aircraft.

In scientific research and surveying, drones are especially helpful in penetrating regions that might be too unsafe for manned aircrafts as high risk of fatal injury in present. Drones are able to fly and communicate using real-time communication system by sending data directly to the scientists. UAV(s) have been applied in gas, oil, mineral and fossil exploration. Also, they have been applied to carry out geophysical surveys, predominantly geomagnetic surveys to measure the earth’s magnetic field and find out underlying rock structure and so on.

In agricultural field, drones have transformed the industry vigorously. Drones aid farmers who use autonomous machines to create robust selections of plants and seeds. For examples, drones are utilized in Japan, China and Germany for aerial application of herbicides and insecticide. Japanese and German farmers continue using various models of agricultural drones since the 1978(s) because they are more cost effective than full-sized planes or helicopters or other aircrafts. In transportation system, some cargo companies consider sending out drones to make deliveries, which reduce the expenditure of using human drivers for their delivery service thus lessening the delivery cost. Drones can also transport small cargo in and out of inaccessible or remote areas.

Drones are also used in warfare. Especially America & Russia use drones in war as destructive weapons. Military drones are used in war to reduce the death rate of human. But, it actually increases the death rate of human of the opposite team.

Drones are also used in rescue mission rather than warfare. Some fire extinguisher drones are being made to be used in fire rescue mission.

1.1 Motivation

In the modern era drones are used mostly in destructive things. There are very few cases that drones are used for saving lives. That’s why we thought if we could use drone for rescue mission. Keeping this thought in our mind, we tried our best to develop the design and develop an algorithm.

1.2 Aims and Objectives

The main aims and objectives are given below:

- To design a new drone architecture capable of moving through air, land & water.
- To recognize animals correctly by implementing ML algorithms.
- To make rescue mission more effective by stablishing satellite connection.

Chapter 2

Background and Literature Review

2.1 Existing Drone

2.1.1 A Brief History of Commercial Drones

A) Parrot AR. Drone 2.0

Figure 2. 1: Parrot AR. Drone 2.0(www.parrot.com)

The most popular drone on the consumer market made a huge splash at the year 2015 and the year 2016. It found a spotlight position on 50 Best Gadgets of 2012 list for several reasons. Three being the improved control system, the built-in camera in this drone is capable of capturing 720HD high quality video, and the ability to create its own Wi-Fi and network. Carrying a 1.5Ah high-density battery under the hood, expecting up to 55 % more power and flight time: 20-22 minutes to be exact. It can fly high.

B) DJI Phantom GPS Drone

Figure 2. 2: DJI Phantom GPS Drone(www.dji.com)

This drone is GPS-enabled inside of it. Thus is comes stacked with an array of high-tech features including a handheld radio frequency control unit that supports a 0.30-kilometer range. Autopilot Mode is included with manual controlling system and an automatic landing option is also set. So when the battery gets down, it can land automatically. What sets this drone apart from other drones like the Parrot or VFX is its built-in camera mount. It supports a number of action cameras like the GoPro HERO 2.0. The amazing thing is you don't have to worry about losing the drone. Because it's been programmed to come back to its last visited location automatically. Not only that, with the GPS tracking system the device can also be tracked from anywhere within the signal range.

Autonomous landing capability is the most essential feature of this drone.

C) H-King Darkwing

Figure 2. 3: H-King Darkwing(hobbyking.com)

This special drone is designed specifically for first-person viewing (FPV). This lightweight drone offers massive payload capability for mounting accessories such as radios, cameras and even food. It is possible because of its lengthy 1.73m wingspan. The machine bears a canopy for large storage space and it has built-in wings which simplify the assembling process to be done easily.

Its main feature is being able to lift much weight. It helps the drone to do plethora of works such as carrying goods from one place to another. It can also be used in small animal rescue mission.

D) Skybotix Coax Autonomous UAV micro helicopter

Figure 2. 4: Skybotix Coax Autonomous UAV micro helicopter(robotshop.com)

Those who work in the research industries and education sectors, they should take Skybotix's offering into account because of its extensive features and cost effectiveness. This special drone is assembled to fly right out of the box. This device comes with premium high quality sensors and high speed processors that are spearheaded by the device's high-performing Gums Tix Overo module. Besides supporting two Wi-Fi modules delivering up to 0.04Gbps, it also comes stacked with two built in cameras that produce 640x480 resolution and 15fps which will enable the drone to do a lot in image capturing, processing and image clustering and distance controlling.

Its main feature is data collecting for research work and image processing capability.

E) Lehmann LA100 GoPro Drone

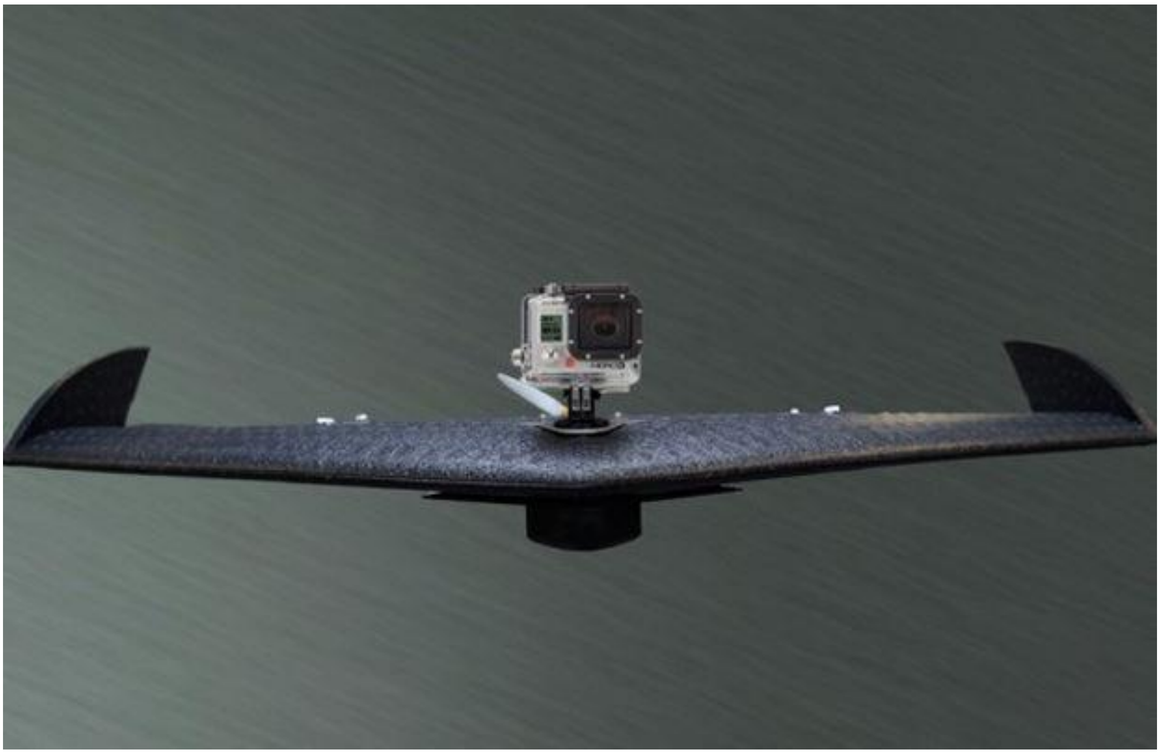


Figure 2. 5: Lehmann LA100 GoPro Drone(lehmannaviation.com)

It is another unmanned aerial drone which was made targeting towards GoPro owners. The control-less LA100 can hit the skies on its own for up to 7 minutes, while capturing high quality images and videos at a near 330 feet distance. It is constructed from foam and carbon fiber for being able to absorb hit. This flying machine makes for one of the more transportable drones with a 1000g G-factor and 1000mm wingspan. Besides, it’s made to sustain the harshest climate conditions ranging from 25°C to 65°C which is often observed above cloud.

Its main feature is being capable of surviving harsh climate. That’s why it can be used in rescue mission while the environment is not suitable for human.

F) Micro Drone

Figure 2. 6: Micro Drone(www.microdrone.co.uk)

This mini drone is consisted of four propellers and an automatic gyro control system, couch potatoes can fly this mini drone safely throughout the house avoiding all family members, pets, and valuable things. It is able to perform sharp turns even instant U-turns and even 360-degree flips in mid-air without having any kind difficulties. The compact remote has a digital panel with customizable layout for both right-handed and left-handed users. This is a pretty dynamic piece of hardware which is capable of doing various amazing things compared to its size. This can be used in spying.

But the problem is the rotors make a lot of noise while spinning. So, the motors and rotors should be modified for the drone to be able to avoid noise.

G) Turbo Ace X830-D Drone RTF

Figure 2. 7: Turbo Ace X830-D Drone RTF(www.turboace.com)

Unlike the majority of drones available in the market, the Turbo Ace X830D is fully assembled and programmed. It has A high payload capacity which allows it to mount heavier video cameras and lenses and even five-liter water bottle. The motors have been re-engineered to sustain heavier crashes and deliver better balance so that it can avoid damages. And best of all: The machine supports the “industry’s longest flight time” at twenty-four to thirty minutes. But the cost of this drone is very high.

Its main feature is too carry weight and fly for longer duration.

H) 4 Channel Predator/Reaper Style UAV Plane

Figure 2. 8: 4 Channel Predator/Reaper Style UAV Plane(www.trendtimes.com)

This drone is made inspired by the real RQ-1 Predator. It’s a drone that is described by the U.S. Air Force as a "medium-altitude, long-endurance unmanned aerial vehicle system". This replica features twenty minutes of flight time per charge and carries a wingspan of over five feet. Its packaging includes a four channel proportional R/C system, Brushless Motor, 8X6 Two-Paddles Propeller, and Lipo Battery so that external parts are not to be bought, if not necessary.

Actually it’s a plane rather than a multi copter. That’s why its speed is greater than a copter. But it hard to control. Besides, specific works cannot be done by this because it cannot stand still in the air.

I) Walkera QR Infra X Smart Drone

Figure 2. 9: Walkera QR Infra X Smart Drone(hobbyking.com)

This is the world's first drone with a CAS (Crash Avoidance System) which comes equipped with ten collision sensors so that it can prevent the machine from crashing into people, objects, and walls. Placing a hand or any other object near it while in the air will send the drone flying in the opposite direction instantly. It has two Ultrasonic Altitude Sensors which allow it to climb up stairs easily without having any difficulties and adjust height for each step. Besides it's small enough to fit in one's palm.

J) Storm Drone FF Flying Platform

Figure 2. 10: Storm Drone FF Flying Platform(www.helipal.com)

This drone has sporting four “well-balanced” rotors and a mount in the middle. That’s why this drone lets us strap on a GoPro camera to record aerial footage for up to eight minutes. It can record videos without compromising stability, blurriness and video quality. It is capable of doing this high precision job with the assistance of a high-speed motor and 9” x 4.7” propellers which even help fight off strong winds. When the wind's not blowing, this drone can stay put for up to ten seconds. Red and white LED lights help users to spot it when the sun goes down so that it can be easily identified without difficulties.

But it has no specialty in regards to ability. This drone just has the regular abilities of other drones in a better way.

