Assignment 3 – Technical Report

By Group 13.6: Muna, Hansel, Jesica, and Ryan

Part A: problem definition

A1. Problem statement and Project Aims

AIM:

The goal of this project is to produce a remote-controlled drone which will be operated in times of natural disasters. The drone will be used to survey terrains as well as assisting trapped victims by delivering supplies such as emergency kits or medical provisions. A trained person would navigate the drone to inspect the surroundings, however the drone must also be autonomous and make decisions by itself in case of disruptive communication and weather conditions. The drone must also be capable of capturing thermal images to detect life nearby.

Objectives:

A1.1 - To choose a camera which specialises in active thermography to detect life or danger zones

A1.2 - To design algorithms to control the activities of the drone, for example flying in a certain direction, communicate with other drones, send reports and traveling long distances

A1.3 - To develop image processing algorithms that detect the impacted area and sends report back to systems connected to the drone.

A1.4 - To produce an algorithm which will allow the drone to make decisions autonomously when there is a disruption with the signal (Thavasi and Suriyakala, 2012)

A1.5 - To design an algorithm that connects to other nearby drones to send a copy of its data before it loses connection with the person manoeuvring the drone.

A1.6 - To consider materials which will be resistant against rapid weather changes such as intense winds or snow fall as well as to carry load without limiting the potential speed of the drone.

A1.7 - To select an efficient battery that is rechargeable and is long lasting to preserve the battery life of the drone

A2. Feasibility Study, and issues on Ethics and Sustainability

A2.1

Sustainability Issues – Carbon footprint would increase if active thermography were used due to the manufacture of a camera Deane, S, (2022) *Ethical Issues* – Active thermography can capture images which tells us the temperature of the individuals which are sensitive information Deane, S, (2022)

A2.2

Sustainability Issues –Factors such as wind patterns should be considered when deciding the flight path so it can be more efficient

Ethical Issues – As algorithms deal with data that is sensitive it is vital to restrict unauthorised access particularly in areas with confidential information

A2.3

Sustainability Issues - Algorithms need to be optimised for efficiency so the drone's battery life can be extended and thus reduce the overall environmental impact.

Ethical Issues - The goal and extent of the image processing operations should be made known to the people next to the drone surveillance zones to prevent uniformed consent.

A2.4

Sustainability Issues –When creating an autonomous decision-making algorithm, sustainable components should be used instead of raw materials

Ethical Issues – Drones should cause the least amount of harm to the surrounding areas and individuals and safety should be prioritised

A2.5

Sustainability Issues - A colossal amount of energy is used in sharing data with nearby drones

Ethical Issues – There are privacy issues regarding sharing data with neighbouring drones as private information can be exposed

A2.6

Sustainability Issues – Materials with a longer lifespan should be used and ones that can be recycled.

Ethical Issues – manufacturing a drone with a camera that is weather resistant means that materials such as nickel is used which involves mining practices with severe labour conditions

A2.7

Sustainability Issues – Emissions must be decreased as the carbon footprint would increase.

Ethical Issues – manufacturing a camera result in using materials such as cobalt and nickel which can harm ecosystems and local communities.

Feasibility Study:

Marketing Segment:

The demand for drones is significantly increasing with each year and are used for several reasons such as: military and defence, logistics, construction and used for medical care in natural disasters. According to research reports (Anonymous. A ,2023) it is said that the global drone market was values at USD 276881.45 million in 2022 and will reach USD 827697.4 million in 2028, with a CAGR of 20.02% during 2022-2028.

Hence our project is feasible since the drone market is expected to rise over the projected horizon and are used worldwide.

Technical Segment:

Internationally drones have been used medically. For example, in 2016 Rwanda used drones for blood deliveries to healthcare facilities. (Levy, M, 2022) The drones had to be able to carry heavy equipment and still be fast so it can get to destinations rapidly. The components used for this drone can be integrated into theses drones without technical difficulties.

A requirement for these drones is to choose a camera which specialises in active thermography as this will allows to capture images with high resolution and which tells us key information about the injured individuals such as their temperature.

Another requirement for these drones is to use consider materials which will be resistant against rapid weather changes such as heavy winds or snow fall as well as to carry load without limiting the potential speed of the drone. This would allow for the drones to be efficient as it can get to locations quickly without the need to wait for the weather to change.

Moreover, the drones are required to have batteries which charges fast so less time on the ground charging so can quickly fly out and be used to move injured individuals to hospitals for urgent care.

In conclusion, our project is feasible when it comes to the market however will require lots of funds to integrate technical elements. However, once manufactured it will result in lots of profit and will have an impact worldwide.

