DroneAI, Human Interacting with Drones Search and Rescue (SAR) Drone

Project Proposal including background research summary (Literature Review)

Chong Jin Yang, Sam Zachary Chee Hao Yuan, Kang Zheng Rong
Monash University, Malaysia
{jcho0134, sche0273, zkan0012}@student.monash.edu

Word Count: 7974

I. Table of content

II. Introduction

In response to the rising interest in hiking activities and the associated need for more efficient search and rescue (SAR) operations, this project is designed to address these challenges through a comprehensive approach. The course of this project will be structured into two distinct segments. In the initial stage, our research will focus on the implementation of real-time Unmanned Aerial Vehicles (UAVs) and the integration of real-time pose-estimation models for the purpose of human detection. This will enable the identification of individuals and the analysis of hand rescue gestures, which can be used to assess the safety and condition of hikers. Leveraging OpenCV's human detection capabilities, we will employ biometric communication, with a specific focus on body recognition (Liu & Szirányi, 2021). Upon detection of the presence of one or more individuals, the drone will be directed to initiate the gesture recognition phase. During this phase, the identified human(s) will briefly communicate their need for assistance or indicate that they do not require any, using the on-board camera of the unmanned aerial vehicle (UAV). The two primary gestures of significance are the dynamic Attention and Cancel gestures, which symbolise the functions of setting and resetting (Liu & Szirányi, 2021). Upon detection of the "Attention" rescue gesture, the drone will progressively advance towards the individuals, employing an enhanced resolution for the purpose of hand gesture recognition.

In the second stage of the project, we will introduce the context of optimal route detection. Recognizing that the successful retrieval of individuals in wilderness settings is hampered by factors such as adverse network conditions, inclement weather and road conditions, our approach includes a methodology wherein multispectral images obtained from satellites and UAV are utilised for the purpose of road extraction and road condition detection (Liu & Szirányi, 2021). This additional layer of technology will enable rescuers to ascertain the most suitable approach for effectively extracting individuals requiring assistance.

This combined approach, integrating real-time human detection, gesture recognition, and optimal route detection, aims to revolutionise SAR missions by significantly improving response times and the overall effectiveness of rescue operations

III. Literature Review

3.1 Background

According to statistical data provided by Statista (2021), it illustrates an inspiring upward trend in the popularity of hiking. This resurgence, particularly noticeable amid pandemic-led restrictions, signals that many have been reigniting their passion for the great outdoors, finding solace and freedom in nature's embrace through activities like hiking. However, this increase comes with its own set of challenges. Annually, there are approximately 2000 instances where the thrill of adventure might take an unexpected turn, leaving hikers disoriented and misplaced. These situations often call for the activation of Search and Rescue (SAR) operations, an invaluable contingency that has proven to be a lifeline for many. While the figure might not seem staggering at first glance, it's a gentle reminder of the unpredictability of nature and the importance of preparedness. More concerning, though, is the realisation that this data captures just a fraction of the true scenario, as not all cases of lost hikers make it to the official records.This reality doesn't diminish the allure of hiking but underscores the need for awareness, caution, and respect for the wilderness that adventurers seek to explore. The growing interest in wilderness exploration poses a new challenge for Search and Rescue (SAR) protocols. Historically, these missions have been predominantly dependent on the physical capabilities and experiential expertise of human operators, enabling them to navigate challenging terrains and situations. While the existing methodologies have historically been tested, there have been cases where rescue teams have faced limits. This raises concerns about the scalability and flexibility of these methodologies, especially considering the significant increase of outdoor enthusiasts. As a result, it is imperative to adopt an innovative approach that incorporates Unmanned Aerial Vehicles (UAVs) within Search and Rescue (SAR) operations.

The implementation of this modernised transition has the potential to revolutionise efficiency and responsiveness, while simultaneously mitigating operational risks that are inherent in models that heavily rely on human involvement. The correlation between efficiency in SAR operation and survival rates emphasises the criticality of time . Traditional SAR operations are encountering difficulties in terms of time delays caused by demanding geographical factors, poor weather conditions, and a shortage of resources. The proposed UAV system seeks to address these difficulties by using its capacity to be rapidly deployed, hence significantly decreasing response times. The timeliness of SAR reaction has a crucial role in determining whether a mission transitions from a recovery operation to a rescue operation, highlighting the significant impact of the project on the survival probabilities.

One frequently disregarded challenge in wilderness rescue operations is the presence of communication barriers. The present dependence on technological devices for the purpose of indicating distress is seen unfeasible in remote areas, hence leading to a significant delay in rescue efforts. The utilisation of biometric communication in the proposed system, particularly through the detection of human presence and recognition of body and hand gestures, adds a groundbreaking non-verbal communication layer. This particular method of communication, which is universally applicable, offers the advantage of prompt and explicit feedback, thereby surmounting conventional obstacles arising from differences in language and technology.

In fact, efficiency is not just about faster response times but also about identifying the most optimal route to reach the distressed individuals. An optimal route not only minimises the time it takes for SAR teams to reach the location but also ensures their safety. It can help rescue operators navigate challenging terrains more effectively. The use of UAVs in SAR operations can facilitate the mapping of optimal routes and significantly ease the tasks of rescue operators. This not only improves their safety but also enhances the likelihood of successfully locating and rescuing individuals in distress.

