Air Quality Index Mapping Using Programmable Unicopter Drone Swarm-Iot(Internet Of Things)

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Abstract—Unmanned Aerial Vehicles (UAVs) with the advances in technologies are becoming more common, UAVs has become a platform to gather data that simply human cannot reach. With the mobility of a drone, it can cover a lot of area in a single take, greatly benefiting the data gathering process, While conventional model drones like quadcopter configurations are too big and too costly. To tackle those issues, this thesis proposed the use of an Unicopter drone design that can make the cost of making the drone unit and the data gathering process by combining it with an Air Quality Measurement Device that uses DHT22 as the humidity and temperature sensor and MQ-135 as the air quality sensor. Which can be programmed to capture the air quality data. The result is Unicopter that can interval takes detect air quality, send it to the Firebase, and displayed it via smartphone. All of the tests are carried out on Sukapura Football Field. The result showed a slight difference in the quality of data when the drone has a different placement for the sensor. The maximum quality when it is moved is 124 PPM and when it is not is 103 PPM. This is because of the intensity while the drone is moving. Besides that, there is no difference between the temperature and the humidity result, with a maximum of 24◦C and 99.6% humidity. With the difference in the quality of data, the result is almost accurate.

Keyword drone, unicopter, programable, air quality measurement, IoT;

I. INTRODUCTION

The impact of economic growth in Indonesia is parallel to the rise of CO2 emissions, Due to the economic rise, more Indonesian people prefer a personal motorized vehicle as their method of transportation, Engine exhaust consists of several gases and particulate emissions, which in turn consist of various chemical mixtures, Air pollution is a concern to public health, either from short-term or long-term exposure, and can cause various illnesses.

The government has taken several efforts to raise awareness against air pollution. There is another research conducted in Sleman that tested the car exhaust emissions in that area, the result is that 13 cars did not pass the emission test with 120 cars [1]. The research on air quality has also been carried out in Bandung, they use Node sensors to collect the data [2]. The result of the air quality research is that carbon monoxide (CO) concentration is high during work hours which makes the air unhealthy to breathe. In 2012 and 2015 in Kalimantan, there was a significant improvement in air quality, this was due to efforts to improve air quality by closing illegal mining and reforestation, this paper suggests educating the public by adding to the curriculum with lessons on the dangers of air pollution [3]. The air quality index (AQI) is used to measure the air quality, AQI is an effective method to tell how polluted the air is or how healthy it is, AQI is calculated based on the concentration of air pollutants, a high AQI detects highly concentrated pollutions appear in that area, a low AQI indicates that the area has suitable clean air, AQI data can be gained by sensors at governmental observation stations, producing an AQI map in the local area [4]. However, these sensors can only obtain a limited number of area samples in the observation area and often induce high costs. To reduce cost, a mobile platform is chosen to use along with the sensors.

The previous research also suggested that this sensor unit can be attached to an unmanned aerial vehicle (UAV). This form made it very agile and compact which the static sensor could not be capable of, gaining the ability to gather data even in remote places. While still maintaining the ability to gather data in large area coverage, This also reduces the production costs and is effective to use in a large-scale area of operations [5]. The traditional quadcopter frame would not do the task optimally, the quadcopter itself produces too much noise to the air quality index data, and the amount of air that is blown away from the trust generated from the four motors will disrupt the sensor greatly, the safety hazard that it can cause if it were deployed to populations dense area and the cost will be too high to produce and maintain. There are many types of drone frames that can prevent or ease these conditions from happening, and the singlecopter frame is the most suitable for this case of usage.

In this undergraduate thesis, I proposed to make Air Quality Index Mapping using a programable unicopter Drone, to survey highly polluted areas and remote places. The data is going to be stored in the cloud using Arduino-based IoT of Arduino. With this hopefully can improve the quality of life for those overall.

II. BASIC THEORY

A. Internet of Things (IoT)

The Internet of things (IoT) is mostly the act of gathering data using an automated device that is connected to the internet, this automation significantly reduces the work, time, and cost to gather data [6]. IoT envisions every object connected to the internet this can be achieved via embedded systems, so those objects can communicate with each other to open tremendous possibilities for a large number of applications that can improve the quality of our daily lives [7].