A.3 User Requirements

A3.1 - Drones must be equipped with a camera that specialises in thermal imaging:

It is necessary for the rescuer to be able to inspect the terrain through live footage, which will assist in determining if the area is safe to travel to. With the aid of thermal imaging, the drone will be able to scan the surrounding area and pick up changes in the wind direction, temperature, and potentially spot fires nearby. Furthermore, the thermal sensors can help to detect life nearby if the rescuer was not able to spot them, through the detection of heat sources. (Hilson, n.d.) Therefore, an uncooled camera with gyroscope is key as it has integrated infrared detection systems for thermal imaging, and it stabilises the camera so that it is not affected by windy conditions.

A3.2 - Drones must have a built-in speaker and microphone:

A speaker is needed so that the rescuers can communicate with the victims and give them instructions and directions. A microphone is also needed so that the victim can use it to report the current situation they are in, the landscape they are facing, report the number of casualties or just communicate with the rescue team.

A3.3 - The technology must have a simple user interface with minimal commands and large screens:

A simple user face is needed for the rescuers who are operating the drone. It should be like a remote which has a large screen displaying the live footage that the drone captures. Buttons that handle the operation of the drone such as the direction of the drone (up, down, forward) or inclining are also needed. Rescuers should have the option to view the screen in normal mode with normal lighting as well as in infrared mode to observe any abnormalities within the environment.

A3.4 - Drones must be able to survey land and analyse it:

Collision detection is a key feature for safe drone navigation and with the help of the camera and depth map-based approaches, a full 3D localisation of the obstacle can be reported and then dealt with. (Carrio et al., 2019) A collision-free path planning means that the drone will be less likely to be damaged by potential threats such as debris, rocks, trees, etc.

A3.5 - Drones must be able to withstand variations in weather conditions:

The drone must be waterproof to protect critical components as it will be equipped with many technologies such as a camera, microphone, and speaker. Drones should also be resistant to wide range of temperatures as both freezing and hot temperatures affect the battery life of the drone resulting to shorter flight time (Rajawat and Gautam, n.d.). Finally, the drone should have enhanced aerodynamics to prevent harm caused by huge wind gusts.

A3.6 - Drones must maintain a network amongst them, pinpoint locations and give accurate data back to the operators:

It is necessary for rescuers to know the location of the impact; therefore, drones must be equipped with a GPS so that it can accurately track the location they are flying. Furthermore, drones must be able to communicate with other drones in a mesh network so that information can be relayed to each other. (Ganesh, Gopalasamy and B, 2021) For example, in case of signal distortion, drones must be able to connect to other drones nearby and send them location data. These can be then passed on to the first respondents’ remote controller which also connects to the drone.

A3.7 - Drones must be wired to make decisions autonomously:

Drones must be able to avoid critical areas of the landscape such as dense forests, to reduce the risk of disasters on the drone. Therefore, in case of disconnections, it is necessary to increase the level of intelligence of a drone by allowing for anonymous flight decision making. It is important that a drone can navigate by itself as it improves the safety of performing reconnaissance and search and rescue operations on it. (Zhilenkov and Epifantsev, 2018)

A3.8 - Drones must be functional for a long time (long battery power):

For functionality to be long lasting, a rechargeable battery with a long battery life is needed so that the drone can fly for long distances. Generally, the optimal choice of use is the polymer lithium battery as it poses the ability to recharge and has a high power density (has a greater battery life compared to its size). (Ahirwar et al., 2019)

A3.9 - Drones must be able to carry at least 5kg for supplies

Generally, it is noted that drones made for search and rescue can carry up to 17kg of equipment such as AED, insulin, and emergency food using a rope suspension method under the manoeuvring of a trained pilot. However, this only applies during favourable weather conditions. (Daud et al., 2022) Therefore, the minimum carrying capacity of the drone should be 5kg as it allows for first aid kits to be carried, as well as defibrillators (which can weigh more than 2.5kg). (St John Ambulance, n.d)

A.4 Constraints

A4.1 - Intense winds, heavy rain, or storms can all have an influence on drone performance and safety, placing flight controllers under additional strain. There are also altitude constraints (less than 400 feet above ground) that make controlling a drone difficult because airspace 500 feet and above is reserved for manned aircraft activities. (Institute, P., 2021)

A4.2 - The amount of weight that drones can carry limits their payload capacity for equipment, sensors, and other devices. Furthermore, if the drone is overweight, the time required for rescue activities is increased as the drone's flight speed may be constrained.

A4.3 - Drone deployment may be hampered by legal and regulatory limits in certain places or during specific circumstances (crossing country borders). Obtaining the appropriate approvals and adhering to local restrictions may take time, impeding the usage of drones in rescue operations. People may also object to being recorded without their consent. (Teare, 2016)

A4.4 - Drones in rescue operations require trained operators to operate effectively. Providing comprehensive training for drone operators and emergency responders, on the other hand, can be laborious and resource intensive. In addition to this drone require routine maintenance to guarantee good operation. Furthermore, repairs or replacements may be required as a result of accidents, inclement weather, or normal wear and tear.

