UNIVERSITY OF SOUTHERN DENMARK

FACULTY OF ENGINEERING

BEng Mechatronics

Mechatronics Semester Project 4

Ladybug

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1 Background

Possessing the ability of flight and minimising effort and casualties has always been desirable for the utility flight can provide. The first unmanned aircrafts can be dated back to 1849, where Austria seemingly had utilised unmanned air balloons with stuffed explosives to attack Venice. [?] Ever since an unmanned aircraft vehicle (UAV), is one that is flown by technological means or as a pre-programmed flight without pilot control, as defined by the ECAA Transport Agency [?], nowadays called drones, have risen in popularity.

Because of this, UAVs come in a wide range of sizes and weights. UAVs often include multirotor, radio-controlled miniature helicopters, and aeroplanes [?]. As a result, there are several methods to categorize drones. The performance parameters of UAVs, such as weight, wingspan, wing load, flight range, maximum flying altitude, speed, and production cost, are typically used to categorize them [?]. According to how the lift is produced, drones may also be divided into fixed-wing and rotating-wing types. According to the drone code category, the European Aviation Safety Agency (EASA) categorizes unmanned aircraft by weight. The EASA regulations for open categories, or drones without an EASA class designation, are summarized succinctly and simply in Figure ?? [?].

Self-built drones weighing up to 250 g, as described in Figure ??, may be used without registration if the drone is a toy or the drone is not equipped with a camera, the remaining drones must be registered, and the pilot must pass examinations [?]. In this paper, self-built rotary drones with four wings or propellers are the objective, making weight-based classification suitable.

UAS	Operation		Drone operator/pilot		
Max weight	**Subcategory**	**Operational restrictions**	**Drone operator registration**	**Remote pilot competence**	**Remote pilot minimum age**
< 250 g	A1 (can also fly in subcategory A3)	— No flight expected over uninvolved people (if it happens, overflight should be minimised) — No flight over assemblies of people	No, unless camera / sensor on board **and** the drone is not a toy	— No training required	No minimum age
< 500 g			Yes	— Read carefully the user manual — Complete the training and pass the exam defined by your national competent authority or have a 'Proof of completion for online training' for A1/A3 'open' subcategory	16*

Figure 1: Classification and restrictions for non-EASA class drones [?]

When it comes to the state-of-the-art project, PULP-DroNet is a deep learning-powered visual navigation engine that enables autonomous navigation of a pocket-size quadrotor in a previously unseen environment. Thanks to PULP-DroNet the nano-drone can explore the environment, avoiding collisions also with dynamic obstacles, in complete autonomy – no human operator, no ad-hoc external signals, and no remote laptop! This means that all the complex computations are done directly aboard the vehicle and very fast. The visual navigation engine is composed of both a software and a hardware part. [?]

When it comes to the future, the simulated pollination of agricultural plants by means of nano copter can provide collecting and delivering pollen in the mode of automatic control. A design of nano copter for pollination can be made on the basis of innovative modification of existing model by its reprogramming with regard to its flight controller that is to be fully adapted to computer interface. The robotic system is offered specially for artificial pollination in conditions of greenhouses and minor agricultural enterprises. [?]

2 Problem statement

The utility of smaller drones are immense, where it can be used in surveillance, toys and potentially to also be part of a swarm of drones. Although, there are smaller drones existing in the current market, we would like to challenge ourselves to build one ourselves, where certain goals ranging from functionality to budget are listed below.

2.1 Primary goals

- Net maximum weight of the drone is 250 grams. Weight under 250 grams ensures it falls under A1 category in EU regulations. 1
- Flight time of 20 seconds.
- Stress of the structural system should not exceed rupture point. System does not experience fracture.

2.2 Secondary goals

- Flight time of minimum one minute.
- Can land with acceleration less than 9.8 m/s2.
- Stress of the drone system should not exceed the yield point. System does not experience plastic deformation.
- Drone is remote controllable.
- Drone can fly in formation with another identical drone.
- Total production cost of the drone is under 500 DKK (Not including remote controller).
- Drone can play audio.

2.3 Constraints

- Budget for entirety of project is 2000 DKK.
- Time available to finish the project is 4 months.
- Drone should have a minimum hover time of 5 seconds.
- Drone should be fully functional and able to take off again after landing.
- No use of flight controller software or unmanned vehicle Autopilot software Suite, capable of controlling autonomous vehicles.