3.2 Project Rationale

3.2.1 Enhancing Efficiency in procurement of SAR operations

The crucial significance of time in search and rescue (SAR) operations is a fundamental aspect of the logic for our approach. The conventional approach, which relies on flogs of ground search teams and piloted aircraft, has an array of limitations. Naturally, these obstacles ultimately result in adverse delays or possibly the abandoning of the operation. In contrast, UAVs provide promptness and accuracy, unhindered by grounded barriers, consequently altering the time-sensitive nature of critical situations. The deployment of this strategy circumvents traditional mobilisation delays, thereby optimising the critical time frame that frequently determines the outcome between survival and mortality.

3.2.2 Mitigating Risk of SAR Operators and Operational Scalability

The physical risks undertaken by SAR operators can't be understated, as these teams frequently navigate over harsh terrains and adverse environmental circumstances. The purpose of deploying these drones is to reduce these risks and prioritise the allocation of human resources for tasks that require human intellectual capabilities and decision-making. Moreover, there is a clear correlation between the rise in wilderness activities and the corresponding increase in accidents, thus emphasising the necessity for scalable solutions. Drones have the capability of remote operation, making them a flexible resource that can be easily scaled. The quantity of deployed drones can be modified to meet operational requirements without the need for significant resource recalibration. This stands in contrast to human operators, whose mobilisation entails intricate logistical considerations.

3.2.3 Integration between Cost efficiency and utilisation of advanced technological software

The extent to which SAR efforts can be carried is frequently determined by financial constraints. The project's scope emphasises the need of cost reduction as a compelling justification, as drones eliminate many expenses involved with conventional search and rescue approaches, such as the need for costly machinery, extensive human training, and transportation. Furthermore, the incorporation of contemporary frameworks such as computer vision and real-time pose estimation computational algorithms amplifies the efficacy of drones beyond their fundamental aerial capabilities. The integration of human gesture interpretation into unmanned aerial vehicles (UAVs) enables a form of non-verbal human-machine connection. Consequently, this integration eliminates the necessity for rescuers to continually rely on cell phone signals for communication.

3.2.3 Ease of navigation

The integration of Unmanned Aerial Vehicles (UAVs) into Search and Rescue (SAR) operations represents a paradigm shift in how navigation is approached, diverging significantly from traditional methods. Traditional SAR operations have historically relied on human expertise and experience to navigate complex and rugged landscapes. While these methods have been invaluable, they are inherently limited by the human capacity to process vast amounts of data to identify the most efficient routes. Optimal route planning, on the other hand, leverages advanced algorithms and geospatial data to make informed, data-driven decisions. Besides, optimal route planning is dynamic and allows for real-time adjustments based on changing conditions. In the wilderness, conditions may change rapidly, and traditional methods may not adapt swiftly. With optimal route planning, we will be able to enhance rescuers safety, have better response times to reach distressed individuals which will significantly increase the chances of a successful rescue.In conclusion, the implementation of optimal route planning in SAR operations represents a fundamental shift from traditional methods. It offers data-driven, objective, and adaptive navigation, resulting in faster response times, enhanced safety, and efficient resource allocation.

3.2.5 The need for user (operator) interaction software

Incorporating a user interaction software, such as a dedicated mobile app, into SAR operations is an essential component of modernising and optimising the rescue process. SAR operations often require effective real-time communication between operators and the UAVs. Thus, a user interaction software facilitates instantaneous updates and instructions from operators to the UAVs, ensuring that they can swiftly adapt to changing circumstances and directives, thereby enhancing operational responsiveness. Moreover, it also provides a platform for operators to receive feedback from UAVs, including high-resolution images and video feeds, enabling them to make informed decisions promptly. Besides, user interaction software can be continually improved based on user feedback. Regular updates and enhancements to the software can be tailored to address the specific needs and challenges faced by operators during SAR operations. Integrating interaction software into SAR operations is essential for enhancing the effectiveness, safety, and responsiveness of modern Search and Rescue missions.

3.3 Related Research

3.3.1 Primary framework for Human UAV designed to support the recognition of body and hand gestures, as well as human detection

The detection of humans and the recognition of body and hand motions were initially accomplished by employing the Guided Transformer I3D (GT-I3D) architecture. The framework described in this study utilises a computer vision algorithm incorporating an integrated Guided Transformer. The algorithm consists of a fisheye stream, which is trained to rectify the distorted fisheye input for the purpose of action recognition. This rectification process is achieved through the use of integrated Guided Transformer Modules. Additionally, a pre-trained RGB stream, which remains fixed throughout the training process, is employed to guide the training of the GT-Modules. The GT-Module is a comprehensive module that employs a 3D localization network to acquire extensive transformation parameters for the original fisheye features. The grid generator is employed to calculate the non-linear transformation by utilising the transformation parameters. On the other hand, the sampler is utilised to deform the distorted fisheye features to the ultimate converted feature, relying on the non-linear transformation. The modified features that were produced are subsequently compared with the flat RGB features in order to impose constraints on the GT-Module, hence enhancing its ability to learn more effective transformations. The transformer models are guided by the use of [1]KL (Kullback-Leibler) divergence, using the associated flat RGB characteristics.

$$L_G = -\sum_{j=1}^{J} f_j^R \cdot (\log f_j^T - \log f_j^R)$$

Where J is the number of inserted GT-modules, i.e. the number of max pooling layers in I3D. In addition, a standard classification loss is used to update the fisheye stream by comparing the predicted score and the class label. The overall objective function used to update the GT-I3D framework is L=LG + LC, where [2]LG is the KL diverge constraint and [3]LC is the classification loss.