2.1.2 Features of Drone

A) 2013 FEATURES:

Features [1,2,3,9,7,4,14,15,16,17]	**Thesis [9,7,4]**
1.Take Photos 2. Capturing Videos 3. Fly accurately 4. GPS Tracking 5. Mapping 6. Resource Finding 8.Photo Journalism 9.War machine 10.Micro drones	1. Mapping 2. Resource finding 3. Collect Data

Table 2. 1: Drone Features of the Year 2013

B) 2014 FEATURES:

Features [1,3,7,5,8,9,10]	**Thesis [7,5,10]**
1.Sky+land [not accurate] 2.Photo+video+gps [accurate] 3.Improved Design 4.War Machine [improved] 5.Carry Weight [improved] 6.Collect data [improved]	1. Collect Data **2.** Improved Design

Table 2. 2: Drone Features of the Year 2014

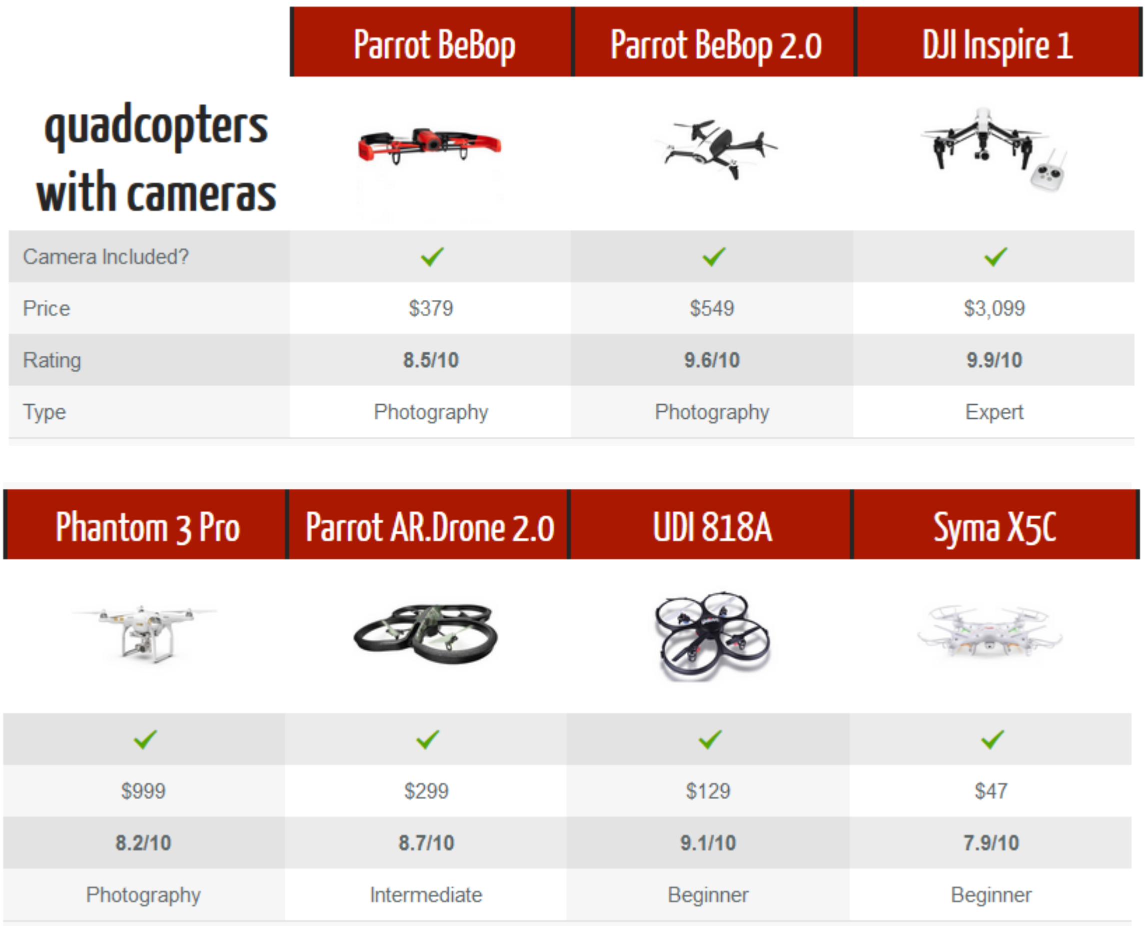
C) 2015-16 FEATURES:

Features [1,10,17,16,3]	**Thesis [1,10,3]**
1.Sky+land [Improved] 2.Sky+water [not accurate] 3.War machine [improved] 4.Improved Design 5.Micro drone [improved]	1. Art of drone warfare 2. Ethics and law **3.** Improved Design

Table 2. 3: Drone Features of the Year 2015-2016

2.1.3 Comparison Among Drones

A) CAMERA AND EXPERTISE



quadcopters with cameras	Parrot BeBop	Parrot BeBop 2.0	DJI Inspire 1
Camera Included?	✓	✓	✓
Price	$379	$549	$3,099
Rating	**8.5/10**	**9.6/10**	**9.9/10**
Type	Photography	Photography	Expert

Phantom 3 Pro	Parrot AR.Drone 2.0	UDI 818A	Syma X5C
✓	✓	✓	✓
$999	$299	$129	$47
8.2/10	**8.7/10**	**9.1/10**	**7.9/10**
Photography	Intermediate	Beginner	Beginner

B) COMMERCIAL

commercial drones	DJI s1000	3DR Aero-M	DJI Matrice 100	3DR Solo	DJI Inspire 1	Phantom 3 Pro	Hubsan H301S
							
Camera Included?	✓	✓	✗	✗	✓	✗	✓
Price	$4,550	$5,400	$3,299	$949	$3,099	$1,259	$400
Rating	**9.5/10**	**9.9/10**	**9.7/10**	**8.6/10**	**8.9/10**	**10/10**	**8.5/10**

2.2 Proposed Drone

2.2.1 Overview

We are proposing a new type of drone that will be able to travel through air, water and land. It will have the ability of interacting with environment with real time dependency. ALW drone has its own database known as temporary database, which is destructible. ALW drone will be able to collect data from environment which is called environmental data. By comparing the data between TD and ED drone will be able to gather information about the recent phase of environment.

2.2.1 Proposed Features

Features
1.A New Design
2.Sky+water+land
3.Database Interaction
4.AI for drone
5.Will be able to collect environmental data
6.Real time communication with environment by comparing data between ED and BI

Table 2. 4: Features of Proposed Drone

DESCRIPTION:

- It’s a drone which we hope to be able to travel through air, land and water
- It will be able to interact with environment by comparing environmental data with real time dependency
- Can be controlled by control room via satellite. Which means ALW drone can be controlled by a controller and it can be controlled from anywhere in the world through satellite.
- Will be able to collect environmental data and Bio Information
- Will be able to use existing database information for interacting with environment
- Autopilot mode will be able to control it by using the built-in AI

Chapter 3

Requirements Specifications

3.1 Hardware Requirements

A) Raspberry pie processor

B) Water propeller

C) Air propeller

D) Robotic legs

E) Sail plane

F) Online server

3.1.1 Raspberry pie Processor

Figure 3. 1: Raspberry pie Processor

Hardware

The Raspberry Pi hardware has been evolved thoroughly. Several versions of this processors are available in the market. Feature variations in memory capacity are seem and peripheral-device support is available.

This processor has several USB ports. So it is easy to mount multiple USB devices in the processor. This processor also can be used in our PC. It is true that it will not be able to do heavy task as playing high graphics games or doing heavy graphics related jobs. But it is good enough to do the basic stuffs as surfing the internet, doing office jobs etc.

Processor

The Broadcom BCM2835 SoC is used in the first generation Raspberry Pi. It is somewhat equivalent to the chip used in first generation smartphones, which includes a 0.70 GHz ARM1176JZF-S processor, Video Core IV graphics processing unit and RAM. It has a level 1 (L1) cache memory of 16 KB and a level 2 (L2) cache memory of 128 KB. The level 2 cache memory is used primarily by the GPU. The SoC is stacked underneath the RAM chip, so only its edge is visible not the full thing.

Raspberry Pi 2 processor uses a Broadcom BCM2836 SoC with a 0.90 GHz 32-bit quad-core ARM Cortex-A7 processor with 256 KB shared L2 cache memory.

Raspberry Pi 3 processor uses a Broadcom BCM2837 SoC with a 1200 MHz 64-bit quad-core ARM Cortex-A53 processor, with 512 KB shared L2 cache memory which is quit good.

Performance

While operating at 0.70 GHz speed by default, the first generation Raspberry Pi provided a real-world performance roughly equivalent to 0.041 GFLOPS. On the CPU level the performance is similar to a 0.30 GHz Pentium 2 of the year 1997 to the year 1999. The GPU provides 1024 Mega Pixel/s or 1536 Mega Texel/s of graphics processing or 24 GFLOPS of general purpose computing performance. The graphical capability of the Raspberry Pi is quite good. It is roughly equivalent to the performance of the Xbox of the year 2001.

We know that the LINPACK single node compute benchmark results in a mean single precision performance of 0.065 GFLOPS and a mean double precision performance of 0.041 GFLOPS for one Raspberry Pi Model-B mother board. A cluster of 64 Raspberry Pi Model B computers, labeled "Iridis-pi", achieved a LINPACK HPL suite result of 1.14 GFLOPS (n=10240) at 216 watts for 3200 Euro.

Raspberry Pi 2 has a quad-core Cortex-A7 CPU running at 0.90 GHz and 1024 MB RAM. It is described as six times more powerful than its predecessor, Raspberry pie 1. The GPU is identical to the original one. In parallelized benchmarks, the Raspberry Pi 2 could be up to fourteen times faster than a Raspberry Pi 1 Model B+ which is amazing.

The Raspberry Pi 3 has a quad-core Cortex-A53 processor. It is described as ten times of the performance of a Raspberry Pi 1. This was suggested to be highly dependent upon task threading and instruction set use. Benchmarks showed the Raspberry Pi 3 to be approximately 80% faster than the Raspberry Pi 2 in parallel tasking.

Raspberry pie processor is good at building drones, RC robots, small intelligent systems. That's why till now it is recommended to use Raspberry pie processor in building robots.

3.1.2 Water Propeller

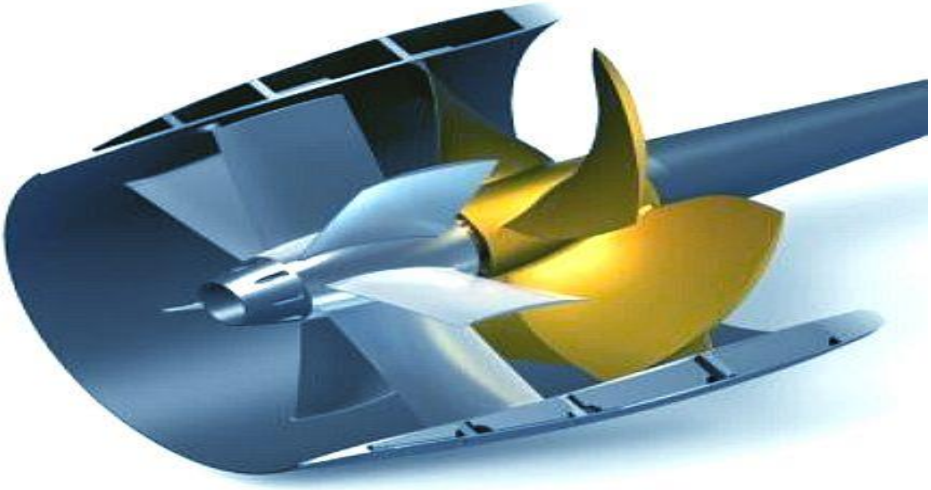


Figure 3. 2: Water Propeller

A water propeller is a type of fan that transmits power by converting rotational motion into thrust under water. A pressure difference is produced between the forward and rear surfaces of the airfoil-shaped blade, and a fluid is accelerated behind the blade. Propeller dynamics, like those of aircraft wings, can be modelled by either or both Bernoulli's principle and Newton's third law accordingly. A marine propeller of this type is sometimes colloquially known as a screw propeller, however there is a different class of propellers known as cycloidal propellers - they are characterized by the higher propulsive efficiency averaging 0.754 compared to the screw propellers average of 0.602 and the ability to throw thrust in any direction at any time. Their disadvantages are higher mechanical complexity and higher cost. Also a water propeller can be of various capacities.

3.1.3 Air Propeller

Figure 3. 3: Air Propeller

An air propeller is used for flying but the ability of it changes with the parameters. Generally, air propellers are of less width. Depending on the RPM and propeller length thrust of the drone increases or decreases.

3.1.4 Robotic Legs

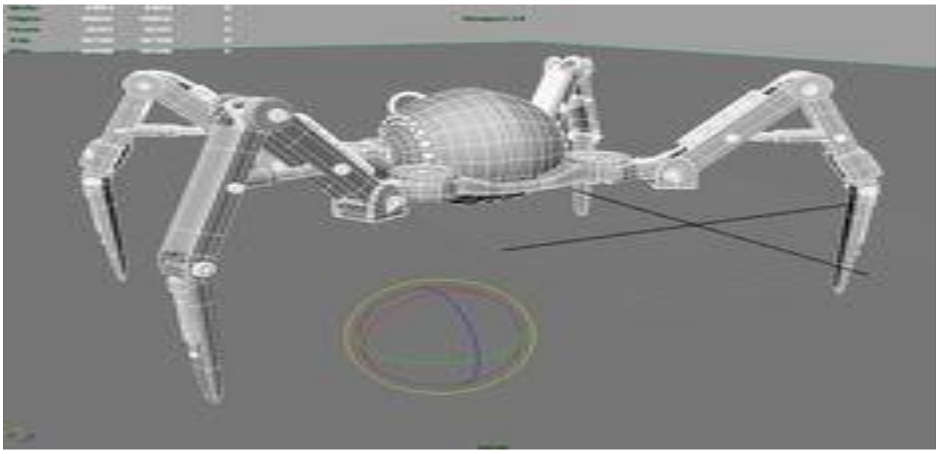


Figure 3. 4: Robotic Legs

A robotic leg is a mechanical leg that can be used to perform the same functions that a human leg or animal leg can do. The robotic leg is typically programmed to execute similar functions that a human leg or animal leg would perform. A robotic leg is similar to a bio-mechanical leg; however, a robotic leg can be controlled electrically or mechanically. In order to have the robotic leg exhibit behaviors of a human's leg, we have to write the program first. Sensors are also embedded in the robotic leg to measure the electrical pulses. We can control the legs manually also in case of emergency situations.

3.1.5 Sail Plane

Figure 3. 5: Sail Plane

A sailplane or glider is a type of glider aircraft used in the sport of gliding. Sailplanes are aerodynamically streamlined and are capable of soaring in rising air. In our Drone, we will use the robotics legs as Sail plane. By straitening the legs and changing the angles the drone will change directions while flying.