B. Air Quality Index (AQI)

Air pollution is both an environmental and a social problem, leading to a multitude of adverse effects on human health, ecosystems, and the climate. Air pollution includes one of the biggest problems in Indonesia. Air quality in urban areas is the most crucial factor as it lowers the community's quality of life and causes disease.

AQI is an effective method to tell how polluted the air is or how healthy it is, AQI is calculated based on the concentration of air pollutants, a high AQI detects highly concentrated pollution appearing in that area, and a low AQI indicates that the area has suitable clean air. With this, we can make a standard for healthy air and a suitable environment.

C. Arduino

Arduino is an open-source hardware and software company that designs and produces single-board microcontrollers for developing digital projects. Arduino mainly utilizes a microcontroller that uses software programming language (C++) to program the board [8].

This technology proved to be very useful, it is easy to learn, cost-efficient and compact. Most of the use of the Arduino is as a microcontroller for sensor units, with it being the compact overall design and low-cost part, it can be mass deployed to the area of survey.

D. Cloud computing

Cloud computing has a function as a storage medium of data in the form of a group of servers that work together, alongside acting as a storage, it can do computing tasks as well. These versatile technologies have been applied to numerous industries like Google, Facebook, and many more. Cloud computing can deliver all the functionality of existing information technology services, and even reduce the cost of a company from having a decent computing ability.

E. Computer-aided design

Computer-aided design, also known as CAD is a computers software that helps us to design 3 dimensions or 2 dimensions products thought with the help of computers hardware to process the design, CAD software can help us determine the size of the product with the help of computers calculations this easily improve the quality of the design itself. CAD is usually used before the manufacturing of the product, to improve productivity and to speed up the designing process.

F. 3D Printing

3D printing, also known as additive manufacturing, is an additive technique in which layers of material are built up to build a 3D component from a computer-generated design. 3D printing techniques were thought to be only suited for the manufacture of functional or aesthetically pleasing prototypes, and a more relevant name at the time was fast prototyping. One of the primary benefits of 3D printing is the capacity to generate highly complicated forms or geometries that would otherwise be difficult to make by hand, such as hollow pieces or items with internal truss systems to minimize weight.

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H. Drone Technology

Drones are wireless aircraft or unmanned aircraft, that can operate autonomously with the given missions. There is some drone that uses a remote control, those drones also have pre-program software making the drone more controllable, so that the pilot can fly with confidence, normally this feature comes with a cinematic drone, the purpose of having this feature is so that the pilot does not have to worry for lack of skill to fly. There is some drone that can fly without using a remote just give the mission using a mission planner and they will fly autonomously. With these abilities, this kind of drone is very versatile.

I. Thrust Vectoring

Thrust vectoring control is the ability that the vehicle has that can manipulate the directions of its flying by making it change the propulsions of the engines so it can redirect the propulsions to its desired route to control the altitude, roll, pitch, and yaw.

This method is designed for aircraft to have vertical takeoff ability, but we can utilize this to make this method the main way to move our aircraft, by using a vane to redirect air generated from the motor.

J. Proportional-integral-derivative (PID) control

Proportional-integral-derivative (PID) control is usually used to control the movement of the robot, while in this case, our target is a drone, it will affect the roll, pitch, and yaw of the drone. Proportional is controlling how well the drone will respond to a movement input. The Integral is how much bounce back happens after the proportional movement is finished or if the drone is out of balance. The derivative is to correct the bounce-back that the integral made, this is to dampen the noise that the integral made.

III. METHOD

A. System method of survey

1. Preparations

This step is just mostly surveying the area of operations, scouting the area of any obstacle for the drone to overcome, traffic of wireless connections in that area, the building to avoid, home point, geonet, and emergency landing point.

2. Planning

The planning step can be done while on-site or online using. In this stage we chose how the drone behaves while doing the missions, we can decide the home point, take-off point, flight pattern, speed of the flight, and where to hover.