[1] **Kullback- Leibler divergence**, measures the distance between one data to another distributions, showing how different the two distributions are from each other.
[2] **LG**, The KL divergence constraint is employed in order to guide each transformer. This is achieved by imposing the KL divergence constraint between the transformed features and the flat RGB features.
[3] **LC**, The classification loss is employed to update the fisheye stream by evaluating the discrepancy between the predicted score and the assigned class label. The GT-I3D framework is updated using the usual classification loss, which involves comparing the projected score with the corresponding class label.

3.3.2 Optimal Route planning

The optimization of Search and Rescue (SAR) operations in challenging wilderness environments hinges upon a comprehensive approach that maximises efficiency, minimises risks, and enhances the prospects of successful outcomes. The key element of this approach is the development of a robust framework for optimal route planning that integrates cutting-edge technologies and methodologies.

The framework described in this study state that the core of this framework is the careful selection of path planning algorithms which is the enhanced version of the A* (A-Star) algorithm customised for SAR missions. This algorithm merges geographical intricacies with real-time adaptability, dynamically responding to inputs such as instantaneous terrain assessments and real-time weather updates to determine and adjust optimal routes for rescuers as they approach the location of a casualty identified by Unmanned Aerial Vehicles (UAVs) during missions.

To ensure the highest degree of route precision, the framework seamlessly incorporates Geographic Information Systems (GIS), harnessing high-resolution maps, satellite imagery, and up-to-the-minute topographical data. This dynamic data integration, coupled with real-time path planning algorithms, upholds an unprecedented level of geographic accuracy, aiding rescuers in reaching their destinations swiftly and safely. Besides, considering the profound influence of weather and environmental conditions on route planning, the system integrates advanced weather and environmental sensors. These sensors deliver continuous updates on critical variables like wind speed, temperature, humidity, visibility, and air quality. This empowers the system to make real-time route adjustments in response to sudden weather changes, thus enhancing mission safety and efficiency for rescuers.

Machine learning algorithms embedded within the framework are engineered to examine historical SAR data and current conditions, offering insight into potential hazards and obstacles. By evaluating historical search patterns, wildlife activity, weather trends, and other mission-critical variables, the system can proactively guide rescuers around potential danger zones, ensuring that chosen routes have minimal risk and maximal mission success likelihood.

Acknowledging the irreplaceable value of human expertise, the system also accommodates SAR operator input and overrides, thereby synergizing algorithmic calculations with human judgement. This approach allows human operators to contribute their collective intelligence and experience, making real-time adjustments when necessary, optimising the routes for rescuers.

The dynamic nature of SAR operations requires continuous route optimization. Thus, the framework leverages dynamic optimization algorithms that adapt routes based on real-time data and operator feedback, ensuring the system's ability to re-route Rescuers during missions in response to unforeseen developments.

3.4 Synthesis of relevant published work and recent advances of its implications

3.4.1 Advances of GT-I3D's for Human detection and pose estimation

Researchers proposed a methodology titled "UAV-human: A large benchmark for human behaviour understanding with UAV" that introduces a new standard for analysing human behaviour using UAVs. The benchmark comprises an extensive dataset of prevalent human actions acquired by UAVs. Additionally, it provides a collection of evaluation metrics and baseline models for multiple tasks, encompassing human detection, tracking, action recognition, and gesture recognition. The primary objective of the proposed benchmark is to enhance research in the domain of human behaviour comprehension using Unmanned Aerial Vehicles (UAVs) and to foster the advancement of new algorithms and methodologies for this purpose. In order to evaluate the effectiveness of their approach, the researchers have employed a variety of sensors, including cameras, GPS, and LiDar, to successfully navigate challenging environments. The application of biometric communication through body and hand action gestures facilitates the identification and comprehension of human body and hand movements. The recognition of body and hand action gestures is accomplished by employing a computer vision algorithm that utilises integrated Guided Transformer Modules (GT-Modules, GR-I3D) for the purpose of rectifying distorted fisheye in order to facilitate action recognition. As previously stated, these advancements have been made possible due to the accessibility of extensive datasets that have been gathered. The application of deep learning methodologies, specifically Convolutional Neural Networks (CNNs) and Recurrent Networks (RNNs), has played a significant role in the progress made towards generating highly accurate outcomes. The employed methodology has demonstrated efficacy in managing the intricate and ever-changing characteristics of human actions recorded by UAVs.

The inherent unpredictability of nature renders the fisheye rectification feature of the GT-I3D module extremely advantageous. The utilisation of a fisheye camera on the drone will enable the collection of a broad visual perspective, which is of utmost importance in facilitating rapid and comprehensive search operations. The rectification mechanism of the GT-I3D effectively mitigates the distortions commonly associated with fisheye lenses, preserving the precision of human detection even when the camera captures a wide angle image. The rectification of this error is of utmost importance in order to prevent the possibility of disregarding prospective observations of hikers who are reported missing, as a result of the presence of lens distortion. The GT-I3D model demonstrates the capacity to identify body and hand motions, as exemplified in scenarios such as locating a missing hiker. In the event that an individual seeks assistance, they have the ability to engage in communication with the rescue team through the utilisation of standardised gestures that have been specifically trained and programmed into the model. Further elaboration on this matter will be provided thereafter. As an illustration, a certain manual motion may serve as an indication that an individual is experiencing physical harm and needs urgent medical assistance. The drone will transmit the data instantaneously to the SAR team, enabling a prompt and well-informed reaction.