3.1.6 Online Server

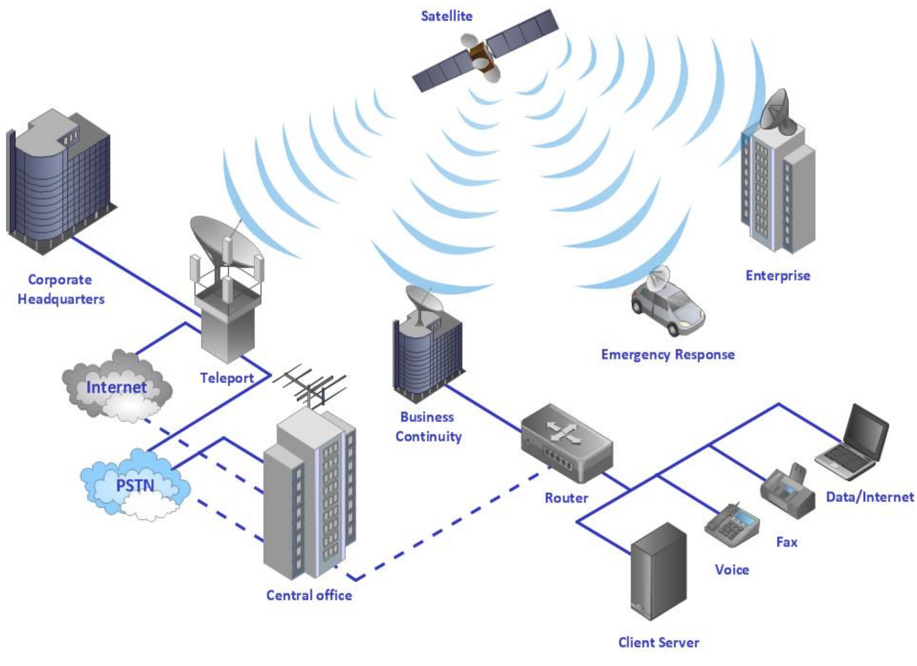


Figure 3. 6: Online Server

Online server will be used in communication purpose. The drone will contain primary memory. But the main data will be in main database. So, satellite will be used for online communication.

3.2 Software Requirements

In our drone AI is a vital part. For that reason, programming is a must. For hardware programming there are several languages. They are:

A) Ruby

B) Python

C) Haskell

D) Rails framework

E) R

3.2.1 Ruby

This language called Ruby is a dynamic, reflective, object-oriented, general-purpose serving programming language. It was designed and developed in the mid-1990s by Yukihiro Matsumoto in Japan. According to its creator Yukihiro, Ruby was influenced by Perl, Smalltalk, Eiffel, Ada, and Lisp. It is specially used in hardware programming.

3.2.2 Python

Python is a widely used high-level, interpreted, dynamic programming language which is especially used for machine learning. Its design policy prioritized code readability, and its syntax is much easier which allows programmers to express concepts in fewer lines than possible in languages such as C++ or Java or other object oriented codes. It is widely used in implementing machine learning algorithms. Machine learning is done easily by using Python.

3.2.3 Haskell

Haskell is an optimized, general purpose serving, robust programming language especially created for machine programming which is not that popular yet. It was named after logician Haskell Curry. The latest standard of Haskell is Haskell 2010.

3.2.4 Rails Framework

The Rails framework helps developers to build robotic apps and software applications, because it simplifies common repetitive tasks and reduces redundancy. Rails framework is developed using Ruby codes. The relation between Ruby and Rails is similar to the relation between PHP and Laravel. Hardware programing is much easier using this.

3.2.5 R

R is a newly invented code that is created especially for handling machine learning and robotics.

Besides simulator software are also needed. They are:

1. Autodesk Inventor
2. Mat lab

3.2.6 Autodesk Inventor

Autodesk Inventor is a 2D & 3D mechanical solid model designing software developed by Autodesk team to create 3D digital prototypes of mechanical devices virtually. It is used for 3D mechanical design, design communication systems, tooling creation and product simulation and so on. This software enables users to produce accurate 3D models to aid the actual designing process, visualizing and simulating products before they are built and used in real life.

3.2.7 Mat lab

MATLAB is a high-performance tool which has a built-in language for technical computing. It integrates computational methods, graph visualization and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation and matrix. Typical uses include: Mathematical and computational functions. Plethora of built in functions are present in Mat Lab to make the work easier.

Chapter 4

Design of Proposed Drone

4.1 Hardware Based Design

4.1.1 External Part

There are some external parts which are visible from the outside. They are:

1. Water Propeller
2. Air Propeller
3. Robotic Legs
4. Main Body
5. Camera

4.1.2 Internal Part

Internal parts are invisible from the outside. They are:

1. Engine Room
2. Sensors
    - Ultrasonic Sound Sensor
    - Temperature Sensor
    - Pressure Sensor
    - Radiation Detector
    - Thermal Radiation Detector
    - Light sensor
    - Vibration Sensor
3. Water Chambers
4. Base

[All these external designs will be constructed by custom design machines. For internal designs we should use existing sensors and existing motors and other available hardware]

4.2 Software Based Design

We used Autodesk Inventor for our software based design. We mainly established a structure for ALW drone. Main parts are given below:

Air Propeller

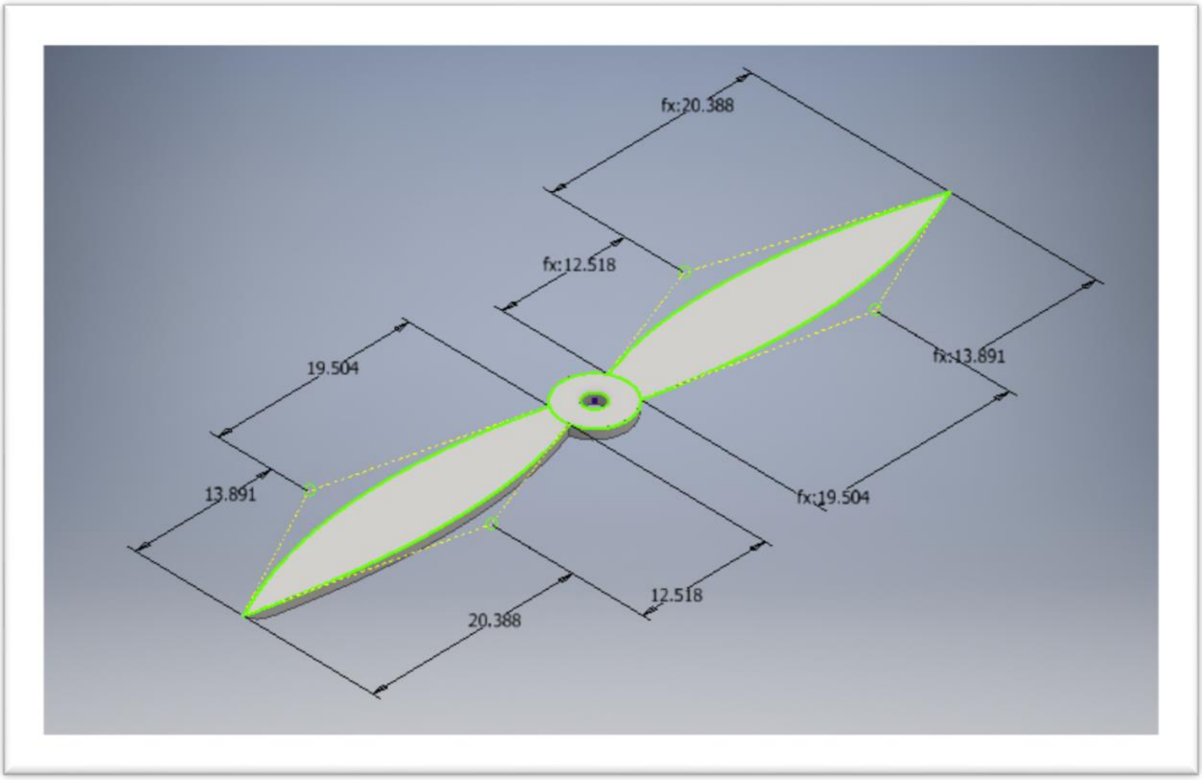


Figure 4. 1: Air Propeller

We designed this air propeller but it's not the final one. Because, during building the actual drone the parameter of the propeller may change. Air propeller is consisting of two stepper motor. We did not add those motors in the picture yet. The function of the motors is to bend the propeller so that it can easily go inside the main body.

Water Propeller

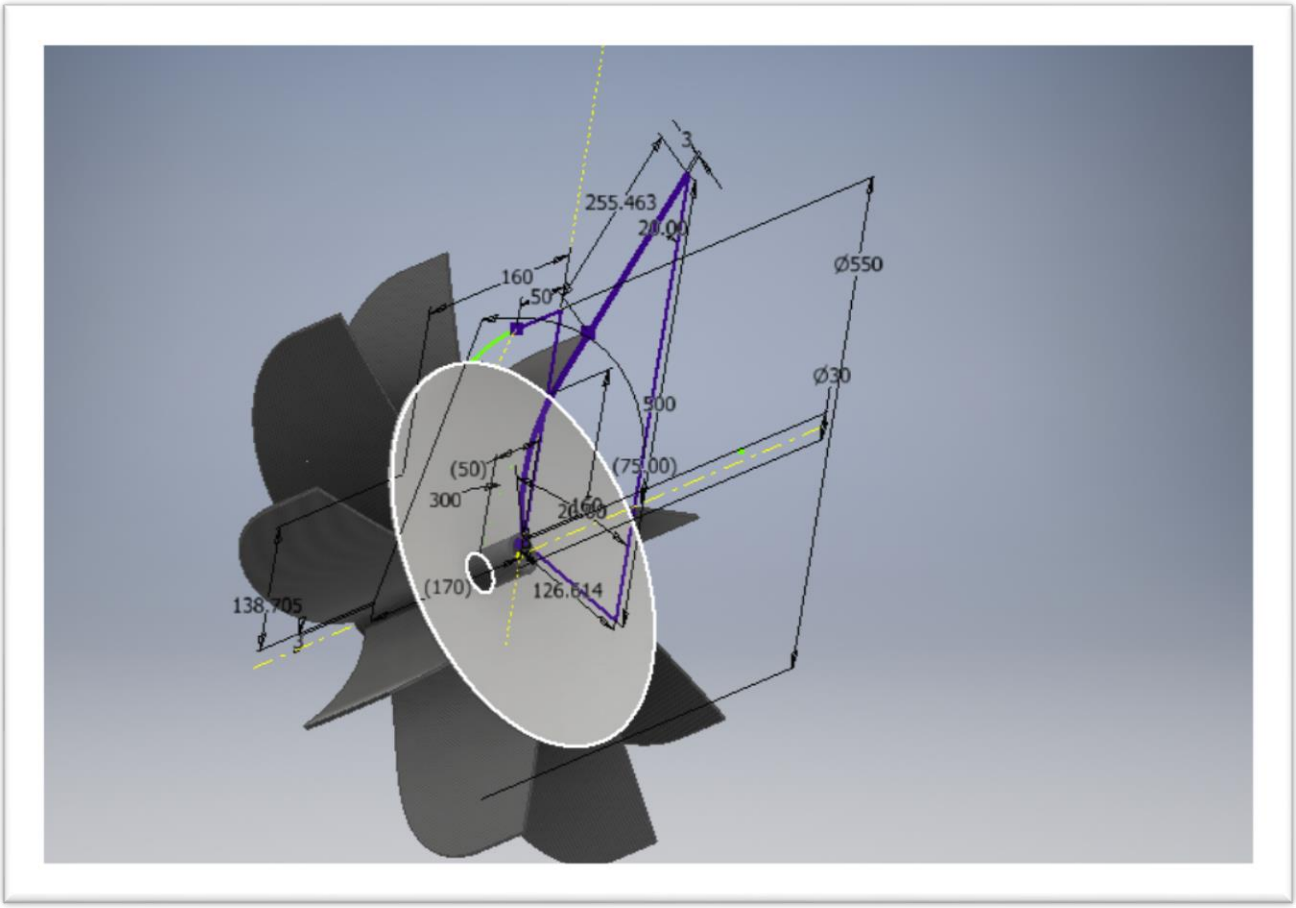


Figure 4. 2: Water Propeller

Same thing goes for water propeller. We have change the number of blades according to needs. The diameter and width is also needed to be changed if necessary. The center whole of the water propeller is bigger than the air propeller. It is big enough so that the air propeller can move through the whole while bended.

