eYSIP2018

Flying Sensor Node

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Duration of Internship: 21/05/2018 – 06/07/2018

2018, e-Yantra Publication

Flying Sensor Node

Abstract

Drone and IoT are two emerging technologies having a plethora of applications. Through this project we aim to bridge these technologies to develop an indoor and outdoor environment monitoring system. A drone acts as a sensor node and flies across a room using way points predetermined by the user, collecting the temperature and humidity data using on-board sensors. The sensor data along with the location and time stamp are sent to central IoT server for data visualization and analytics.

Different drones were used for indoor and outdoor environments to tackle the unique challenges faced in terms of mobility and localization in each environment. The concept of charging the drone through a landing deck was also explored in order to realize the potential of Flying Sensor Node in real world applications.

Completion status

Indoor Flying Sensor Node Tasks

- Pluto X on-board sensor and peripheral interfacing using existing APIs
- STM32f303CB peripheral interfacing using standard peripheral libraries
- AR Drone navigation in Gazebo simulation for both Whycon and GPS
- AR Drone communication in Gazebo simulation for IMU values
- IoT Server for sensor data visualisation and live tracking was created on the control station
- Establish communication between Drone and IoT Platform in simulation and reality

- Decawave UWB tag and anchor hardware setup and configuration
- UWB tag interfacing on Pluto X
- Pluto X location co-ordinates transmission and reception using Multi Wii Serial Protocol
- Complementary Filter design for localization data (Needs Improvement)
- Payload Testing of Pluto X
- Waypoint planning and navigation with data logging using UWB and Whycon
- Landing of Pluto X on designated charging area

Outdoor Flying Sensor Node Tasks

- Quad-Copter assembly and RC remote testing
- Pixhawk setup and configuration using Mission Planner and Q Ground Control was attempted
- Pixhawk control using mavros, dronekit and companion computer was attempted
- Navio 2 setup for quad-copter was done on RPI 3B
- Quad copter configuration and calibration was done using Mission Planner
- IoT Server for sensor data visualisation, live tracking and video streaming was created on the RPI 3B
- Location logging using GPS was implemented
- Temperature and humidity value from DHT-22 is communicated to the flight controller and is logged
- Mounting structure for Sensor node was designed
- Battery consumption was analyzed and appropriate power source was selected
- Fail safes were removed to enable indoor testing
- Stabilize mode of operation was tested indoors using RC transmitter

1.1 Hardware parts

Pluto X

- Purpose : Indoor Drone based on STM32f303CB
- Vendor : Drona Aviation

RPI 3B

- Purpose : RPI 3B is the processing unit for the outdoor quad-copter when using Navio 2
- Product Link : RPI 3B
- Datasheet : RPI 3B Datasheet

Arduino Nano

- Purpose : Arduino Nano is used as sensor node
- Product Link : Arduino Nano
- Datasheet : Arduino Nano Datasheet

Navio 2

- Purpose : Navio 2 is an autopilot hat for RPI
- Product Link : Navio 2
- Product Brief : Navio 2 Documentation

Decawave DWM1001

- Purpose :Indoor Localization
- Product Link : DWM 1001
- Product Brief : DWM 1001 Resources

LiPo Battery 6200 mAh, 40C & 11.1 V

- Purpose : Powering the quad-copter
- Product Link : Orange Battery
- Product Brief : Orange Battery Specifications

Pixhawk

- Purpose : Flight controller
- Product Link : Pixhawk
- Product Brief : Pixhawk Resources

Telemetry Radio 433MHz for Navio 2

- Purpose : Communication between ground control station and quad-copter
- Product Link : Mrobotics Telemetry Module

Telemetry Radio 433MHz for Pixhawk

- Purpose : Communication between ground control station and quad-copter
- Product Link : Pixhawk Compatible Telemetry Module

DHT-22

- Purpose : Sensor for obtaining temperature and humidity data
- Product Link : DHT-22
- Product Brief : DHT-22 Datasheet

BRUSHLESS MOTOR SPEED CONTROLLER ESC 30A

- Purpose : Electronic speed controller for BLDCs
- Product Link : ESC Specifications

RC BRUSHLESS MOTOR 2212 1000KV WITH SOLDERED BANANA CONNECTOR

- Purpose : BLDCs with propellers to
- Product Link : BLDC Specifications

1.2 Software used

1.2.1 Indoor

- Java

  For Windows:Link
  For Ubuntu:Link

  Use Java 8 only as it is required for Cygnus.