3.5 Contributions and Shortcomings of previously proposed implementations

3.5.1 Contributions and Shortcomings of the GT-I3D module

The application of the GT-I3D module in the analysis of human behaviour during drone operations offers significant advancements in emergency response efforts. The GT-I3D module had been found to greatly boost the ability to detect humans in remote areas, which is relevant to the proposed research on search and rescue drones. The enhanced accuracy of this technology not only facilitates the prompt location of those who are lost, thereby potentially minimising their vulnerability to adverse environmental conditions, but also enhances the likelihood of survival for hikers who have gone missing. Furthermore, the inclusion of the model's body and gesture recognition capability facilitates instantaneous communication between rescuers and hikers who have been located. This technological development holds significant value, especially in situations where hikers who are lost and injured can benefit from the deployment of drones. These drones enable hikers to communicate crucial information about their location by utilising straightforward visual signals. In addition, the integration of the GT-I3D module within the drone has the potential to enhance the allocation of search and rescue (SAR) resources. The use of precise coordinates for search sites by these UAVs eliminates the necessity of deploying substantial rescue teams to traverse vast areas in remote and untamed regions. Historically, this has constituted a resource-intensive component of SAR operations. This strategic advancement not only optimises the utilisation of resources but also mitigates potential risks for rescue personnel who navigate hazardous settings. The research proposed is an important milestone for future technical advancements in emergency response protocols. This includes areas such as navigating through natural disasters to locate missing individuals and monitoring hazardous environments. The implications of the project surpass the immediate boundaries of the research. Future implementations have the potential to expand upon the existing framework by incorporating night vision capabilities, establishing satellite communication for real-time weather and road condition updates, and developing coordinated operations involving multiple drones.

Although the GT-I3D module offers advantages in the context of SAR operations, it is essential to acknowledge its limitations. The usefulness of drones and the accuracy of human detection and gesture recognition might be negatively affected by unpredictable weather conditions, such as fog, rain, or wind. Furthermore, drones are limited by their battery life; when there is a need for extended searches in distant locations at bigger sizes, strategic planning for effective coverage within operational restrictions is required. Another issue arises regarding the reliability of the system. The inherent lack of transparency in artificial intelligence systems, such as GT-I3D, poses potential dangers associated with an excessive dependence on technology, hence diminishing the significance of human judgement. The reliance on this dependency presents challenges, particularly when the model encounters unexpected situations. For example, it may mistakenly classify a human as a tree, resulting in a potential false positive outcome. The efficacy of the model is contingent upon the quality of the data it has been trained on. The inherent unpredictability of habitats requires a broad collection of data that encompasses diverse ecological settings and scenarios. Insufficient data diversity undermines the accuracy of the system, hence elevating the risk of false positives that may jeopardise the effectiveness of rescue missions.

3.5.2 Contributions and shortcomings of optimal route planning

The previously proposed implementations of optimal path planning have made significant contributions to the search and rescue operations. They have focused on enhancing efficiency by introducing algorithms that can swiftly calculate optimal routes which is a critical factor in the success of search and rescue operations. Besides, real-time adaptability has also been a central theme in these contributions, allowing path planning algorithms to dynamically respond to changing conditions, such as real-time weather updates and unexpected terrain changes in order to ensure the safety of both rescuers and those in need of assistance.

Moreover, the integration of Geographic Information Systems (GIS) has improved the precision of path planning. By incorporating high-resolution maps and satellite imagery, these systems have provided a valuable boost to geographic accuracy. Some implementations utilised advanced sensors that offer real-time data on weather conditions, environmental variables, and more. This integration of these sensors empowers the system to make instant route adjustments based on actual conditions, thereby increasing the efficiency and safety of missions.

However, these implementations also come with shortcomings. Some of these systems can be overly complex, posing challenges in terms of implementation and maintenance. The complexity of these solutions may result in a steep learning curve and potential operational difficulties. In some cases, path planning systems may demand substantial computational resources, which can be a limitation in resource-constrained environments. In fact, the cost of integrating these sensors is notably high. Thus, not all SAR teams are able to afford it.

Additionally, a few solutions may struggle to adapt to rapidly changing conditions, impacting their ability to ensure the safety of rescuers and those in need of help. There is also the risk of over-reliance on technology in certain implementations, potentially diminishing the role of human operators and their judgement, which can limit the system's adaptability.

Moreover, path planning systems are designed for specific environments or use cases. Thus, it might face challenges when scaling to different terrains or operational scenarios. Scalability is vital in search and rescue due to the diverse and unpredictable nature of wilderness environments. In summary, recognizing both the contributions and shortcomings of previous implementations is essential for developing a path planning system that optimally addresses the unique needs of search and rescue missions in challenging wilderness settings. By learning from past implementations and addressing their limitations, we can create a solution that maximises efficiency, minimises risks, and increases the chances of successful outcomes.

IV. Project Management

4.1 Project Overview

4.1.1 Breakdown of Search and Rescue Drone major milestones

The proposal comprises two crucial stages, each of which is critical to improving the effectiveness of SAR operations using computer vision powered drones. The first stage focuses on the deployment of unmanned aerial vehicles (UAVs) equipped with real-time pose estimation methods. These pose estimate algorithms are critical for person detection, allowing UAVs to identify people stranded in remote regions and examine their body and hand motions to assess their status. Notably, this level requires the usage of OpenCV's biometric communication features, such as body and hand recognition. When the on-board camera recognises people based on their body gestures, the hand gesture recognition phase begins, which translates their requests for assistance. This phase is dependent on comprehending two dynamic gestures, "Attention" and "Cancel," which drive the UAVs subsequent activities. The intricacy of wilderness rescue is frequently hampered by natural variables such as poor network access and extreme weather conditions. To overcome this issue, the second stage of the project employs a complex technique based on multispectral/pre-downloaded satellite images. This technique is critical for gathering road data and assessing conditions, allowing rescuers to plan the safest and most efficient paths to the individual in need of assistance.