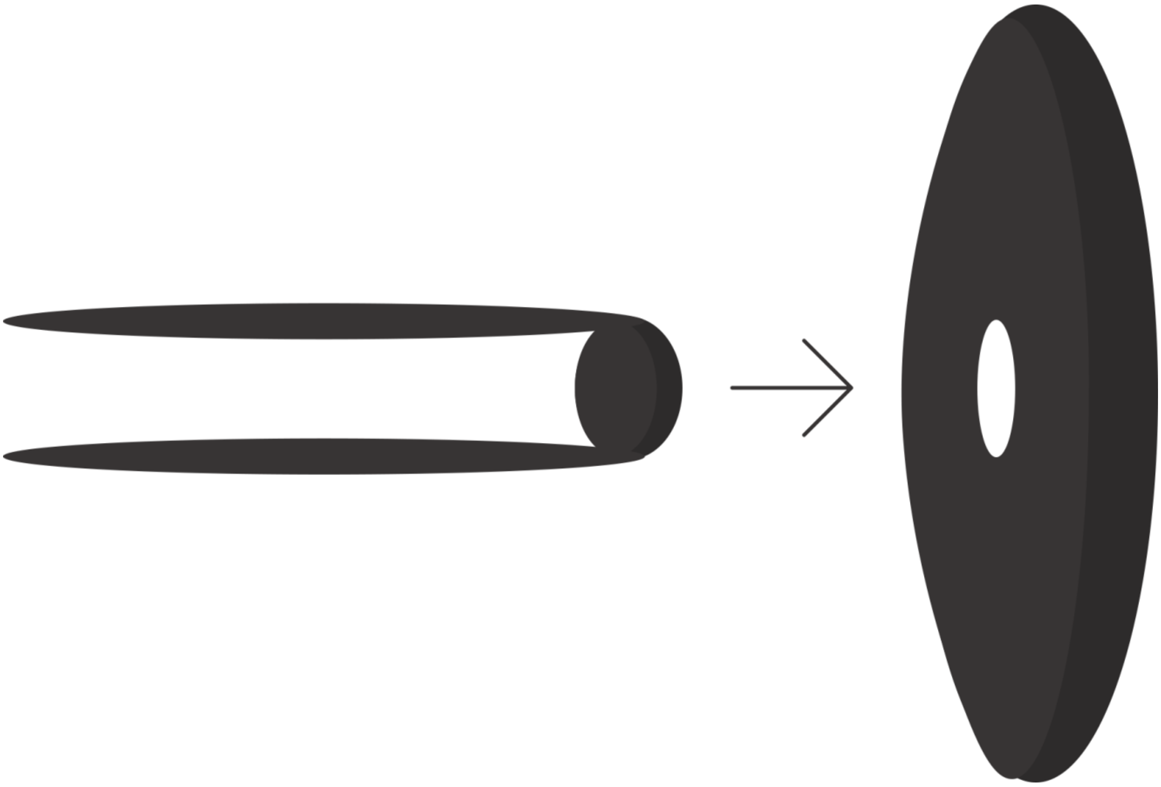


Figure 4. 3: Air propeller bending mechanism

This picture is not an actual part of our design. This is just to show the mechanism of how the air propeller will bend and enter in the main body through the center of the water propeller.

Two stepper motor is needed for the propeller to be able to being bend. It is very tough to show the stepper motors in the picture that’s why we did not include the stepper motors in the picture. This is just to describe the mechanism.

To summarize the whole thing in short we should say that, in the rear side of our drone there are two propellers. One in air propeller and the other is water propeller. The air propeller is the one which comes out from the water propeller. While surfing in the sky, the air propeller will come out. But when diving under water, the air propeller will be bended using the stepper motors in its joint and go inside the main body of the drone through the center whole of the water propeller.

Water Propeller

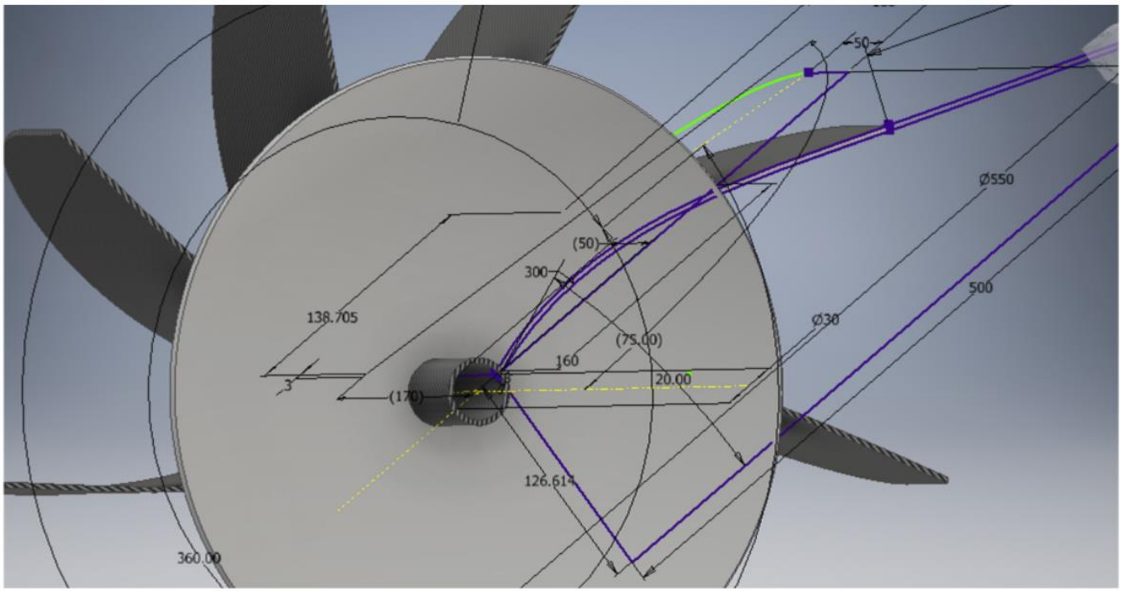


Figure 4. 4: Water Propeller(continue)

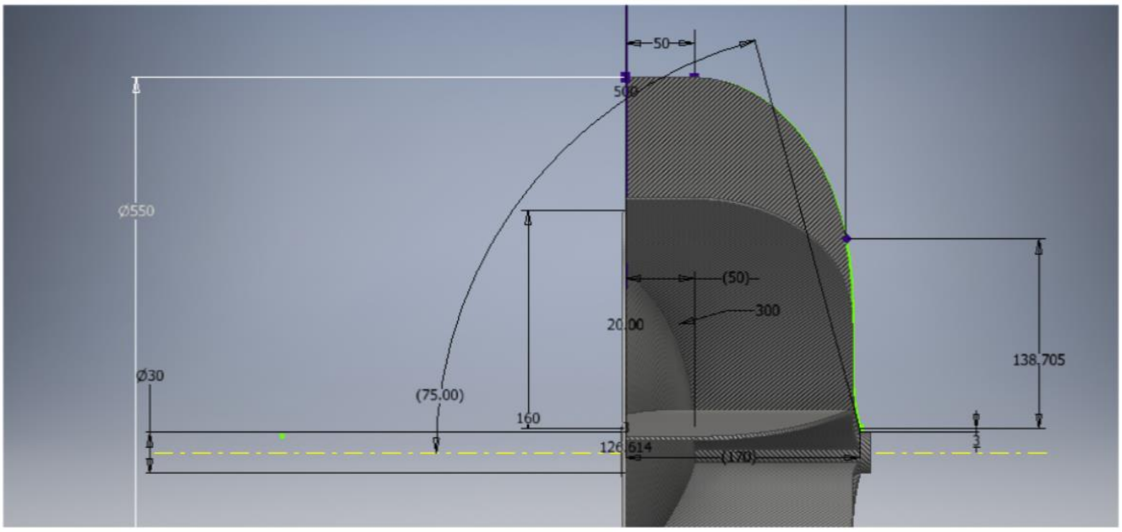


Figure 4. 5: Water Propeller(side view)

These pictures represent the detailed mechanical layout of the water propeller.

Main body

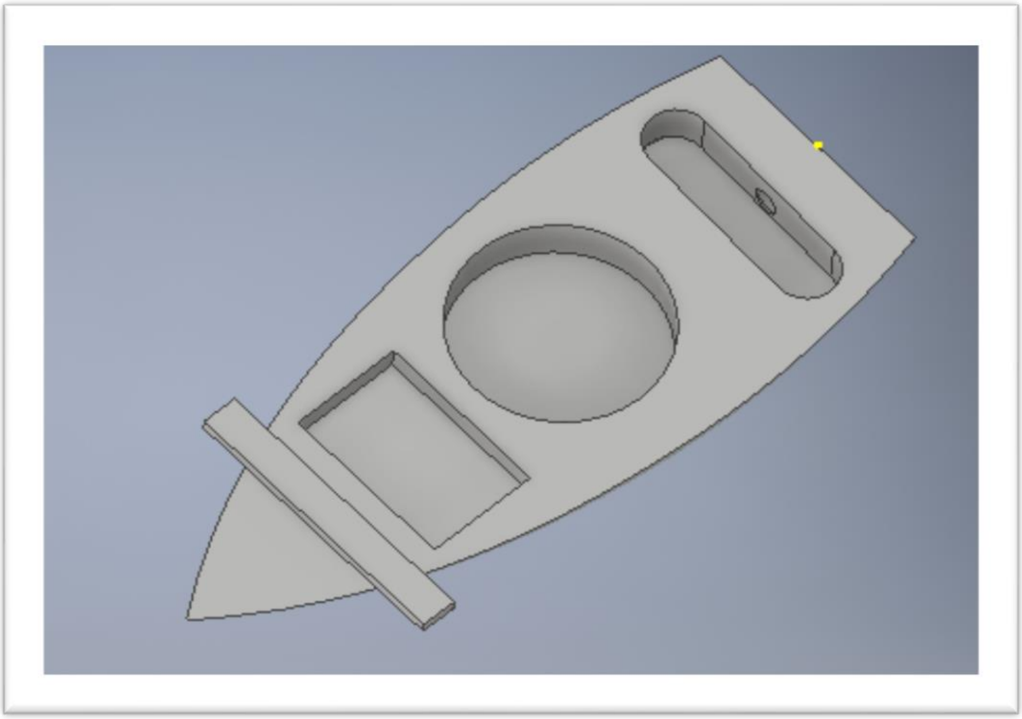


Figure 4. 6: Main Body

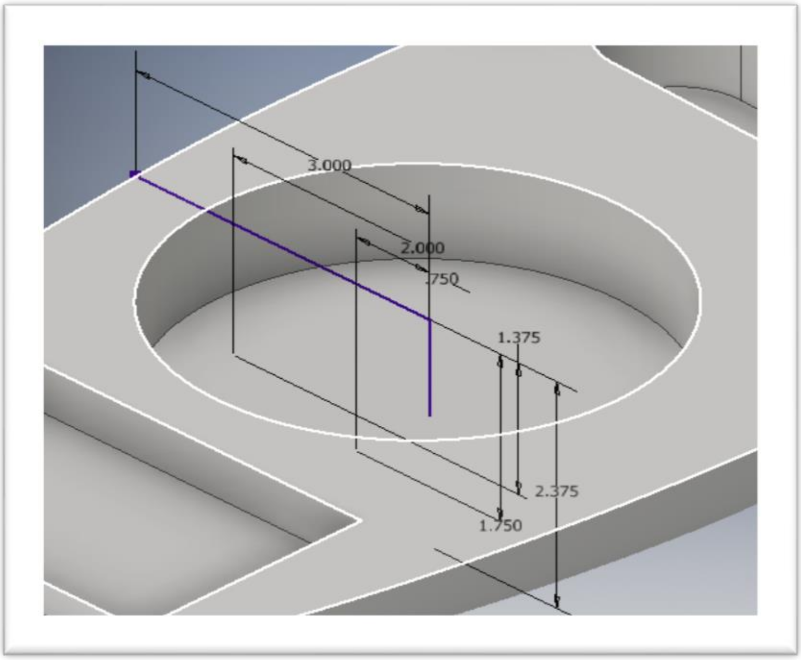


Figure 4. 7: Main Body (Central Part)

Main Body

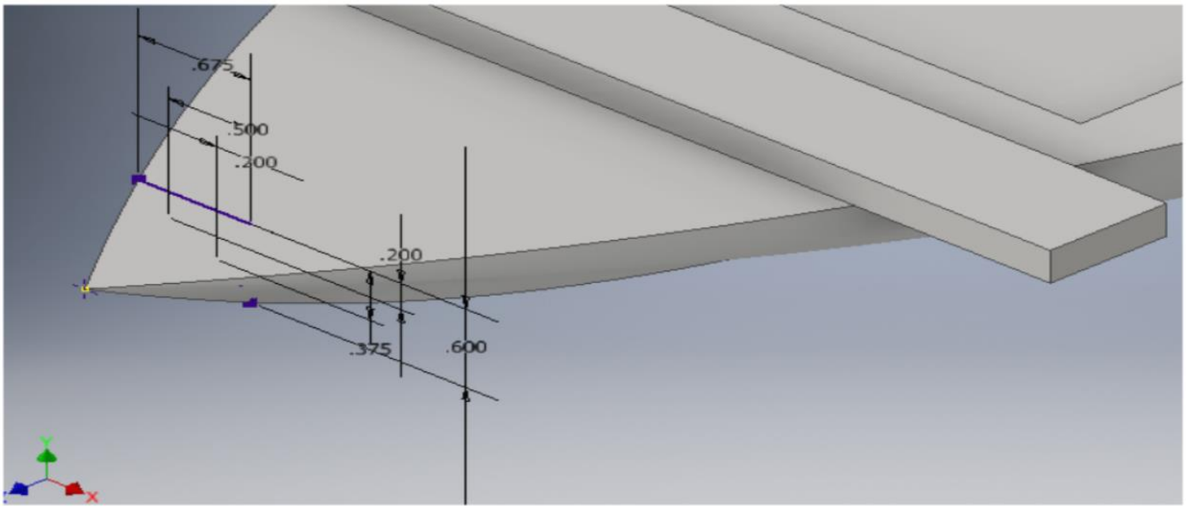


Figure 4. 8: Main Body (lower part)