- Cygnus IDE

  This integrated developement environment is necessary for flashing code to the pluto drone.Install cygnus from here.Follow the instructions to setup Cygnus on you system.Enjoy coding!!!!

- ROS(Indigo)

  Robot Operating System (ROS) is robotics middleware (i.e. collection of software frameworks for robot software development).Ros is required for interfacing Pluto and PlutoX.To know more about ROS visit here.

  The main ROS client libraries (C++ and Python) are geared toward a Unix-like system, primarily because of their dependence on large collections of open-source software. Hence these client libraries require Linux operating system.
  You **must** install the **ROS-Indigo in Ubuntu 14.04** on your PC/Laptop.

  Follow the installation instructions from here.

- pluto_drone

  Metapackage to control the plutodrone via service and topic wiki

- Roslibjs

  Roslibjs is the core JavaScript library for interacting with ROS from the browser. It uses WebSockets to connect with rosbridge and provides publishing, subscribing, service calls.

Download link: min :: full Source:Github Wiki:Roslibjs

- Rosbridge_suite

  Rosbridge provides a JSON API to ROS functionality for non-ROS programs. There are a variety of front ends that interface with rosbridge, including a WebSocket server for web browsers to interact with. For installation visit this link.

1.2.2 Outdoor

- Ground Control Station

  A ground control station (GCS) is a land- or sea-based control centre that provides the facilities for human control of Unmanned Aerial Vehicles (UAVs or "drones").It may also refer to a system for controlling rockets within or above the atmosphere, but this is discussed elsewhere.

  You may install one the below GCS:

  Mission Planner::Link(only for Windows)
  QGroundControl::Link

- Python

  Python is an interpreted high-level programming language for general-purpose programming. Created by Guido van Rossum and first released in 1991, Python has a design philosophy that emphasizes code readability, notably using significant whitespace. It provides constructs that enable clear programming on both small and large scales.

  We used Python 2.7 for this project. **Always use same python version for every library as it may cause errrors**.
  For installation visit here.

- Emlid Image for Raspberry Pi

  Raspberry Pi needs an Operating System for operation.A custom image of Raspberry Pi comes with pre installed Ardupilot,Ros and other necessary packages required for automatted vehicles.
  Download the image and flash it on a memory card using Etcher
  Run and install Etcher using admin rights.
  Select the archive with Image and drive location.
  Click Flash!!.This may take a few minutes.

- Motion

  Motion is a highly configurable program that monitors video signals from many types of cameras. It was used for displaying live video feed on the web server coming from RPi Camera mounted on the Raspberry Pi. Setting it up on raspberry pi can be understood from this link. If the video doesn't start as soon as the server starts and a gray screen is visible visit this discussion

- Flask is a micro web framework written in Python. It is classified as a microframework because it does not require particular tools or libraries. It has no database abstraction layer, form validation, or any other components where pre-existing third-party libraries provide common functions. However, Flask supports extensions that can add application features as if they were implemented in Flask itself.Download flask from here.

1.3 Assembly of hardware

The assembly for both indoor and outdoor drones is explained in this section.