4.2 Project Scope

4.2.1 Project Scope

The project's scope is defined by its requirements, definitions, and work breakdown structures. Clear project requirements are crucial to guide the team and prevent scope creep. Tools like the requirement traceability matrix in **Appendix B** are used to highlight tasks that fulfil both functional and non-functional requirements. The project's scope specifically involves tasks related to creating a drone with basic AI human recognition, for example, training and integrating AI models into drones. Tasks such as building a user data storage database are considered out of scope as a rescue drone usually operates in the wilderness, which lacks stable connection to any databases. Certain tasks such as creating a user interface is within the scope of the project but with relatively low priority as the target audience of a rescue drone is professionals.

4.2.2 Product Characteristics and Requirements, functional and non-functional requirements

In order to establish the characteristics and requirements of the product, it is important to analyse and categorise the functional and non-functional attributes. Functionally, The UAV is anticipated to contain a highly sophisticated platform capable of effectively detecting humans using real-time pose estimation algorithms. This capability facilitates precise identification of individuals in remote regions. Moreover, it is imperative to promptly activate a mode for gesture recognition upon the detection of a hiker's presence. The proposed hand gesture recognition mode aims to read dynamic gestures and subsequently activate the aid of rescue operators. This is enhanced by the inclusion of an interactive library of UAV-human gestures, which contributes to the establishment of a comprehensive database for the recognition of various human actions. The UAV offers a distinction between the recognition of body gestures across long distances and the analysis of hand gestures in real-time. This distinction enables rescue operators to accurately interpret and respond to requests for assistance from hikers.The analysis of satellite-derived multispectral images by the UAV is of equal importance, as it aids in the provision of real-time data for the formulation of a rescue route.

The reliability of the UAV holds significant importance in relation to non-functional requirements. Ensuring a consistency of UAVs functionality is crucial in various wilderness environments. Additionally, the assessment of the efficacy of UAV is of paramount importance, as it necessitates striking a delicate balance between prompt reaction durations and battery preservation, thereby guaranteeing an extended and more efficient undertaking of rescue operations. The system's scalable architecture should also be taken into consideration, as it is responsible for future improvements, particularly in increasing the UAV-Human activities library. As the developers of this product, it is imperative for us to ensure the provision of a system interface that is user-friendly and to reduce the complexity of interactions with hikers lost in the wilderness. Furthermore, the sustainability of our products is an essential factor for rescue operators, as it enables them to conveniently access maintenance schedules, consequently ensuring the long-term reliability of the UAV as an indispensable instrument for their operations.

4.2.3 Product user acceptance criteria

The efficacy of the UAV in the context of search and rescue operations is measured against a set of user acceptability criteria. Among these standards lies the precision of the hand gesture recognition system, such that it provides a stellar accuracy rate, ensuring the unerring interpretation of crucial hand signals. Parallel to this, the integrity of the communication link's extremely important, as the system is built to guarantee a robust and uninterrupted connection between rescue operators and hikers. This functionality serves as a lifeline that can't be faltered even in the most challenging conditions. Augmenting the UAVs navigational phase, the pre-downloaded satellite imagery mechanism will be optimised for rapid efficiency, empowering the drone to devise the most effective trajectories for rescue teams to locate missing individuals. While the technical perspectives hold a huge responsibility in the search of missing individuals, the user accessibility is equally prioritised. The UAVs system's interface is tailored to be intuitive, ensuring that both SAR teams and individuals in distress can seamlessly interact with the UAV. Despite the deliverance of an optimised SAR functionality, the project's purpose remains grounded in its commitment to affordability and scalability. These are the key factors that allow its potential for a wider adoption in the SAR community.

4.3 Project organisation

4.3.1 Process Model

The planned development of the SAR Drone system incorporates the utilisation of an agile life cycle model, which is renowned for its characteristics of adaptability, cooperation, and rapid iteration capabilities. The proposed model is deemed to be an optimal choice, considering the complexity of the system and the expected requirement for continuous modifications. The development process commences with a preliminary phase of planning, when the requirements of the stakeholders are identified. This is followed by further phases of design and development, which involve the integration of numerous elements to create a comprehensive prototype of the system. As the development of our drone system advances, comprehensive testing is conducted to guarantee that the system fulfils the user acceptance criteria outlined earlier. Once the SAR Drone is operational, SAR operators will receive comprehensive training and demonstrate a constant commitment to staying updated on system maintenance and updates. This approach guarantees the effectiveness and adaptability of our product.

The selection of an agile life cycle model for this project is motivated by its prioritisation of feedback, adaptability, and collaboration. This strategy would guarantee that our technology maintains the forefront of its field in terms of industry standards, while also being in line with the practical demands of a SAR operation.

4.3.2 Project Responsibilities

Project Manager (Kang Zheng Rong)
The project manager is at the helm of the operation, overseeing the entirety of the project's life cycle. It starts from the planning phase to the maintenance stage. The mandated core of the project manager includes ensuring timely completion, that adheres to the budget constraints, and meeting the stakeholder's expectations. He'll also be specialising the development of the reroute optimisation software, and leveraging pre-loaded satellite imagery to plot the optimal routes for the SAR operations.