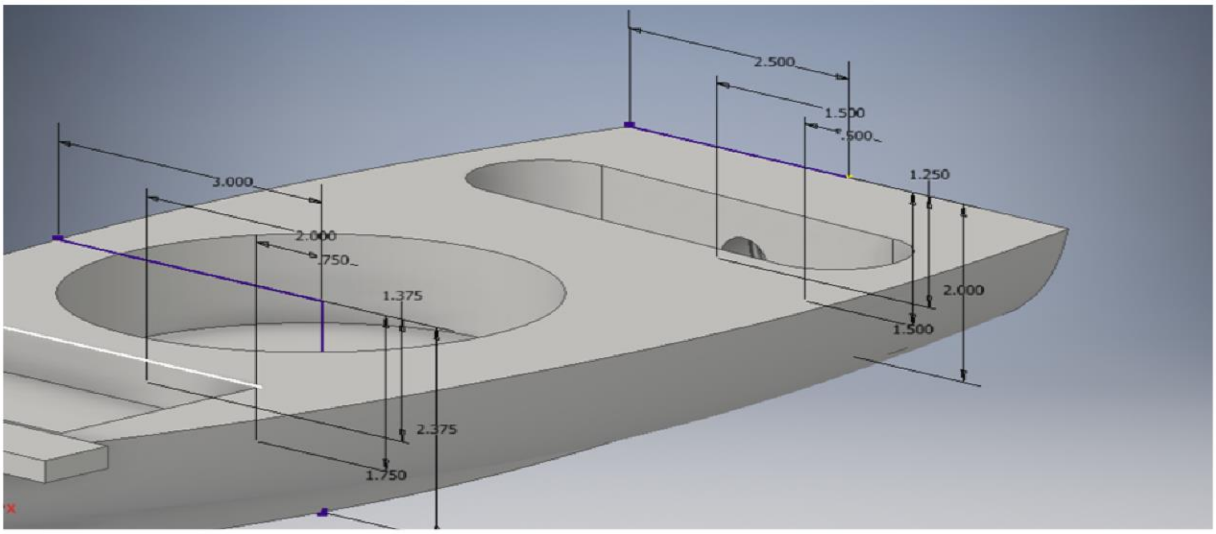


Figure 4. 9: Main Body(perspective view)

In these pictures water chambers and engine chamber are shown. While going under water the water chambers will gradually filled with water. While leaving water the water chamber will be opened and the water will spill out and make the drone lighter.

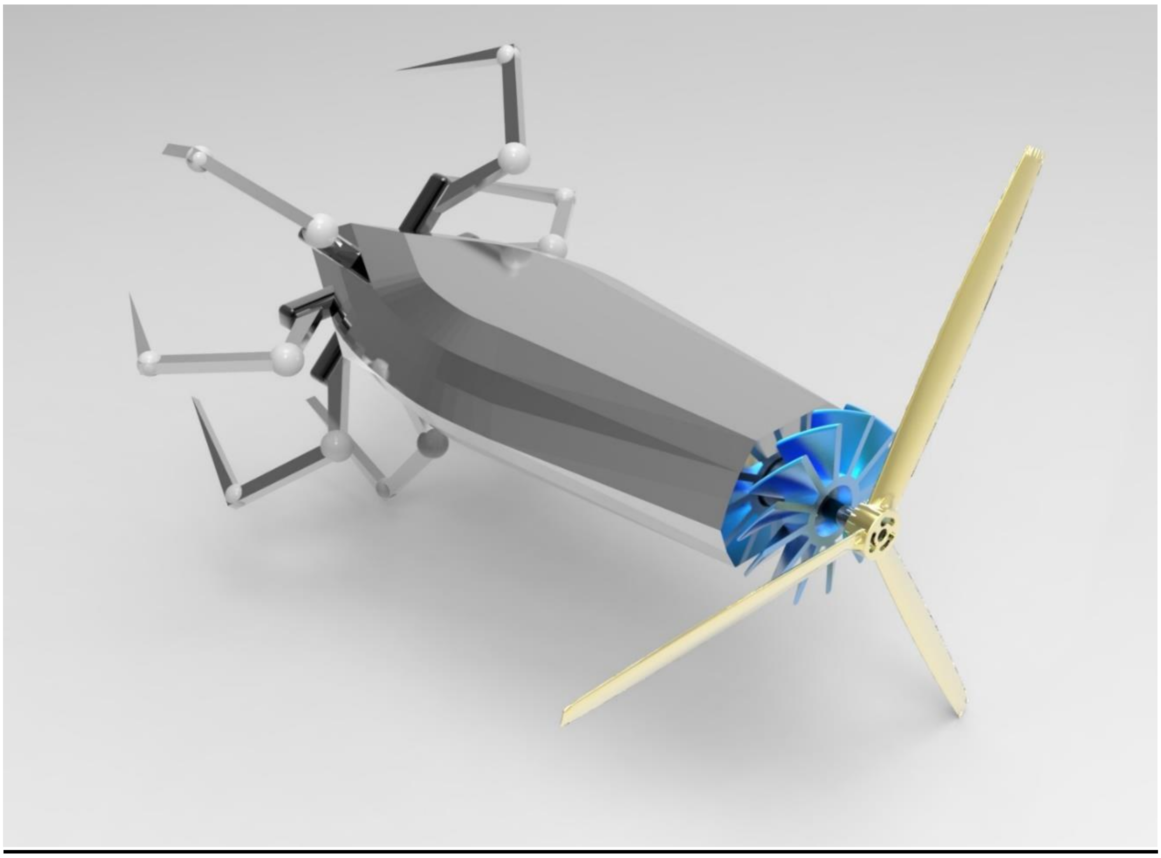


Figure 4. 10: Perspective view

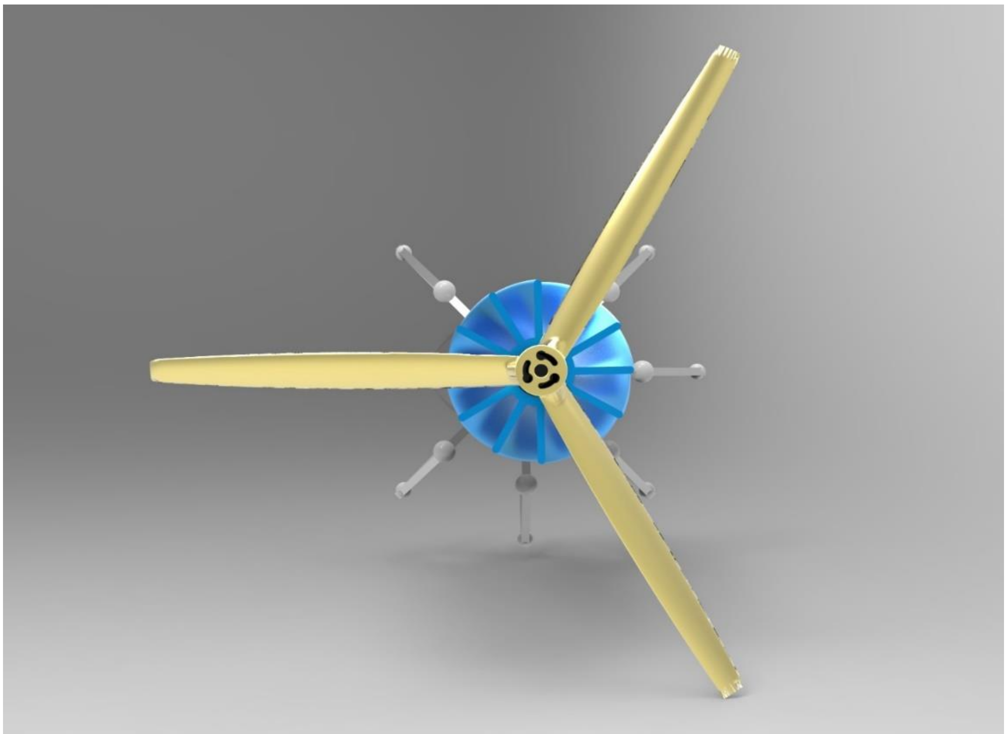


Figure 4. 11: Rear view

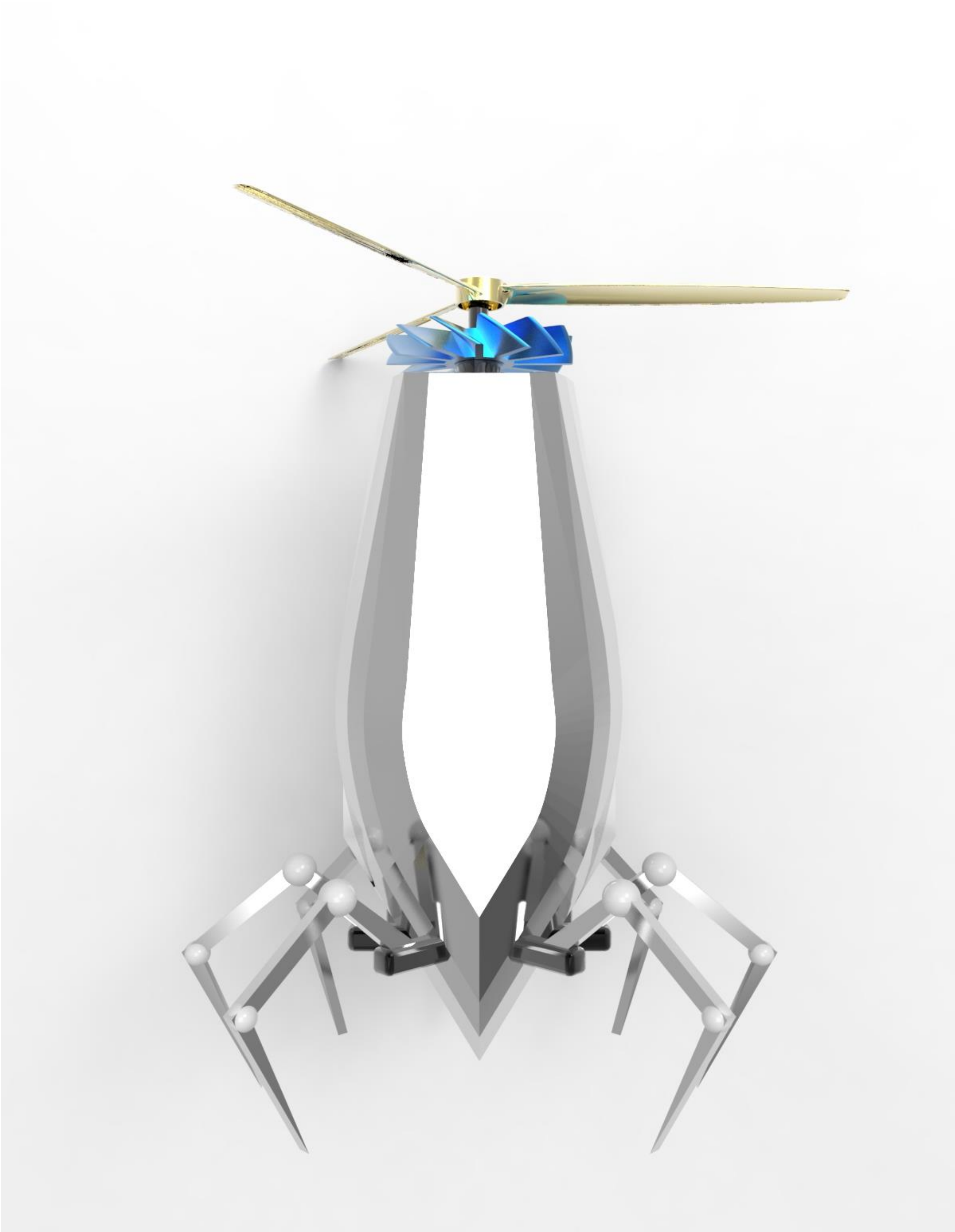


Figure 4. 12: Full view

While moving on the ground this drone will use its t2 fuzz like robotic legs to move. It's better to use robotic legs instead of wheels because using legs the drone can avoid jerking.