A4.5 - A drone's weak design could lead to security issues such as unauthorised access to the drone's systems which could lead to sabotaging of rescue operations. (Krishnan and Murugappan, 2023)

Part B: System Requirements

<u>B1 inputs and outputs</u>

B1.1 - Inputs to the drone are delivered through a remote-control system, where skilled flight controllers will control the drones to deliver the cargo, however in case of a disruption in signal there will be an input delivered to the drone to be autonomous by an algorithm detecting an absence of manual control.

B1.2 - The DJI Mavic 2 Enterprise Advance, a drone specialised for rescue operations will be used. The inputs would be routed through a DJI drone's remote-control system using a combination of radio frequency (RF) communication and OcuSync 2.0 technology. (DJI., n.d.).

B1.3 - Drones must constantly output their position data while being controlled, and in the event of signal distortion, they must output their data to nearby drones. The DJI Mavic 2 Enterprise can use AirSense to gain input of other nearby drones and relay the required data. (DJI., n.d.).

B1.4 - High resolution thermal and visual cameras will be mounted and will be constantly outputting JPEG format images to the specialised flight controller allowing him to navigate through various airspaces. (DJI., n.d.).

B1.5 - The integrated thermal sensors would output the various objects in its radius which would help identify the objects in extreme conditions as it supports techniques such as spot metering and area measurement. (DJI, 2023).

B1.6 - A microphone would take the voice input from the flight controller and output the voice through a speaker on the drone to the rescue victim to help communicate the situation.

B1.7 - The drone can make use of the input gained from the High resolution thermal and visual cameras to create 2D maps, 3D topographic models, or thermal maps to help rescue operations.

<u>B2 Operation requirements</u>

B2.1 - There are 4 operational modes: Manual Navigation, Automatic Navigation, Communication, and Delivery.

B2.2 - Manual Navigation Mode: The drone is piloted via a remote control. The direction, rotation, and speed of the drone are the main navigational functions being controlled. To assist the pilot, the drone will relay positional data alongside thermal, and non-thermal images. This data will then be used to create 2D and 3D maps. This mode can override automatic navigation mode.

B2.3 - Automatic Navigation Mode: If no signal is received for a predetermined amount of time, the drone enters this mode. Its navigation is defined by an onboard algorithm, where it will aim to find trapped victims in the affected zone.

B2.4 - Communication Mode: The drone will maintain its position while broadcasting communications from the pilot. The drone will attempt to counteract any unexpected movement (such as intense winds) by using the positional data gathered from its sensors.

B2.5 - Delivery Mode: The drone lowers itself above a trapped victim and releases a stored care package.

B3 Functional requirements

B3.1 - Navigation Function: The direction, rotation, and speed of the drone must be able to be controlled by a pilot via remote control or a built-in algorithm (depending on the navigation mode). The drone must be able to rotate in all 360 degrees as well as move in all cardinal directions at a speed of 50 kph (DJI, 2023).

B3.2 - Data Transmission Function: The drone must be able to wirelessly transmit high resolution imagery and positional data in real time. This data can be processed to create 2D and 3D maps.

B3.3 - Communication Function: The drone must be able to receive and broadcast the pilots voice input via its speakers.

B3.4 - Delivery Function: The drone must have a small container capable of storing supplies weighing up to 5kg. This container must be able to be opened at the pilot’s request or when the decision-making algorithm decides it needs to be.

B4 Non-Functional

B4.1 - The drone must be capable of rotating in all directions and reaching speeds up to 50kph.

B4.2 - The drone should be equipped with a high-quality camera that can capture images that are high resolution, and the drone should be able to modify its transmission rate in response to changes in signal strength. (Yerra, T., 2022)

B4.3 - The drone should have a voice recognition system which can recognise and understand orders form the pilot and it should have speakers which can project the pilots voice so can be heard clearly.

B4.4 - To ensure that the supplies are kept safe and undamaged during transit, the drone must come equipped with a secure container.

PART C: Key Design Challenges

C1.1 - Selecting Weather Resisting Material without compromising drone's performance:

To ensure that the drone can withstand harsh weather, identifying and implementing materials that can withstand various weather conditions, including heavy winds, rain, and snow, without compromising the drone's performance is critical, and the challenge lies in balancing durability, weight, and aerodynamics to ensure that the package safely reaches its destination. Equipping drones with weather monitoring devices such as humidity sensors and wind gauges will aid in the collection of environmental data which will help flight controllers navigate the drones away from dangers. (Asmal, E., 2021)

Lightweight materials with high durability, such as carbon-fibre composites or aluminium will be employed in the frame design when considering the weather. (Jo, D. and Kwon, Y., 2017)

Carbon fibre is more expensive, but it is an investment worth making due to its low thermal expansion. As a result, its shape, area, volume, or density do not alter much in response to temperature fluctuations. Aluminium, on the other hand, has twice the weight of carbon fibre and is corrosion resistant, but it is considerably cheaper. Carbon Fiber Gear. (2023).