3 Test Specifications

3.1 Primary goals:

- To test this, the drone will be weighed with a scale of a precision on 0,1 grams.
- In order to test the flight time, a stopwatch will be started from the moment the drone leaves the ground and is stopped as soon as it lands.
- This goal will be the tested trough FEM, ensuring that the chosen material for the drones body, will not rupture.

3.2 Secondary goals

- This will be tested with the same method as primary goals tests point 2.
- This will be tested with a mobile phone, recording the drones landing, using the drones position compared to the timestamp of the video.
- This will be tested with the same goals as primary goals test point 3.
- This will be tested by the possibility of sending wireless signals to the drone, with the drone reacting to those send signals.
- This will be tested purely by ear, listening to the drones output.
- This will be tested by mobile phone video, looking at the drones positions at given timestamps.
- This will be tested trough summing the price for each single part, ensuring that it doesn't exceed 500 DKK.

3.3 Constraints

- This will be done with the same method as the secondary goals test, though ensuring the project cost is over 2000 DKK.
- To evaluate the time constraint point of the project, the goal fullfilments will be evaluated in the end of the project period. In the case that all primary goals are fulfilled, the constraint is succeeded.
- This will be tested with a stopwatch, ensuring that the hover time is atleast 5 seconds.
- This will be tested with making the drone take off right after a landing, making sure that the drone is fully operational at the second take-off.
- This will fulfilled by not employing any of the aforementioned in the drone.

4 Design and manufacturing of quadrotor

5 Control prototyping

article
graphicx
Motor thrust testing:

6 Motor Thrust Testing

The 4th semester project in mechatronics is based on building a VTOL drone. For the drone to take flight, sufficient thrust provided by the propellers attached to the motors of the drone is required. Thus, the following is the report of thrust testing using different motors and propellers. Initial testing setup

6.0.1 Initial Assumptions

The initial idea to test the thrust provided by a certain motor was to create a x-shaped frame where, the motors were connected to their respective corners and a bolt was tightened in the centre as a means of weight. The frame with the motors were then placed on a scale where the motors were facing in the direction of the ceiling, thus meaning that propellers were pushing the air downwards and the setup upwards. The initial weight of the frame was then noted, where after powering up the motors, the weight of the setup would decrease due to the thrust.

6.0.2 Initial Results

The setup of the bolt supporting the frame on the scale was unstable, and because of that the wiring of the motors had also interfered with the weight. Additionally, as the propellers were pushing the frame with a certain thrust force, the air that was being pushed down also had the same force. Therefore, as the frame was very close to the scale, the force by which the setup was being lifted by was also being pushed down by the air on the scale, thus making almost no changes on the scale readings.

6.0.3 Final Assumptions

To fix the problems of the initial test setup, a second version of the x-shaped frame was made where the corners were connected to 3d printed pillars, to make the system more stable. Additionally, instead of placing all the motors at each corner and measuring thrust, only one motor would be placed in the centre instead, as the other motors were identical and thus would produce close to identical thrust. Moreover, the motors would now be placed in a direction opposite to the ceiling as then the air would not be pushed on the scale, but the frame would be. Thus, the additional weight that occurs after the motors are powered on would be equal to the thrust provided by the motor and propeller.

6.0.4 Final Results

The motor used had an operating voltage window of 0-4,2 volts, therefore the motor was tested between 1-4,2 volts incremented with 0,1 volts. Characterizing the motor yielded

Motor thrust 1.jpg

Figure 2: Initial Thrust Setup

Motor thrust 2.jpg

Figure 3: Final Thrust Setup

the following results:

It became clear that the total thrust that could be produced by a single motor was 17.5 grams at 3.7 Volts (The minimum level of the battery). Subtracting the weight of the motor itself, the motor can produce a net thrust of 12.4 grams, and since the drone would be flown in a quad configuration, the total net thrust possible for the four motors were 49.6 grams at lowest voltage. This then set the limits of how heavy the drone could be, and since a general rule of thumb is that the motors need to produce double the needed thrust to lift the drone , it's clear that the remaining components of the drone can weigh 24,8 grams for it to handle optimally. At maximum voltage level of the battery, a motor produces 22.2 grams of thrust, so an excess of 17,1 grams subtracting the motors weight itself. So at maximum voltage level, the drones remaining components can weigh 34.2 grams.

Graph Thrust.jpg

Figure 4: Final Thrust Setup