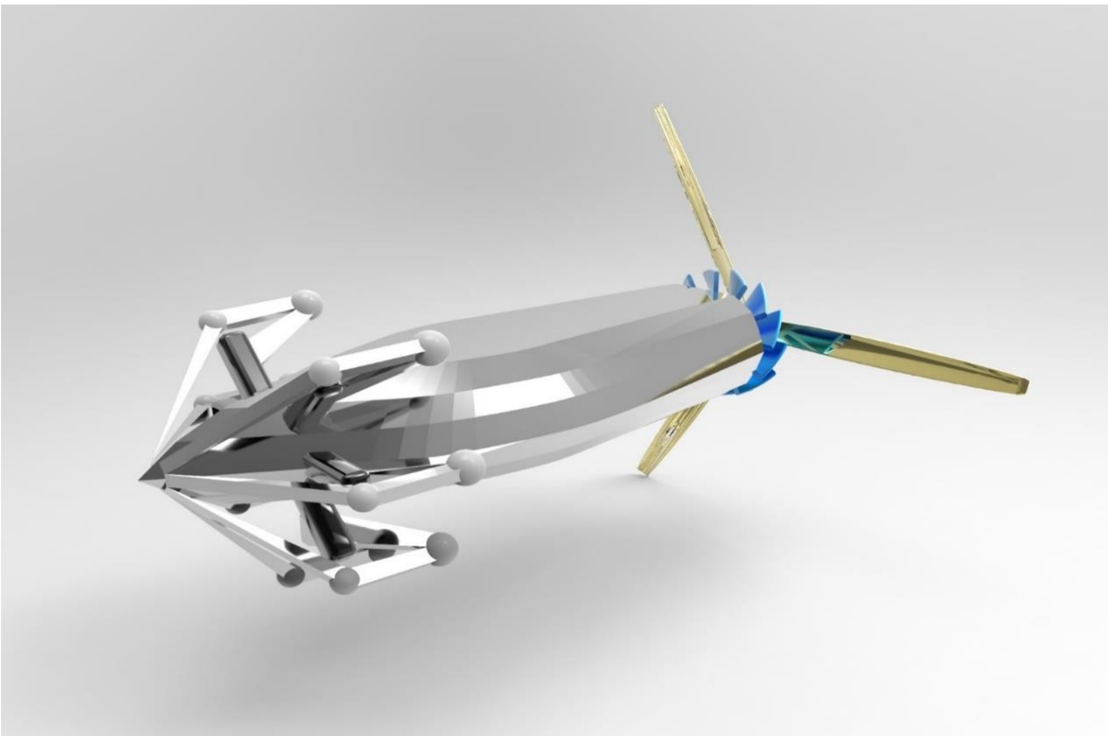


Figure 4. 13: Side view

While moving under the water, the spikes will be closed so that it may move efficiently.

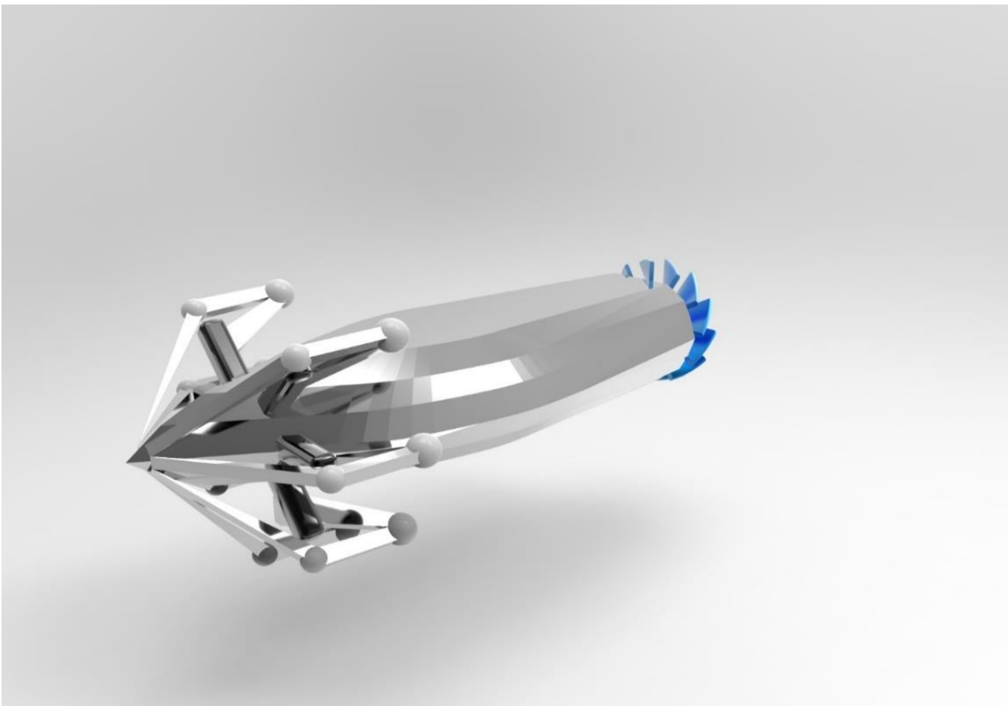


Figure 4. 14: Under Water Stance

When moving under water, the air propeller will be bended and moved inside the main body through the hole which is in the center of the water propeller.

All the designs are made by using ‘Autodesk Inventor’ & ‘Autodesk 3d Max’. These are custom designs. The drone is not physically built. These are some virtual images of the prototype. So, the mechanical dimensions may need some changes while building the drone in real life.

We will have to calculate the weight, length & height during constructing the real one.

We also have to select the material carefully so that the process of drone’s movement doesn’t hamper. We have to calculate the density of the body material. Because while flying in the air the drone must be light enough. But while diving under water the drone must have a minimum amount of weight so that it can dive easily. Also we should take consideration that the ability of being capable of absorbing the pressure and force under water should be present in the drone.

All these factors are vital and very important for the drone. But to calculate all these factors in real life is not possible without building a bunch of prototypes physically and doing the experiments in real life.

But, by doing some simulations, we can get idea about some of the factors. The simulation figures and results are described briefly in chapter six. Besides the true mechanical design requires some extensive mapping and calculating. For this we need some expert mechanical engineers also.

Chapter 5

Proposed AI

5.1 Overview

Robot is a physical intelligent agent which performs tasks by imitating animal or human and manipulating the physical world. They are equipped with sensors to perceive their environment and effectors to apply physical forces on it (according to previously done program in the micro controller board). As mentioned before, Robots can be put into four main categories: manipulators, mobile robots, humanoid robots and industrial robots.

Artificial intelligence (AI) is the intelligence exhibited by machines or software or computer systems. It is also the name of an academic field of computer science and engineering which studies how to create computers and computer software that are capable of intelligent behavior such as cats, dogs or even human.

5.2 AI for Drone

ALW will be an intelligent drone. It will contain its own improved AI. It will work with its own unique logics and process. They are given below:

5.2.1 Logics

1. **Object Detection:**
   While travelling through the path our drone will detect any object in its way.
2. **Object Avoidance:**
   It will avoid any object even if there are multiple objects in its travelling path.
3. **Real time interaction with Environment:**
   Drone will collect environmental data from environment and compare these data with existing data. By doing this it will predict and act on its own.
4. **Interaction with Database:**
   There will be two databases. One is called main server database and the other one is called temporary database. There will be interactions between the two databases through satellite.
5. **Analyze Bio information:**
   Using the sensors, the drone will understand the presence of living being.

5.2.2 Processes

- **PROCESS 1:**

  Run and analyze main logics. Five main logics are processed in P1.

- **PROCESS 2:**

  Calculate possible ways, this means it will find all possible ways to go to the destination and optimize them by time or cost. If the drone wants to go to the destination as fast as possible then it will ignore the cost. For cost it will work as vice versa.

- **PROCESS 3:**

  Select-value-forward Checking. This will help the drone to travel one place to another.

- **PROCESS 4:**

  Use Safe Zone to Travel. If ALW Drone has four/five possible paths to reach the destination, then it will find the safest path among them by analyzing positive and negative factors.

- **PROCESS 5:**

  Analyze Environmental Data. ALW Drone will be able to collect environmental data & bio information and compare them with the TD. By comparing this it can learn about the present phase of the environment.

[For every environment we consider it has three phase. They are normal, slightly different and extremely strange]

5.3 Overview of Algorithm

As modern drones address real-world problems in dynamic, unstructured, and open environments, plethora of novel challenges arise in the areas of robot controlling algorithms and motion planning. These types of challenges are derived from an increased need for autonomy and flexibility in drone’s movement and program execution. Adequate algorithms for control and motion planning will have to capture high-level motion strategies that adapt to sensor feedback. The technical committee for Algorithms for planning and Control of the drone motion and movements promotes algorithms research, both theoretical and practical-driven, towards these objectives. Priority areas include:

1. consideration of accurate sensing modalities, Program prosecution in dynamic environment and uncertainty in planning and control algorithms;
2. development of representations and motion strategies in various environments capable of incorporating feedback signals
3. motion & movement subject to constraints, arising from kinematics, dynamics, and no holonomic systems;
4. addressing al the characteristics of both and dynamic environments;
5. creating & developing control and planning algorithms for hybrid systems;
6. understanding the complexity of algorithmic problems in control and motion planning and developing the mathematical factors that boost result;
7. Encouraging the application of planning algorithms in novel application areas such as vehicle systems, industrial machineries and so on.

5.4 Algorithm for Drone's AI

Genetic Algorithm:

In the field of artificial intelligence, the genetic algorithm (GA) is a search heuristic that mimics the process of natural selection in virtual graphs to get to the destination point. This heuristic also sometimes called a Meta heuristic which is routinely used to generate useful solutions to path finding problems and optimizing search problems.

Path Finding Algorithm:

Path finding is the plotting, by a computer software application of the shortest route between two points. It is a more practical variant on solving mazes or maze like real life areas. This site of research work is based heavily on Dijkstra's algorithm for finding a shortest path or most cost effective route on a weighted graph.

Chapter 6

Simulation Results

6.1 Animal Species Prediction

In this section we used one datasets containing five categories The first one is used for direct image recognition. The categories are (1) Cat (2) Eagle (3) Elephant (4) Crocodile (5) Horse.

Our dataset has 750 observations. For image recognition we used:

1. Deep Learning with Keras

2. Convolutional Neural Network

Deep Learning with Keras

```
> # Model
> model <- keras_model_sequential()
> model %>%
+   layer_dense(units = 512, activation = 'relu', input_shape = c(3072)) %>%
+   layer_dense(units = 256, activation = 'relu') %>%
+   layer_dense(units = 128, activation = 'relu') %>%
+   layer_dense(units = 5, activation = 'softmax')
> summary(model)
________________________________________________________________________________
Layer (type)                        Output Shape                    Param #
================================================================================
dense_9 (Dense)                     (None, 512)                     1573376
________________________________________________________________________________
dense_10 (Dense)                    (None, 256)                     131328
________________________________________________________________________________
dense_11 (Dense)                    (None, 128)                     32896
________________________________________________________________________________
dense_12 (Dense)                    (None, 5)                       645
================================================================================
Total params: 1,738,245
Trainable params: 1,738,245
Non-trainable params: 0
```

Figure 6. 1. 1: Deep Learning model for animal image data which has 3072 input.

From the figure 6. 3. 2. 1 we can see that, we have 3 hidden layers in our primary model; first one containing 512 nodes, second one containing 256 nodes and the third one containing 128 nodes. We have 5 output units and 3072 input units. Here, the activation for output is ‘softmax’.

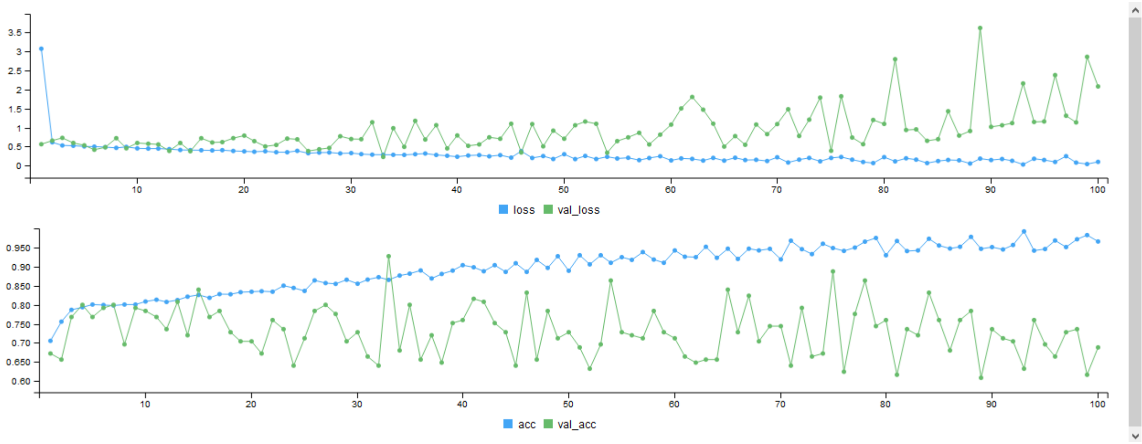


Figure 6. 1. 2: Deep Learning fitting graph of animal image data.