3. Survey

The survey stage is going to be where the drone gets the chance to survey the area, we load the mission that previously has been made in the planning stage with some retweaking to adjust with the environment at the time like the wind speed and the altitude control, after that, we can begin the mission. As soon as the drone fly we want to monitor the drone carefully, and if something goes south, we can abort the mission and have the choice to land it carefully or just crash the drone, as the impact is not deadly and any broken part can be repaired easily, this is because the drone itself does not carry a lot of mass. The measurement unit going to take data every second after it is turned on, and give the average of the total data at the end of the missions, this can take several tries to get the perfect result.

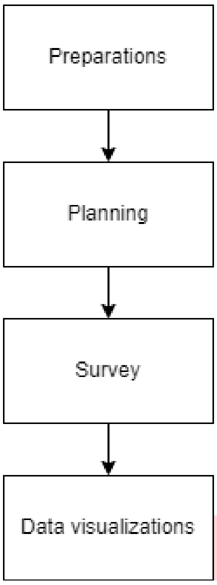

FIGURE 1. Survey method

4. Data visualizations

This is an example of the data visualizations the data will consist of quality, humidity, and temperature of the air. This data will be concluded by a python script, the data itself will be the average of the total, and test will be taken in some test.

B. Drone Design and Wiring

This is the design of a unicopter, unicopter only utilizes one rotor to gain thrust, while some propeller keeps it steady in the air. The design of the flaps works like plane flaps, the bottom flaps have the purpose of redirecting air that has been generated from the single rotor, with this the flight controller can control the PID (proportional–integral–derivative) movement of the drone.

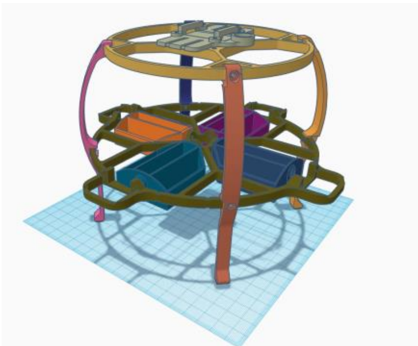

FIGURE 2. Unicopter design

1 We can mount the flight controller below the battery holder, then the flight controller is secured with a screw and hex nut.
2 The Electronic speed controller and the receiver are placed underneath the battery holder using a zip tie.
3 The brushless motor is placed underneath the flight controller with some screw and lock nut that hopefully dampened the jitter the motor gener- ated.
4 The servo is placed in each slot at the bottom of the frame, it will be connected to the flaps, and the flaps are connected to the center ring using a screw and hex nut.
5 The servo is placed in each slot at the bottom of the frame, it will be connected to the flaps, and the flaps are connected to the center ring using a screw and hex nut.
6 The battery is placed at the very top of the drone and will be strapped securely.

Spesifications	Frame 1	Frame 2	Frame 3
Material	Nylon carbon	PETG	PLA
Weight (gram)	152	107	120
Characteristic	Flexible	Rigid	Britle
Durability	Most durable	Durable	Crumbling
Cost per gram (Rp.)	2500	1200	700

FIGURE 3. Frame material

C. Drone Design and Wiring

The Figure 3 showed the behavior for the drone stabilizations after liftoff the stabilizations will happen, each servo is designated to stabilize dif- ferent scenarios. Servos 1 and 3 are responsible for roll stabilizations, Servos 2 and 4 are responsible for roll stabilizations, and all the servos are responsi- ble for yaw stabilizations.