Indoor Flying Sensor Node

DWM1001 Module Setup

- One module is used as a tag on the drone and the connections are as shown in the figure
- Four modules are used as anchors on the wall and only require a power source of 3.3V

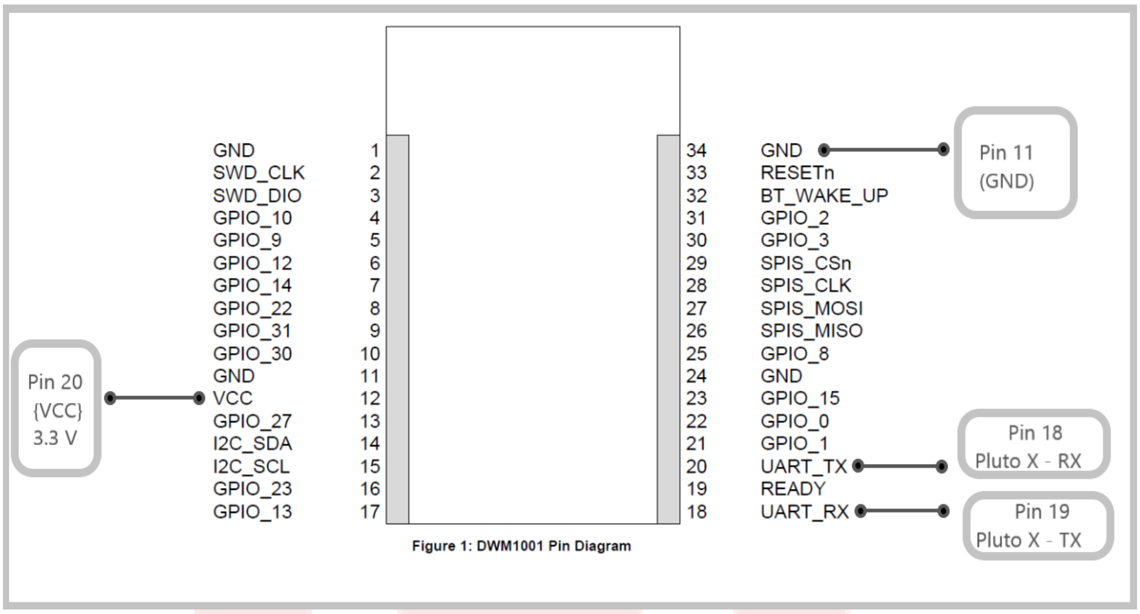


Figure 1: DWM1001 Pin Diagram

- The modules are configured using the official Decawave Android App
- The instructions for the same are explained in the above application in great detail.

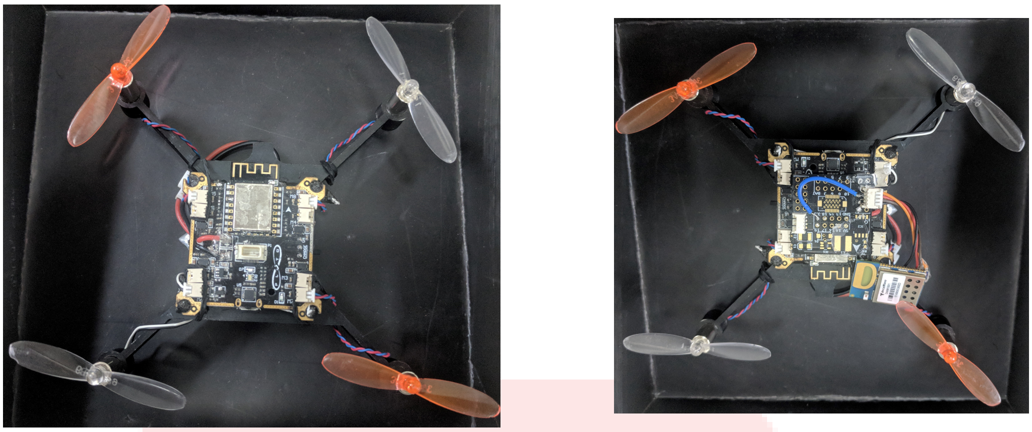
Pluto X

- After attaching the tag on the gpio shield of Pluto X, place the shield on the Pluto X as shown in the figure, "Pluto X Shield Setup"
- The pin mapping of the shield with respect to the STM32f303CB micro-controller on Pluto X is as shown in the table below