From the graph we can see that, in 100 epochs, the accuracy of training data and validation data are respectively 93.68% and 76%.

```
> # Evaluation & Prediction - train data
> model %>% evaluate(trainx, trainLabels)
500/500 [==============================] - 0s 94us/step
$`loss`
[1] 0.2348827

$acc
[1] 0.9368

> pred <- model %>% predict_classes(trainx)
> table(Predicted = pred, Actual = trainy)
         Actual
Predicted   0   1   2   3   4
        0  76   0   0   0   1
        1  24 100   9  16  19
        2   0   0  91   3   6
        3   0   0   0  80   2
        4   0   0   0   1  72
```

Figure 6. 1. 3: Deep Learning performance for animal image data (training).

In the above mentioned picture, we can see that, for training data, loss is 0.23 and accuracy is 93.68%. In the confusion matrix we can see that, out of 500 observations 81 were misclassified and 419 were correctly classified. The diagonal line represents the correct prediction. The columns represent the actual status and the rows represents the prediction.

```
> model %>% evaluate(testx, testLabels)
25/25 [==============================] - 0s 115us/step
$`loss`
[1] 1.208242

$acc
[1] 0.7600001

> pred <- model %>% predict_classes(testx)
> table(Predicted = pred, Actual = testy)
         Actual
Predicted 0 1 2 3 4
        0 1 1 0 0 0
        1 3 3 0 4 3
        2 1 0 4 1 1
        3 0 1 1 0 0
        4 0 0 0 0 1
```

Figure 6. 1. 4: Deep Learning performance for animal image data (test).

In the above mentioned picture, we can see that, for testing data, loss is 1.2 and accuracy is 76%. In the confusion matrix we can see that, out of 25 observations 8 were misclassified and 17 were correctly classified. The diagonal line represents the correct prediction. The columns represent the actual status and the rows represents the prediction. So,

Accuracy in training data is 93.68%.

Accuracy in testing data is 76%.

But if we add hidden layers the performance increases.

```
> summary(model)
________________________________________________________________________________
Layer (type)                        Output Shape                     Param #
================================================================================
dense_1 (Dense)                     (None, 1024)                     3146752
________________________________________________________________________________
dense_2 (Dense)                     (None, 512)                      524800
________________________________________________________________________________
dense_3 (Dense)                     (None, 256)                      131328
________________________________________________________________________________
dense_4 (Dense)                     (None, 128)                      32896
________________________________________________________________________________
dense_5 (Dense)                     (None, 64)                       8256
________________________________________________________________________________
dense_6 (Dense)                     (None, 5)                        325
================================================================================
Total params: 3,844,357
Trainable params: 3,844,357
Non-trainable params: 0
```

Figure 6. 1. 5: Enhanced Deep Learning model for animal image data.

From the picture 6. 1. 5 we can see that, in the secondary model the number of hidden layers is 5 and the layers contains 1024, 512, 256, 128, 64 nodes respectively. Here input units are 3072 and the output units are 5.

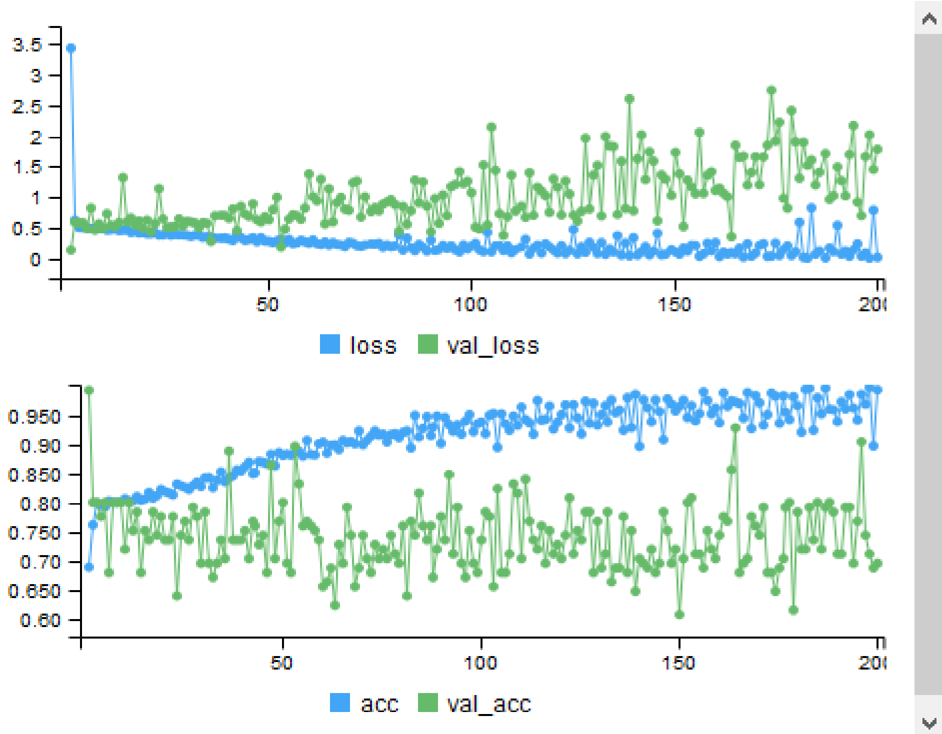


Figure 6. 1. 6: Enhanced Deep Learning fitting graph of animal image data.

From the above mentioned fitting graph we can see that, 200 epochs were done reach the conclusion. The training accuracy is 98.04% and the loss is 0.10. The validation accuracy is 82.4% and loss is 1.15. So, we can say that, both the training and validation accuracy increases after adding hidden layers in the next model. But not all time this works. In our model we increased the number nodes even more but the result was slightly better than the primary model but worse than the secondary model. So, this secondary model works perfectly for our dataset.

Increasing the number epochs helps to get better performance. But in 200 epochs we got almost stable output that’s why we didn’t increase the number or epoch more. Sometimes increasing epochs causes over fitting which decreases the performance.

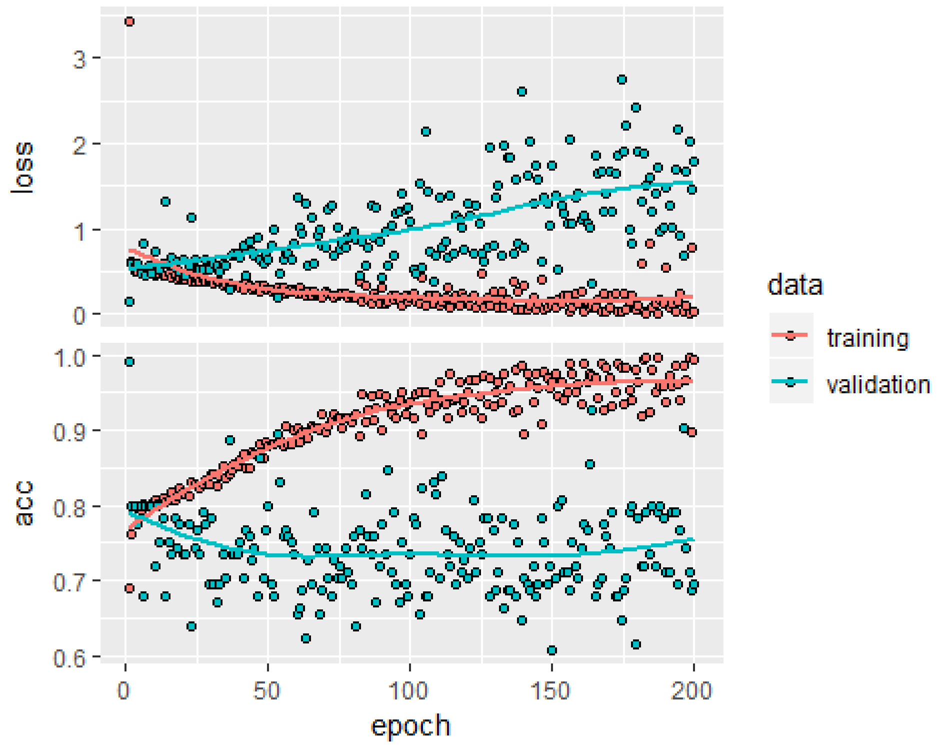


Figure 6. 1. 7: Deep Learning fitting plot for enhanced animal image data model.

This is the Final plot of Deep Learning using ‘keras’. From the graph we see that, the validation accuracy is 82.4% and training accuracy is 98.04%.

```
> model %>% evaluate(trainx, trainLabels)
500/500 [==============================] - 0s 212us/step
$`loss`
[1] 0.1021954

$acc
[1] 0.9804

> pred <- model %>% predict_classes(trainx)
> table(Predicted = pred, Actual = trainy)
         Actual
Predicted   0   1   2   3   4
        0 100   0   3   0   1
        1   0 100   1   0   8
        2   0   0  96   0   3
        3   0   0   0 100   7
        4   0   0   0   0  81
```

Figure 6. 1. 8 : Deep Learning confusion matrix for animal training data.

Here we can see accuracy has increased. Accuracy for training data is 98.04%. The diagonal line represents the correct prediction. The columns represent the actual status and the rows represents the prediction. We can see that, out of 500 observations 23 were misclassified where 477 were correctly classified.

```
> model %>% evaluate(testx, testLabels)
25/25 [==============================] - 0s 240us/step
$`loss`
[1] 1.15408

$acc
[1] 0.824

> pred <- model %>% predict_classes(testx)
> table(Predicted = pred, Actual = testy)
         Actual
Predicted 0 1 2 3 4
        0 3 1 0 0 0
        1 1 2 0 3 2
        2 0 1 4 1 1
        3 1 1 1 1 0
        4 0 0 0 0 2
```

Figure 6. 1. 9: Deep Learning confusion matrix for animal testing data.

In the above mentioned picture, we can see that, for testing data, loss is 1.15 and accuracy is 82.4%. In the confusion matrix we can see that, out of 25 observations 10 were misclassified and 15 were correctly classified. The diagonal line represents the correct prediction. The columns represent the actual status and the rows represents the prediction.

Accuracy for testing data is 82.4%.

Number of hidden layer and number of epochs improves performance for our model.

Convolutional Neural Network

```
> summary(model)
________________________________________________________________________________
Layer (type)                        Output Shape                      Param #
================================================================================
conv2d_1 (Conv2D)                   (None, 30, 30, 32)                896
________________________________________________________________________________
conv2d_2 (Conv2D)                   (None, 28, 28, 32)                9248
________________________________________________________________________________
max_pooling2d_1 (MaxPooling2D)      (None, 14, 14, 32)                0
________________________________________________________________________________
dropout_1 (Dropout)                 (None, 14, 14, 32)                0
________________________________________________________________________________
conv2d_3 (Conv2D)                   (None, 12, 12, 64)                18496
________________________________________________________________________________
conv2d_4 (Conv2D)                   (None, 10, 10, 64)                36928
________________________________________________________________________________
max_pooling2d_2 (MaxPooling2D)      (None, 5, 5, 64)                  0
________________________________________________________________________________
dropout_2 (Dropout)                 (None, 5, 5, 64)                  0
________________________________________________________________________________
flatten_1 (Flatten)                 (None, 1600)                      0
________________________________________________________________________________
dense_1 (Dense)                     (None, 256)                       409856
________________________________________________________________________________
dropout_3 (Dropout)                 (None, 256)                       0
________________________________________________________________________________
dense_2 (Dense)                     (None, 5)                         1285
================================================================================
Total params: 476,709
Trainable params: 476,709
Non-trainable params: 0
```

Figure 6. 1. 10: Convolutional Neural Network model.

The above picture describes the structure of our Convolutional Neural Network model. We can see that, in our model we have 4 convolutional layers, 3 dropout layers and 2 max pooling layers.

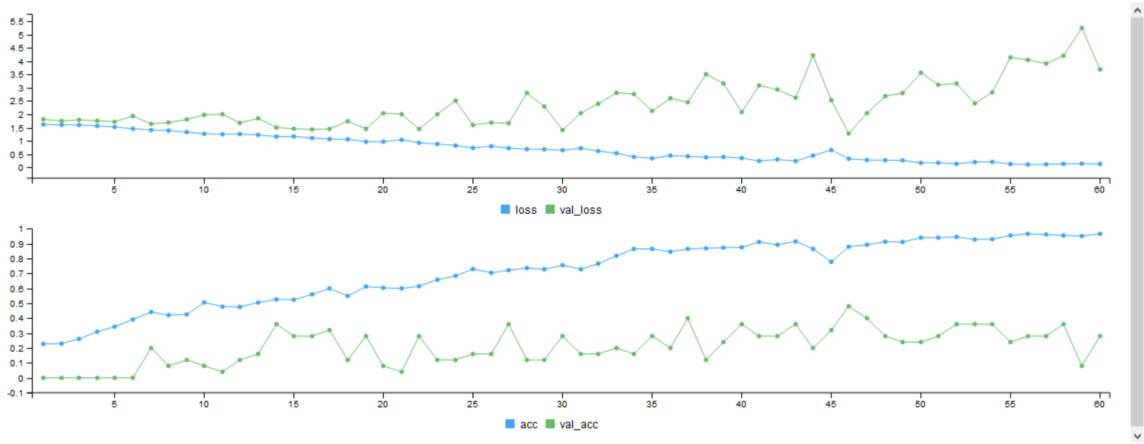


Figure 6. 1. 11: Convolutional Neural Network fitting graph.