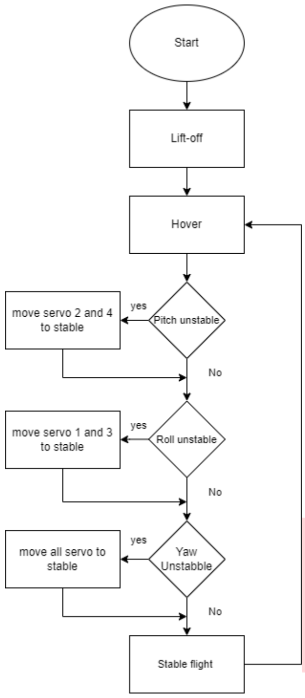

FIGURE 4. Stabilizations

D. System method of the measurement unit

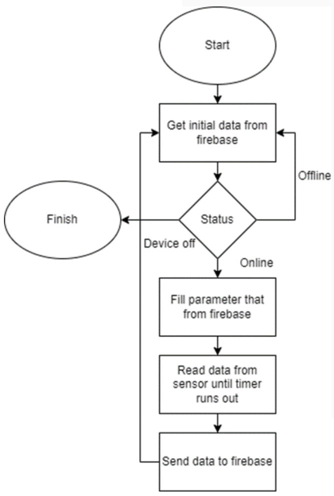

FIGURE 5

The measurement unit going to take data every second after it is turned on, and give the average of the total data at the end of the test. Every cycle takes about 10 data snapshot and then it will be average at the end of the cycle and then upload it.

E. Testing Scenario

In this thesis, we tested 2 main parameters namely drone performance, and sensor performance. This way we can improve the part that lack, ensuring the best quality of data reading and reliability.

1 Drone Performance
This test will test the performance of the drone itself. From the frame per- formance, and the Flight configurations. The Flight configurations contain a servo configurations test and PID output test. This test aims to find a stable configuration for the flight process.
2 Sensor Performance
This test will test the performance of the sensor. From the placement of the sensor, the effect of the airflow on the sensor, and the measurement of the time.

This test ensures we get the best performance for the drone flight and the sensor reading. By ensuring the drone flight characteristic, we can ensure drone safety and reliability.

IV. RESULTS AND DISCUSSION

A. Frame Realizations

In this thesis, we tested 2 main parameters namely drone performance, and sensor performance. This way we can improve the part that lack, ensuring the best quality of data reading and reliability.

Spesifications	Nylon carbon	PETG	PLA
Upper plate	Durable	snap after failed landing	easily snap
Bottom plate	Durable	snap after failed landing	easily snap
Leg	Durable	Durable	easily snap
Vane	easily chip	Durable	Durable
Battery holder	Durable	Durable	Durable

Figure 6. Frame durability

1 In Figure 6, in the nylon carbon row, almost every part is durable, ex- cept the vane. This is because the build surface is rough, this easily chips the surface, and this affects all the parts. All the part is thick enough to withstand this effect, except the vane.
2 PETG plastic has a rigid and smooth surface characteristic. It provides advantages and disadvantages. The advantage of having a smooth sur- face is that it does not get chipped easily, but the disadvantage of having a rigid body is that it can not withstand impact from falling.

3 I believe PLA is just the worst version of PETG, considering the cost is much cheaper than PETG. While it has a smooth surface, it is also brittle, and it does not have the rigid characteristic of PETG. This puts PLA in so many disadvantages.

B. Crash test

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C. performance test

1 We can see this in Table 4.4. Nylon carbon has good overall good per- formance, except in the vane and legs. The vane is so flexible, that the redirected air from the motor changes the shape of the cane during the flight, and this result the inconsistent flight. The legs are also flexible, during flight, it introduces left and right wobble at the bottom plate.

2 PETG has good overall performance because PETG is taking advantage of the rigidness characteristic. It can reduce the vibration, that the motor generated. The legs do not vibrate as much as nylon carbon.

3 While PLA plastic has a similar performance to PETG plastic, because of its brittle nature every time it is tested, it loses material over time, so it becomes a thinner profile, and the performance degrades over time.

D. Optimal setup.

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F. Servo Cofigurations

1 Yaw moves along with thrust, the stabilization of this configuration is not working because the thrust value overpowers the PID value in the calcula- tions. As a result, the configurations can not be tested.

2 The yaw is at a fixed angle and the vane is fixed to the left at a 15-degree angle, thus resulting in the only stabilizations that the drone has being the pitch and roll. This configuration is effective at certain motor speeds as the higher speed required a higher angle of the vane.

3 In the last configurations, the yaw is controlled by the PID. This configuration proved to be the most effective method to fly a unicopter. The only thing that affects this method is the propeller angle of attack because if the propeller has a low angle of attack, it has to spin faster to generate lift, and if the angle of attack is high it required less effort to generate lift.