	S. No	Pin	FT		STM pir	STM r	TIM I	TIM II	ADC	DAC	IR	I2S2	USART3	UART2	I2C1	OPAMP4	debug
POWER	1	1	-	VBAT		-											
-	12	2	FTf	GPIO	34	PA13	T4C3	T16_CH1N			Y						IO
-	13	3	FTf	GPIO	37	PA14	T8C2							TX			CLK
M7	14	4	TTa	GPIO	21	PB10	T2C3						TX			VINM	
M8	15	5	TTa	GPIO	22	PB11	T2C4						RX			VINP	
I2C	7	6	TT	SDA	46	PB9	-	-	-	-	-						
I2C	6	7	TT	SCL	45	PB8	-	-	-	-	-						
DAC	19	8	TTa	GPIO	15	PA5	T2C1		A2_IN2	Y							
M6	18	9	FT	GPIO	39	PB3	T2C2	T8C1~						TX			SWO
SPI		10	FT	SS	29	PA8	T1C1										
POWER	3	11	-	GND		-											
POWER	17	12	-	GND	-												
DAC	16	13	TTa	GPIO	14	PA4	T3C2		A2_IN1	Y						VINM	
SPI	11	14	TTa	SS	25	PB12			A4_IN3			WS				VOUT	
SPI	10	15	TTa	SCK	26	PB13	T1_C11		A3_IN5			CK					
SPI	9	16	TTa	MISO	27	PB14	T1_C2~		A4_IN4			EXT_SD					
SPI	8	17	TTa	MOSI	28	PB15	T1_C3~	T15_C2,1~	A4_IN5			SD					
UART	5	18	TTa	RX	13	PA3	T2_C4	T15_C2	A1_IN4					RX			
UART	4	19	TTa	TX	12	PA2	T2_C3	T15_C1	A1_IN3					TX			
POWER	2	20		3.3V		-											

LEGEND	
(yellow)	Shared pins; Use with care
(green)	SWD debug pins, but can be used freely
(red)	Power pins

GPIO	16
Anaglog channel	8
Timers	11
Uarts	2
SPI	1
I2C	1
DAC channels	2
Debug port	SWD