This is the fitting graph of our model. We used 60 epochs to train our model. We can see that the training accuracy is 95.4% where the testing accuracy is only 52%.

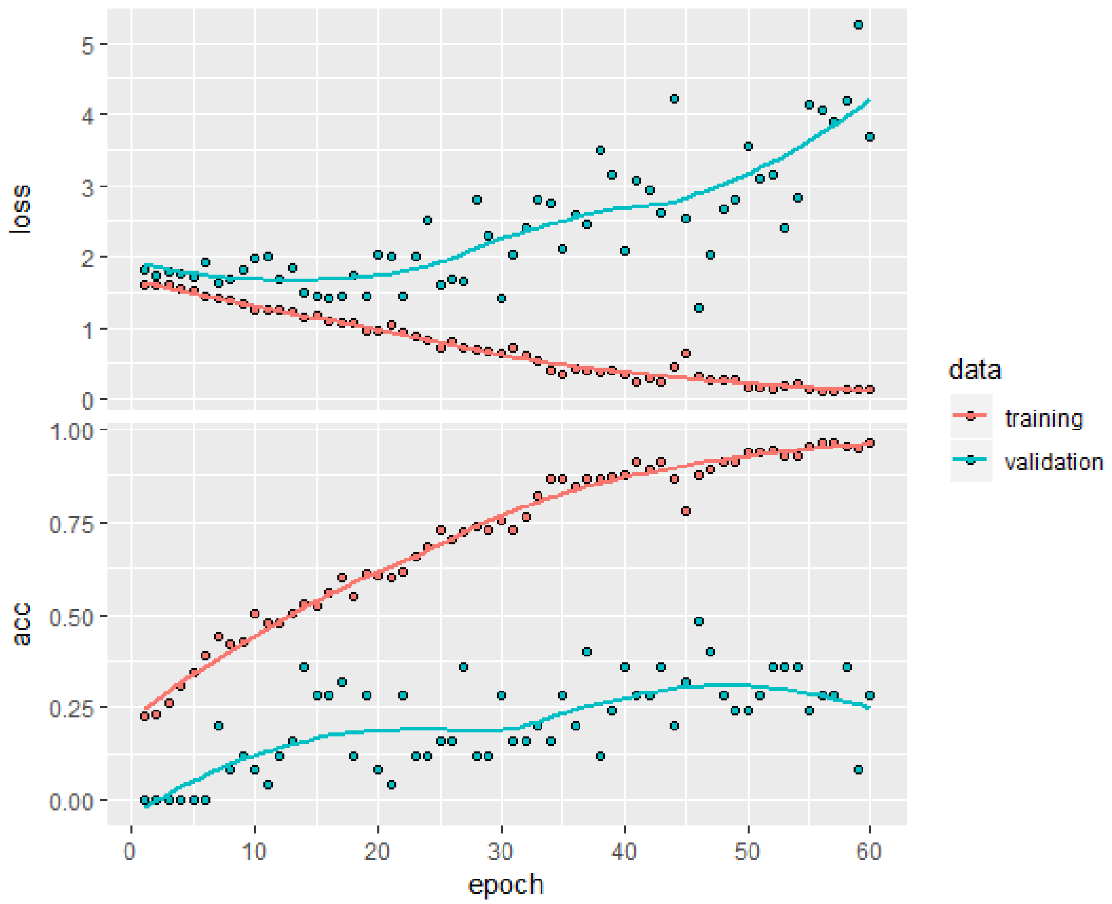


Figure 6. 1. 12: Convolutional Neural Network fitting plot.

From the graph we can see that, though test data accuracy is good but validation data accuracy is far from good.

```
> model %>% evaluate(train, trainLabels)
500/500 [==============================] - 1s 1ms/step
$`loss`
[1] 0.2179169

$acc
[1] 0.954

> pred <- model %>% predict_classes(train)
> table(Predicted = pred, Actual = trainy)
         Actual
Predicted   0   1   2   3   4
        0 100   1   1   0   4
        1   0  97   0   0   3
        2   0   0  99   0   4
        3   0   0   0 100   8
        4   0   2   0   0  81
```

Figure 6. 1. 13 : Performance of Convolutional Neural Network (training data).

This is the confusion matrix for training data where the diagonal line represents the correct prediction.

```
> model %>% evaluate(test, testLabels)
25/25 [==============================] - 0s 1ms/step
$`loss`
[1] 2.666374

$acc
[1] 0.52

> pred <- model %>% predict_classes(test)
> table(Predicted = pred, Actual = testy)
         Actual
Predicted 0 1 2 3 4
        0 3 2 0 1 0
        1 2 3 1 1 0
        2 0 0 4 0 2
        4 0 0 0 3 3
```

Figure 6. 1. 14: Performance of Convolutional Neural Network (test data).

Here, we can see out of 25 observations 12 were misclassified and 13 were correctly classified which is not at a satisfactory level.

Accuracy for training data is 95.4%.

Loss for training data is 0.21.

Accuracy for testing data is 52%.

Loss for testing data is 2.66.

So, we can conclude that, for image recognition, Deep Learning is far better than Convolutional Neural Network.

Comparison Table for algorithms used for animal prediction:

Machine Learning Algorithm	Accuracy
Deep Learning with Keras	56%
Convolutional Neural Network	64%

Table 6. 1. 1: Comparison table for animal species prediction algorithms.

Chapter 7

Complexity Analysis

7.1 Design

This drone design we are proposing has new features in its design. Generally, drones are consisting of four or six propellers [6, 10] and they can only travel through air. Some drones are able to move through both air and land. ALW drone will be a unicopter. It will have only one air propeller. It can change its direction using sail plane. Actually, there will be no actual sail plane, rather the spikes will work as sail plane.

Besides, this drone hopefully will be an amphibious flyer. It will move through land, water and air. Nowadays, this type of environment independent drones is not frequently seen yet. May be there are some, but they are used for military purposes and built inside secret labs that's why we can't access the sources.

Also, the design is a quit complex one. That's why it needs to be experimented a several times in real life. There will be some performance issues until we build one physically and test in real life. May be we will have to change some parameters of the physical elements to make it work efficiently.

7.2 Artificial Intelligence

Besides, artificial intelligence is commonly used in recent times. But, in this drone, AI will be used in a higher level. This drone hopefully will have the capability of interacting with environment frequently. It will be able to recognize temperature, pressure, thermal radiation, nuclear radiation. Besides it will also be able to capture photos and analyze those. By analyzing the bio-information it will learn about the animal type. This environmental data will gather in drone's database. In near future this kind of data will help this drone to improve its AI. But, the code needed for this kind of AI is not that comprehensive. Python, Ruby, Haskell and C is used for AI based devices. But in recent times there is another programming language called 'R' which is being popular in recent days. This language is being developed till now. So, using this language is a better option for us. So, we need to wait for the language to be fully developed.

‘R’ is a new language with no similarities with the previous ones so we will have to face some difficulties using this code but hopefully we will overcome the difficulties and proceed through.

7.3 Algorithm

A higher class of algorithm will be used in this drone. For decision making it will be capable of communicating with main server through satellite. The algorithm is designed in such a way that; the drone will be capable of making its own decision through continuously communicating with the main server. Before, this drone a few number of drones had this capability. Previous drones had limited AI in them [12]. So, some tasks had to be done manually as the algorithms were not perfect. But, in this drone, we tried to make the algorithm to be good enough. Machine learning algorithms are quit complex to be implemented in this type of project. Because, we have to implement several machine learning algorithms. The proficiency of rescue mission is dependent upon the algorithms. The next step will always depend on the result of the previous algorithm. That is why it is quite difficult to implement these algorithms effectively. But we are highly hopeful that, in the future we will implement the algorithms in our drone if we get enough funding and a number of experts in different fields such as Computer Science, Electronics and Mechanical Engineering.

Chapter 8

Conclusion

8.1 Discussion

ALW drone will be an evolving class of drone. We hope It will be able to challenge the concept of modern drone technology and will have the ability to take this technology to the next level. However, it’s a challenge to accurately program this system. This paper proposed an unpretentious and new architecture, a modest algorithm and finally a conceptual AI system which we hope has the ability to overcome this challenge. It’s simple but sole algorithm will open the new door of environmental learning and environmental data mining. ALW drone will raise the bar high for current drone technology with its vast capability of learning and then use that information to upgrade its AI. This kind of flexible AI is the future of robotics and ALW drone is a proposed drone of this kind of technology.

8.2 Future Work

We believe that we can improve our algorithms and expand our logics and processes and after that we have to optimize these algorithms. For super AI we have to combine all these small algorithms in one strong and highly optimized algorithm. These super AI will control the ALW drone. Besides, to build the drone physically we need a large team of mechanical engineers, computer engineers and electrical engineers. We need external funding for building this drone in real life successfully. We also need to develop a large database consisting of bio information and environmental data. We hope we can establish satellite connection with our drone. For that we need international permission for accessing the satellite. Also we have to enrich the database for calamity and animal. Because, the more data the database contains the more accurate prediction will be generated from the Machine Learning algorithms. At the same time, we will also add more attributes in the dataset which will help us identifying weather and animal more accurately.

Bibliography

[1] N. Dijkshoorn. Simultaneous localization and mapping with the AR.Drone, University of Amsterdam, page(7-33) . California, July 14, 2012.

[2] J. C. Jarvis. The Ethical Debate of Drone Journalism: Flying Into the Future of Reporting, Southern Illinois University Carbondale, page (8-31) , 2014.

[3] J. J. Dengler. An Examination of the Collateral Psychological and Political Damage of Drone Warfare In The Fata Region of Pakistan. Naval Postgraduate School Monterey, California, September 2013.

[4] S. Goodrich. Targeted Killings: How The U.S. Perpetuates Terrorism. Westminster College Salt Lake City, page (1-60), UT May 2014.

[5] L. Brooke-Holland, Overview of military drones used by the UK armed forces, House of Commons Library research briefings – Parliament, Briefing Paper, Number 06493, page (18-52), 8 October 2015.

[6] The Rise of the Predator Empire: Tracing the History of U.S. Drones, Understanding Empire, page (1-24),2013-2014.

[7] N. Lekić, S. Djukanović, M. Bajčeta, T. Savić. A bioinformatic system for collecting and processing environmental data. Telecommunications Forum Telfor (TELFOR), 2015 23rd.

[8] W. C. Evans, A. Bahr, A. Martinoli . Distributed Spatiotemporal Suppression for Environmental Data Collection in Real-World Sensor Networks, 2013 IEEE International Conference on Distributed Computing in Sensor Systems, 20-23 May 2013.

[9] J. Irizarry, M. Gheisari, B. N. Walker. Usability Assessment of Drone Technology as Safety Inspection tools. September 2012 at http://www.itcon.org/2012/12.

[10] A. Conner-Simons | CSAIL, Wireless tech means safer drones , smarter homes and password-free Wi-Fi, page(5-35), March 31, 2016.

[11] K. Dauntu, B. Kate, J. Waterman. Programming Micro-Aerial Vehicle Swarms with Karma. 4th November 2011.

[12] P. K. Gerke. Astro Drone: Using crowdsourcing to collect visual data for distance estimation. Department of Artificial Intelligence, Radboud University Nijmegen, page (5-32), 19th August 2013.

[13] O.H. Boyers. An Evaluation of Detection and Recognition Algorithms to Implement Autonomous Target Tracking with a Quadrotor. Grahams town, South Africa, page (5-53) , November 2013 , Rhodes University.

[14] Christian Sommer, PhD thesis, Approximate Shortest Path and Distance Queries in Networks, page (2-12) , University of Tokyo, 2010.

[15] Anjan Chakrabarty, Flight Path Planning of UAV Based on Atmospheric Energy Harvesting, page (9-33), August 2010.

[16] Andrea Ponza, Optimization of Drone-Assisted Parcel Delivery, page (3-50), 2015-2016.

[17] E. Sonmezocak, S. Kurt. Optimum Route Planning and Scheduling for Unmanned Aerial Vehicles, December 2008.

[18] T. Lozano-Perez, A simple motion-planning algorithm for general robot manipulators, IEEE Journal on Robotics and Automation ,06 January 2003.

[19] L.Geng,Y. F. Zhang , P. F. Wang , J.Wang ,J. Y. H. Fuh ,S.H. Teo .UAV surveillance mission planning with gimbaled sensors.11th IEEE International Conference on Control & Automation (ICCA) , page (224-236),18-20 June 2014.

[20] C. Davids, G. Ormazabal and R. State. Real-Time Communications Topics for Research and Methods of Collaboration. Illinois Institute ofTechnology's Real-Time Communications Conference and Expo,co-located with the IPTComm Conference , October 15–17, 2013.