G. PID Output Test.

This test is usually conducted in a closed environment and secured to a fixed place, with minimum motor input to hover, this way if the drone starts to be- have strangely, we can quickly shut down the entire system. After that, we can see the characteristic of the drone itself, and tune the PID to get a better result. The firmware that I use is Betaflight, to ensure the best performance and frequency looping is at 2 kHz because the ESC can not handles frequencies above that.

Test	Roll			Pitch			Yaw			Result
	P	I	D	P	I	D	P	I	D	
1	100	0	0	100	0	0	100	0	0	Stabilizations are in effect, still drifting and unstable
2	0	100	0	0	100	0	0	100	0	No stabilizations
3	0	0	100	0	0	100	0	0	100	No stabilizations
4	100	100	0	100	100	0	100	100	0	Stabilizations, There is slight movement after lift applied
5	100	0	100	100	0	100	100	0	100	Stabilizations, There is a slight jitter effect after stabilizations
6	100	0	100	100	0	0	100	0	0	Stabilizations, no jitter, slight drift
7	100	0	0	100	0	100	100	0	0	Stabilizations, slight jitter, slight drift
8	100	0	0	100	0	0	100	0	100	Stabilizations, There is a slight jitter effect after yaw stabilizations
9	100	0	100	100	0	100	100	0	0	Stabilizations, slight jitter, slight drift
10	100	0	50	100	0	50	100	0	0	Stabilizations, no jitter, slight drift
11	100	10	50	100	10	50	100	20	0	Stabilizations, no jitter, no drift

•We can see Table 4.7, at tests 1, 2, 3, 4, and 5. We can see the P or pro- portional is acting the role of the overall movement or the percentage of the movement. We can see in test numbers 2 and 3, we can not determine the test result for I or integral and D or derivative unless we apply the P, like test numbers 4 and 5.

•We can see Table 4.7, at tests 4. We can see the I act as the counterbalancing force after the motor input was applied, this counterbalancing force can be seen as a slight movement to the servo that grows gradually within the signal position and the timing. So basically I can act as the trim for the drone.

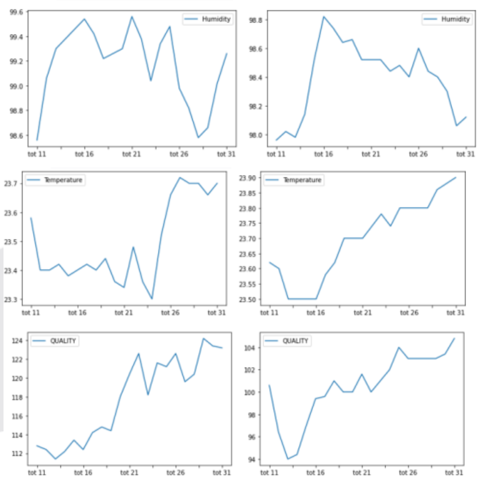
•We can see Table 4.7, at tests 5. We can see the D act as the future reference after the stabilizations were done, there is a slight bit of movement with the servo, and the greater the D, the movement would become noticeable. If the D was too high, it will generate wobble because of the unnecessary movement or overshot by the servo.

•In tests 6, 7, and 8. We are still testing D, if D is applied to pitch and roll, the stabilization against pitch and roll is improved. When a D is applied to the yaw, the drone shakes if there is movement in the yaw and the servo tries to correct it. This happens because, after stabilization for the correction there is little movement, if applied correctly the drone will increase stability, but otherwise, the drone will make unnecessary wobble or overshoot.

•Tests 9, 10, and 11 have the goal to stabilize the drone completely, the P can be set freely in the range of 80 until 100, then I have the functions of trimming the unnecessary movement Integral find 10 until 20 is the acceptable value, and the D has functions to correct movement after stabilizations, the value that I choose is 50, and left out the yaw.

H. Placement of the Sensor.

This test is usually conducted in a closed environment and secured to a fixed place, with minimum motor input to hover, this way if the drone starts to be- have strangely, we can quickly shut down the entire system. After that, we can see the characteristic of the drone itself, and tune the PID to get a better result. The firmware that I use is Betaflight, to ensure the best performance and frequency looping is at 2 kHz because the ESC can not handles frequencies above that.