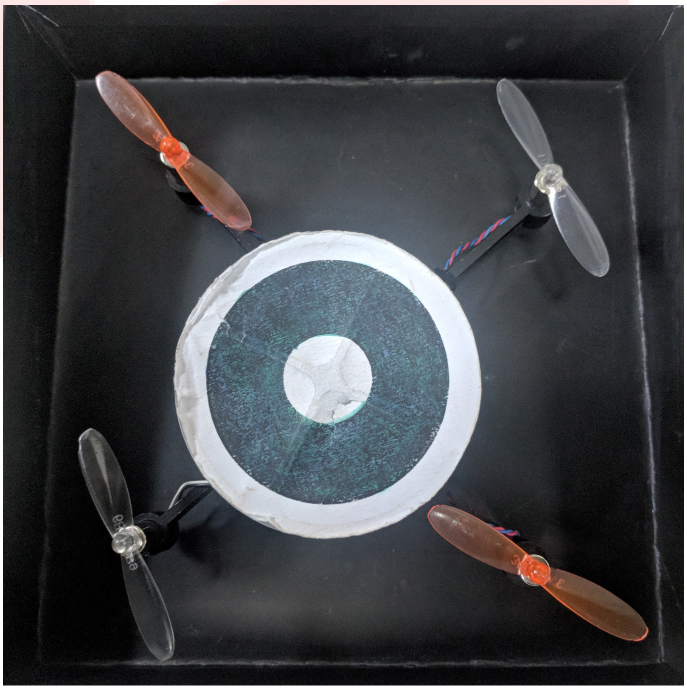


(a) Pluto X without shield

(b) Pluto X with shield

Figure 1.1: Pluto X Shield Setup

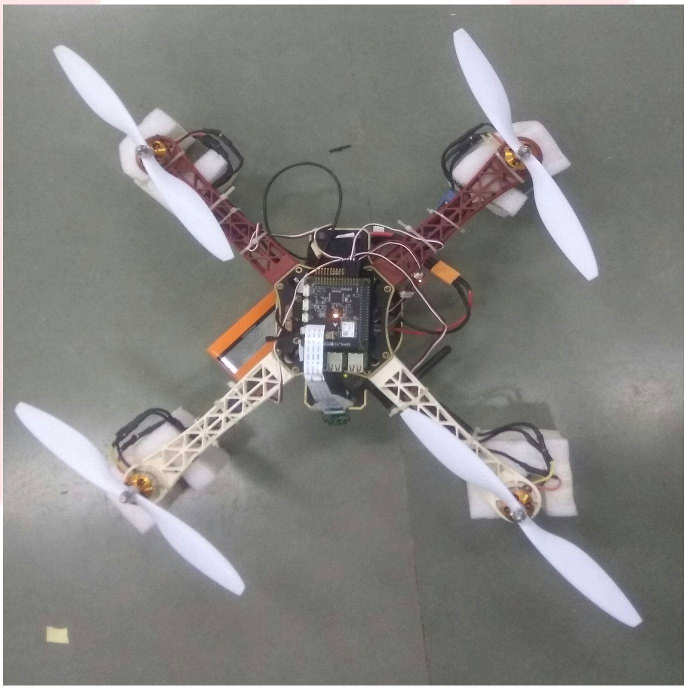
- A whycon marker is also added on top of the Pluto X as shown in the figure below to enable landing on charging area using an overhead camera



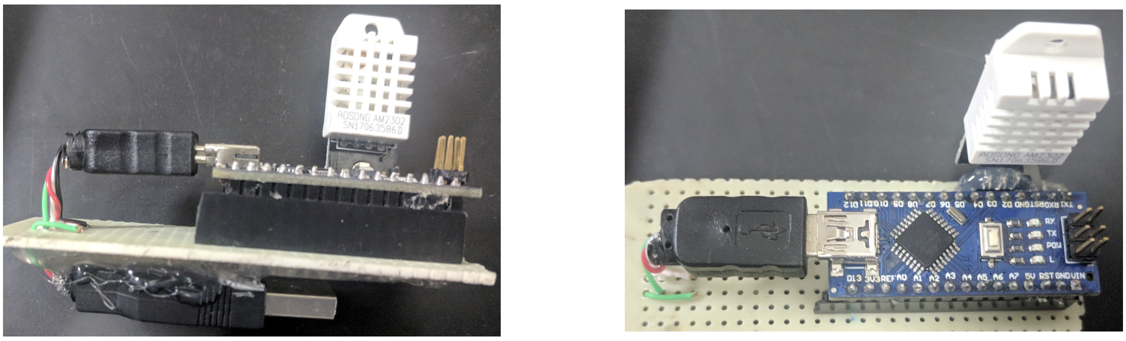
Outdoor Flying Sensor Node

Auto Pilot Assembly

- Raspberry Pi, Navio 2, GPS antenna, Telemetry transreceiver, battery monitor, remote receiver through ppm encoder and electronic speed controller inputs are connected as shown here
- The other parts of the drone such as motors and propellers are assembled in accordance to this guide
- A three cell 11.1V, 6200mAh, 40C lithium polymer battery is used to power the drone
- The completely assembled quad-copter is as shown in the image below



- The sensor node comprising of the arduino nano, DHT-22 and usb connector is as shown in the figure below.
- The sensor node needs to be plugged in any of the usb ports of the raspberry pi 3b on the drone.