Software Lead (Sam Zachary Chee Hao Yuan)
Dedicated to enhancing the user experience, this engineer's tasked with crafting a user interface for the SAR Drone. The intuitive design aims to ensure rescue operators can seamlessly navigate and control the drone during SAR missions.

Software Engineer (Jin Yang Chong)
This role primarily focuses on the utilisation and refinement of the software aspects of the drone system, such as the UAV-human library. The purview of this role encompasses the body and hand gesture recognition system, to project communications between lost individuals and rescue operators

4.4 Management process

4.4.1 Risk management

The importance of risk management is often underestimated in project management, but it is vital for a project's success as it helps anticipate and proactively address potential obstacles. It begins with risk identification where specific areas such as budget management, technical stability, schedule adherence, and quality assurance need careful attention to prevent issues and meet stakeholder expectations. Following that, risk analysis is applied, which involves assessing the potential impact and severity of identified risks. The priority of the risk can be calculated using a risk matrix in **Appendix A**. Risk analysis is essential for responding to these risks, and there are two key strategies to alleviate the impact of risks: mitigation and contingency planning. Mitigation focuses on taking preemptive measures to reduce risks, while contingency planning provides predefined solutions for emerging risks. These strategies are used in conjunction to develop the risk register in **Appendix A**.

4.4.2 Stakeholder analysis and communication plan

In order to ensure each stakeholder is kept abreast of the progressing state of the project, effective communication methods are necessary. Brief but meaningful communication plays a crucial role within our group's dynamics as we value productiveness. We conduct weekly SCRUM meetings on Discord to ensure that every member is aligned in terms of ideas as well as progress. This approach is aimed at enhancing our overall efficiency and ensuring that we are collectively working toward our shared goals and objectives. Furthermore, we will actively exchange ideas and share information gathered throughout the week to avoid duplication and to integrate valuable insights into our project. In terms of contacting our project's supervisor, Prof. Raphael, we schedule a biweekly meeting using Zoom to obtain feedback on our progress and to address any questions or uncertainties that may arise. In addition to our regular sessions, email communication will serve as a means to promptly address any new issues as they arise. Meetings with unit supervisors will usually be conducted during weekly tutorial sessions if necessary. Additionally, consultation serves as another means of communication for urgent and unforeseen matters.

4.4.3 Monitoring and control mechanisms

Constant monitoring and controlling of project quality is necessary to ensure that progress achieved is of suitable standards. Version control systems such as GitHub are used so that various versions of the project can be maintained and rollback to older versions can be performed if needed. Meaningful documentation is prioritised to provide a clear and robust understanding of the code base. Finally, weekly reviews and refactoring is required to ensure a sustainable and scalable code base.

4.5 Schedule and Resource Requirements

4.5.1 Schedule

Effective project scheduling is of paramount importance in ensuring the success of our project, particularly given the tight timeframe at our disposal. When developing a schedule, several key considerations come into play. Primarily, it's essential to gain a comprehensive understanding of the complexity associated with the various tasks that define our project. This understanding will enable us to make more accurate estimates regarding the time required for each task. To acquire the necessary information for comprehending each task, we engaged in the analysis of relevant research papers and conducted coding trials and errors. The dependencies between various tasks are also heavily considered to make a chronological sound plan. The final result is the Work Breakdown Structure combined with a Gantt chart in **Appendix B**, for better visualisation of the project's timeline. The chart illustrates the five phases of our project, with each phase consisting of related deliverables that must be completed to satisfy the project agreement. As of the writing of this proposal, we have reached the execution phase of our project.

4.5.2 Resource Requirements

Resource requirements can be categorised into two key elements: manpower and equipment resources. In terms of manpower, a group of three students is sufficient for the starting phases of this project. As the project progresses, additional manpower in terms of assistance from supervisors may be required for troubleshooting and technical guidance. Estimation of man-hours required for the project is 300 hours split between three team members across 12 weeks. Likewise, computer time required for the project scales with the amount of man-hours as most of the time is spent on programming and testing AI models. The final estimation of computer time required is around 60 to 80 hours per team member. Equipment resources such as software and hardware specifications are described more in detail under the external design and methodology section. Generally, software and hardware requirements are fulfilled by ordinary essentials used by a computer science student with the exception of the drone, which is covered by the budget of RM6000. This budget allows for the purchase of three DJI Mini 3 drones.

V. External Design

The external design of our software surrounds the externally observable features, user interface, interaction with external packages, APIs, files, and sources.This section will describe the user interface, external packages, datasets, data sources and performance in detail.

5.1 User Interface

The user interface design focuses on creating an intuitive, user-friendly experience for both rescuers and potential casualties.

1) **Main Dashboard**: The main dashboard provides an overview of the drone's status, including its current location, battery life, and connectivity. It also displays real-time video feed from the drone's camera.

2) **Video Feed**: A dedicated section displays the live video feed from the drone, allowing operators to visually assess the surroundings.

3) **Human Detection**: The UI includes a human detection module that highlights detected individuals on the video feed, helping rescue operators quickly identify potential casualties.

4) **Gesture Recognition**: For biometric communication with casualties, a gesture recognition panel is available. It interprets hand gestures such as "Attention" and "Cancel" for effective communication.

5) **Route Planning**: The software offers route planning tools that calculate and display the optimal route for rescuers to reach the casualties. The route is overlaid on the map with clear visual cues.

6) **Performance Metrics**: Users can access performance metrics such as the drone's speed, altitude, and distance covered during the mission.

7) **Alerts and Notifications**: The UI provides real-time alerts and notifications about potential matches which are the detected casualties in this case and environmental changes, such as weather updates.