The design would finally be chosen based on efficiency vs. cost, and the drone's performance would be evaluated under various weather situations before use.

C1.2 - Thermal imaging:

The use of the technology requires powerful data gathering programs which trains machine learning systems to detect humans from other heat traces. (Burke et al., 2019) This is both time consuming and costly as large amount of data needs to be gathered to develop the systems. Furthermore, human involvement is also needed, where trained individuals must also detect and analyse what the heat sources are, which can lead to fatigue for the first responders as they must constantly look at the footage reported from the drone. (Burke et al., 2019)

There are also further issues with deploying thermal cameras, for example, depending on the camera being used, the frame rate can decrease the quality of the images as it may not capture the all the data needed. (Abdelrahman, n.d.) This can lead to significant loss in data which can reduce the quality of search and rescue operations. It also contributes to the decrease of the sharpness of the images rendered. (Abdelrahman, n.d.)

Therefore, in order to overcome this issue, more time is needed for research and data gathering to create vast and extensive data sets for thermal imaging. An appropriate thermographic camera can also contribute to the success of thermal imaging, preferably, a camera that is used in military operations for example.

C1.3 - Drone battery power and tracking location:

As this drone requires quick deployment in scenarios were injured individuals need to be taken to hospitals for urgent care, it charges fast so less time on the ground and can quickly fly out so can be used during natural disasters. The more time the battery is used the performance and battery health plateaus, so it is vital to have regular replacements of the battery. (Lesley, J., 2021) For these drones to be useful during natural disasters it is required for the GPS system to have features such as being long lasting and having a strong signal. However, as weather conditions can affect the signal it is vital to make weather-resistant GPS systems and to have backup systems which would always ensure reliable location data as well as alternative tracking methods. (Anonymous, A., 2023)

C1.4 - Choosing an Effective Automatic Navigation Algorithm:

As this drone is intended to be used during natural disasters, it is likely to lose signal from the pilot. To keep the drone operational, a machine learning algorithm that can take over its own navigation must be chosen.

A major constraint to this is that machine learning algorithms are overly complex. This means running such an algorithm would require a great deal of processing power, which in turn requires plenty of energy, and therefore a bigger battery. The trade-off between algorithm complexity and cost/weight will need to be considered.

Another constraint with machine learning algorithms is their reliability. Hidden biases and poor training can lead to undesirable outputs. For example, if the algorithm is not trained to deal with sensor limitations that arise from the weather conditions, it could lead to the drone getting lost or colliding with other objects (Kurlekar, 2019). In life-threatening situations such as natural disasters, this is not an option. The algorithm will need to be thoroughly tested to ensure the drone can always carry out its function successfully, to guarantee victim safety.

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MEMBER NAMES & ROLES TAKEN ON IN LAB ACTIVITIES

Member	Lab 5	Lab 6	Lab 7	Lab 8
Jesica	Manager	Questioner	Scribe	Questioner
Hansel	Scribe	Manager	Questioner	Manager
Muna	Questioner	Scribe	Manager	Scribe
Ryan	Questioner	Scribe	Manager	Scribe

TEAM CONTRIBUTION STATEMENT

Evaluation Criteria	Muna	Jesica	Hansel	Ryan
Attends group meetings regularly and arrives on time	4	4	3	2
Contributes meaningfully to group discussions.	4	4	4	4
Completes group assignments on time.	3	2	4	4
Prepares work in a quality manner.	3	3	4	4
Demonstrates a cooperative and supportive attitude.	4	4	4	4

Contributes significantly to the success of the project.	4	4	4	4
TOTAL	22	21	23	22

Feedback on team dynamics

How effectively did your group work?	What did you learn about working in a group from this project that you will carry into your next group experience?
Our group work was effective as we had effective communication and were able to have meaningful group discussions about the assignment and split off the tasks resulting in each member cooperating.	From this project I learned the importance of clear communication and that it is vital to regularly update the group on each person's progress. I will carry these lessons into my next group, emphasizing effective communication which will help to result in the success of the project.

	Full Name	**Signature**
1	Jesica Uddin	Jesica Uddin
2	Ryan Thomas McCallum Ali Tait	Ryan Thomas McCallum Ali Tait
3	Muna Mohamed	Muna Mohamed
4	Hansel Natividade Rodrigues	Hansel Natividade Rodrigues

DECLARATION:

We, the team members, have discussed and agreed with the ratings and comments given above.