(a) Sensor Node Side View

(b) Sensor node top View

Figure 1.2: Sensor Node Module

1.4 Software and Code

Github link for the repository of code

Outdoor

- **Arduino Code** - Contains code to interface DHT-22 using arduino nano on a Raspberry PI.
- **Drone-Server** - Contains server for drone.Copy the folder on Raspberry PI.
- **Ardupilot Setup** - link

Indoor

- **Documents** - Contains API for interfacing PlutoX board.
- **Codes** - Contains testing codes for PlutoX and RF.
- **Pluto-X Navigation-Whycon,Final,Navigation** - Different Navigation scripts for PlutoX
- **PlutoX Firmware** - Firmware Changes for MSP protocol
- **Server** - Establishing server for logging data and controlling drone remotely
- **pluto_drone** - Contains changes in navigation packages

Use and Demo

Outdoor

- After setting up the raspberry with the custom image and configuring the quad-copter using mission planner do the following :-
- **Step 1** - Change directory to Drone-Server
- **Step 2** - Run command "sudo modprobe bcm2835-v4l2" to get video on web server.
- **Step 3** - Run command "sudo python SensorLog.py" to get real time sensor data i.e. temperature and humidity
- **Step 4** - Run command "sudo python GPS.py" to get real time sensor data i.e. GPS (only if the drone is outdoors)
- **Step 5** - Run command "sudo python app.py" to start the server
- **Step 6** - If the IP address of the raspberry pi is 192.168.43.238 open a browser on a device connected to the network and enter the URL 192.168.43.238:5010 to get access the IoT platform.

Indoor

After setting the DWM1001 module,whycon on the drone and the overhead camera follow the below steps.

- **Step 1** - Make changes to the serial_msp.cpp and flash the firmware.
- **Step 2** - Add changed files to pluto_drone metapackage
- **Step 3** - Run the data_via_rosservice.py file to get coordinates and other data
- **Step 4** - Run the launch file and on another terminal run the navigation script.
- **Step 5** - Run the rosbridge_websocket launch and open comm.html in browser to control the drone and get data
- **PS** - Play with the code to understand it better.

Youtube Link of demonstration video

1.5 Future Work

1.5.1 Outdoor

- Manual and Autonomous testing of drone in outdoor environment using Ground Control Station.
- Full fledged IOT server for large scale use using internet.
- Buildng Charging Dock for the drone.
- Using Dronekit and similar libraries for controlling drone using server.

1.5.2 Indoor

- Building a Charging Dock for PlutoX.
- External Sensor(Temperature,Humidity) Interfacing for PlutoX.
- Designing a better noise reduction filter so that navigation is much smoother.
- On-board Computing of path to reduce latency and improve performance.

1.6 Bug report and Challenges

1.6.1 Outdoor

- No heartbeat received from the FCU.
- Arming the quadcopter without GPS fix.
- Bad logging error due to SD card.
- Telemetery issues with Pixhawk flight controller

1.6.2 Indoor

- Understanding the firmware of PlutoX.
- Reconfiguring the firmware to accept the coordinate values coming from DWM1001.

- Understanding Multi Wii Serial Protocol of data transfer from drone to control station and vice versa.
- Reconfiguring the ROS communication package for PlutoX 'plutodrone' to accept new MSP headers.
- Designing a filter to reduce noise in the coordinates.
- Navigating drone using PID and then switching dynamically between whycon marker and Ultra Wide Band for better navigation.
- Fine tuning of PID for smooth control of drone.

Bibliography

[1] Mastering ROS for Robotics Programming - Lentin Joseph

[2] Ros tutorials- Link

[3] Programming Robots with ROS: A Practical Introduction to the Robot Operating - Brian Gerkey, Morgan L. Quigley, and William D. Smart

[4] ROS cheatsheet

[5] Navio Documentation-link

[6] Linux-Documentation

[7] Python-Documentation

[8] Multi Wii Serial Protocol-link

[9] Navio2 drivers-Github