5.2 External packages and APIs

1) **DJI Mobile SDK**: Our software utilises the DJI Mobile SDK to access and control DJI drones. It simplifies various functions related to flight, signal transmission, and communication, ensuring seamless drone operation.

2) **OpenCV**: The OpenCV library is integrated to facilitate image processing tasks, including human detection and gesture recognition. It is crucial for the interaction between humans and drones.

3) **TensorFlow/PyTorch**: TensorFlow and PyTorch are used for developing, training, and running machine learning models. These libraries enable the software to define, train, and use neural networks for gesture recognition.

4) **DroneKit**: DroneKit's APIs are used to control drones. It allows our software to communicate with the drone's flight controller for precise navigation and control.

5) **UAV Human Dataset**: The UAV Human dataset serves as an essential resource for developing and training AI models for recognizing human behaviour. It includes a wide variety of real-world scenarios captured during day and night in urban and rural settings.

5.3 Data Sources and Data Sets

1) **Satellite Images**: Satellite images are used as a data source for road extraction and condition detection. They provide critical information for route planning and navigation.

2) **Real-Time Weather Data**: Weather data sources provide real-time updates on crucial variables such as wind speed, temperature, humidity, visibility, and air quality. This information is vital for making informed route adjustments in response to changing weather conditions.

3) **Geographic Data**: Geographic data sources, including maps and topographical data, are accessed to ensure accurate route planning. These sources provide high-resolution maps, satellite imagery, and topographical data.

5.4 Performance

1) **Time Performance**: The software is designed to provide real-time performance in various aspects, such as video streaming, human detection, gesture recognition, and route planning. Thus, low latency is essential for timely decision-making during SAR missions.

2) **Memory Performance**: Efficient memory management is crucial to ensure that the software runs smoothly on devices with varying hardware capabilities. Memory optimization is a priority to avoid performance degradation.

3) **Communication Efficiency**: The software's communication with external APIs, drones, and data sources is optimised for efficient data retrieval and transmission. Minimal communication delays are vital for the success of search and rescue operations.

To sum up, this section outlines the user interface, interaction with external packages and APIs, data sources, and performance of our software. It builds upon the previous assignment with additional features to ensure effective human-drone interaction and optimised performance during Search and Rescue operations.

VI. Methodology

6.1 Software Tool Sets

1) **Programming language:** Python is chosen as our primary programming language for AI development. Its readability, simplicity, and, most notably, its extensive support for AI and machine learning through libraries like TensorFlow and PyTorch make it the ideal choice. Leveraging pre-trained models and training algorithms from these libraries, we can effectively build AI capabilities for our drone. As the latest version of the DJI Mobile SDK only supports Android operating system, Java is selected as the backbone for the mobile application user interface due to its compatibility with android operating system

2) **Integrated Development Environment (IDE):** Visual Studio Code stands out as an excellent selection due to its rich feature set, encompassing code suggestions, debugging utilities, and seamless integration with version control systems like Git. Jupyter notebook for our model development activities, which encompass tasks such as training, testing, and evaluation, we have opted for the Jupyter notebook. Finally, Android Studio is used to develop the mobile application which provides a user interface for controlling and testing the AI model integrated into the drone.

3) **Version control systems:** Git proves to be invaluable for effective version control. Git offers the capability to monitor and document changes, establish personalised branches for distinct tasks, and facilitate seamless collaboration among team members. This ensures not only organised version management but also enhanced efficiency in our collaborative efforts.

6.2 Software Components

1) **UAV-human framework:** The UAV-human framework encompasses four primary tasks: action recognition, pose estimation, person re-identification, and human attribute recognition. In the action recognition task, a total of 155 activity classes were considered, involving 119 individuals of various ages, genders, and cultural backgrounds naturally engaged in different actions. They play a crucial role in detecting individuals who require special attention. After an individual is detected and counted, the pose estimation task identifies 17 major body joints, further aiding in determining the individual's actions. Subsequently, a recognized human triggers hand gesture recognition, where unique and identifiable hand gestures are used for communication within the UAV-human framework. Examples of these gestures include "thumb up" or "thumb down," which serve as alerts to rescuers about the individual's current condition.

2) **Optimal Route Planning algorithm:**
Real-time video streams of the road network captured by the drone are processed into both RGB and multispectral images. These RGB images then undergo road extraction through a D-LinkNet, separating roads from the background and extracting length and width characteristics. Simultaneously, multispectral images are employed to compute the NDVI index, a measure of vegetation cover that can distinguish between bare soil and gravel roads. Following the processing of RGB and multispectral images, data collection encompasses road surface material and weather information, enabling predictions of pedestrian walking speeds on various roads and

road throughput (the number of pedestrians passing through a road segment within a given timeframe). In the next step, weights are assigned to each road segment based on the road extraction outcomes, estimated pedestrian speeds, and road throughput. Higher weights signify more favourable road conditions and lower travel costs. Subsequently, an optimal route planning algorithm, specifically the A* algorithm, will be employed to plan the most efficient route. This algorithm, an extension of Dijkstra's, calculates the shortest path between two nodes in a graph and can be adapted to our weighted road network for finding the optimal route.

3) **Android mobile application interface:**
The current version of the application is exclusive to Android due to the absence of support from the DJI mobile SDK for iOS. The DJI Mobile SDK provides the skeleton code for the mobile application. Additional features are added via integration of Java libraries or programming. The final application encompasses both the UAV-human framework and the optimal route calculation algorithm and provides a user interface to run and test the functionality of each model integrated into the drone.