With this test, the only result difference is in the quality of data reading by almost 20 PPM, and at the humidity and temperature, there is not much of a differ- ence. The measurement test will use configuration 2 as the main way to read the data because configuration 1 is often caught by the propeller if not secured properly, and it has a much slower air velocity.

I. Measurement test

This test was done at Sukapura football field at 8 am, 2 pm, and 6 pm. The Sukapura football field itself is near a public road. The connections between the nodeMCu and the internet were done using a mobile phone hotspot that uses Telkomsel as the provider.

	Humidity (%)	Quality (PPM)	Temperature (Celcius)
test 11	98.56000	112.8	23.58
test 12	99.06000	112.4	23.40
test 13	99.30000	111.4	23.40
test 14	99.38000	112.2	23.42
test 15	99.46000	113.4	23.38
test 16	99.54000	112.4	23.40
test 17	99.42001	114.2	23.42
test 18	99.22001	114.8	23.40
test 19	99.25999	114.4	23.44
test 20	99.30000	118.0	23.36
test 21	99.56001	120.4	23.34
test 22	99.38000	122.6	23.48
test 23	99.04000	118.2	23.36
test 24	99.34000	121.6	23.30
test 25	99.48000	121.2	23.52

	Humidity (%)	Quality (PPM)	Temperature (Celcius)
test 11	94.25999	469.00000	27.92
test 12	94.24001	468.70000	27.90
test 13	94.25999	468.70000	27.90
test 14	94.30000	468.30000	27.87
test 15	94.47778	468.00000	27.80
test 16	94.64000	467.80000	27.78
test 17	94.71000	467.60001	27.77
test 18	94.55000	466.00000	27.74
test 19	94.83000	466.20000	27.70
test 20	94.67999	466.00000	27.72
test 21	94.41001	467.39999	27.70
test 22	94.53999	467.80000	27.70
test 23	94.70000	467.20000	27.69
test 24	94.74001	466.00000	27.60
test 25	94.80000	465.70000	27.70

	Humidity (%)	Quality (PPM)	Temperature (Celcius)
test 10	92.08000	393.0	28.00000
test 11	92.16000	393.0	28.00000
test 12	92.16000	390.6	27.98000
test 13	91.82222	390.0	27.97778
test 14	98.04001	420.4	26.28000
test 15	98.04001	420.4	26.28000
test 16	98.04001	420.4	26.28000
test 17	97.80000	412.2	26.30000
test 18	97.63000	407.6	26.30000
test 19	97.60001	405.8	26.34000
test 20	97.12999	402.7	26.40000
test 21	97.00999	402.8	26.35000
test 22	97.00000	403.0	26.40000
test 23	96.83000	403.0	26.34000
test 24	96.78000	403.0	26.40000

J. Quality of Service

With this test, we may assess the overall performance of a service, which refers to any technology that controls data flow on a network to decrease packet loss, latency, and jitter.

Category	Value
Throughput	2222 kbps
Packet loss	1.4%
Delay	96 ms
Jitter	95 ms

V. CONCLUSIONS

With the tests that have been run previously, we can conclude that:

- Although it's a bit difficult to set the drone to be stable. This proof can be done, with the PID output test and servo configurations test. This drone can be used to take air measurement data, and there is a minimal effect that affects the data gathering process.
- With the unicopter platform, it can be used in many applications, because the overall shape is small compared to conventional drones, it can be used in a populated area without having the fear of becoming a health hazard. The overall cost is fairly inexpensive, so it can be mass produced in high quantities, on a minimum budget.
- Despite a unicopter having many advantages over a quadcopter, most of the firmware still does not support the unicopter design, and it blocks access to features in that firmware.

A. Sugestions

- A dedicated flight firmware to control unicopter drone design, the goal of this research is to reverse the PID of pitch and yaw, so that the unicopter can utilize GPS capabilities. With the new firmware, this drone can use GPS and fly according to the mission planner.
- To achieve swarm-IoT we have to increase the quantities of the drone it- self. This proves to be inexpensive comparing it to conventional quadcopter drones.