6.3 Final prototype

The core focus of the product revolves around two primary software components, namely the UAV-human framework and the optimal route planning algorithm, which are supplemented by an Android mobile application interface. A diversified dataset comprising 155 activity classes including 119 individuals will be collected and annotated in the Human-UAV framework, covering various ages, genders, and cultural backgrounds naturally engaging in different behaviours. A curated set of action classes will be used to successfully determine the common activities of a human figure based on these sources of data. This is critical attention for further identifying the folks who require attention. Following that, the pose estimation will identify the 17 key body joints in order to improve understanding of an individual's through hand gesture recognition. This provides a framework for the missing hikers to interact with rescuers using dynamic gestures like "attention" or "cancel." Simultaneously, the best route planning algorithm will convert real-time drone video streams into RGB and multispectral images, using the D-LinkNet technique to separate roads from the background and extract important length and width parameters. This data collection will allow forecasts of the rescuers' walking speed and road throughput, with weights assigned to the road segments based on a variety of parameters. Moving forward, the A* algorithm will be modified to discover the most efficient routes on the weighted road network. Because of DJI mobile SDK limitations, the Android mobile application interface will serve as the user-friendly control hub, integrating both the UAV-human framework for human, body, and hand gesture detection and the Optimal Route planning algorithm for testing and operation. To ensure a solid SAR drone system, the product will then go through thorough testing, validation, user interface refinement, and a full set of documentation on github.

VII. Test Planning

This section ensures that the developed software fulfils the project scope requirements and identifies and corrects potential errors. In this section, we will describe the critical areas where testing is required to verify the software's performance. Each test in this section is a high level overview, it outlines the approach of testing in that area , methods and scheduling.

7.1 Test Coverage

This section specifies the project requirements and scope that need to be validated and tested. We will be validating and testing the project requirements at various phases in order to ensure the flaws and errors of our software and system are minimised. The test coverage and test cases are shown in the test coverage table(table 1) in **Appendix C**.

7.2 Test Methods

The test methods that will be carried out are functional test, performance test, security test, usability test, integration test, regression test, compatibility test, and acceptance test. The description, test methods and scheduling will be shown in the test method table(table 2) in **Appendix C**.

VIII. Conclusion

The growing popularity of hiking has led to a pressing need to improve the safety and effectiveness of search and rescue (SAR) operations. The recognition of this necessity enables us to propose the notion of a SAR drone equipped with features that enhance the detection of humans and recognition of gestures, utilising the GT-I3D module. Additionally, a collection of advanced route optimisation algorithms is incorporated to efficiently and precisely guide rescue operators through demanding terrains. In addition to the aforementioned technological frameworks, our conceptualised drone is designed to attain an effective balance between the promotion of safety measures and the augmentation of operational efficacy. By mitigating the inherent hazards encountered by SAR operators, it facilitates the implementation of a broader and more comprehensive rescue mission. Moreover, our approach emphasises the vital combination of cost-effectiveness and technology advancements, presenting a solution that is both economically feasible and revolutionary. As we further explore the process of refining and developing this concept, we hold a strong conviction that our efforts in this domain possess the capacity to significantly revolutionise the terrain of SAR operations. By undertaking this endeavour, our aim is to develop a product that plays an essential part in preserving an increased number of lives during times of distress.

IX. Appendix A: Risk Management

9.1 Risk Matrix

Likelihood	**Consequences**				
	Insignificant *Risk is easily mitigated on a day to day basis*	**Minor** *Delays up to 10% of schedule.*	**Moderate** *Delays up to 30% of schedule.*	**Major** *Delays up to 50% of schedule.*	**Catastrophic** *Project abandoned*
Certain *> 90% chance*	Medium	High	Extreme	Extreme	Extreme
Likely *50% - 90% chance*	Low	High	High	Extreme	Extreme
Moderate *10% - 49% chance*	Low	Medium	High	High	Extreme
Unlikely *2% - 9% chance*	Low	Low	Medium	Medium	High
Rare *< 2% chance*	Low	Low	Low	Low	Medium

9.2 Risk Register

Risk Description	Impact Description	Risk Likelihood	Impact Level	Priority Level	Mitigation Notes
Brief summary of the risk	*Brief description of the consequences if risk is not mitigated*	*The probability of the risk occurring based on the risk matrix*	*The severity of the impact based on the risk matrix*	*The priority level obtained using the risk matrix*	*Mitigation strategies for the risk, either to eliminate or reduce severity of impact*
Electricity supply is cut off	Slight delay in progress for online work	Unlikely	Insignificant	Low	Create offline copies of task. Prioritise online task if possible before moving on to offline tasks
Laptop malfunction (Can be troubleshoot within a day)	Programming tasks are delayed	Moderate	Minor	Medium	Help in troubleshooting issues immediately. Members can still contribute to non-programming tasks such as research and giving ideas
Laptop malfunction (Severe such as water damage)	Team member is unable to contribute to programming tasks, leading to delays	Unlikely	Moderate	Medium	Member may have to work on campus provided PCs temporarily. Members can still contribute to non-programming tasks such as research and giving ideas
Personal matters (Up to 2 days)	May lead to delay in progress	Likely	Insignificant	Low	Reschedule affected member's tasks to another date. Key is starting the work early to allow for time to reschedule
Moderate Injury (Fractures, Dislocation, Soft Tissue Injuries)	Severe delays depending on the recovery period of team member	Unlikely	Major	Medium	Revise project scope to enure feasibility with one less member. Project modularity allows for easier restructuring of project responsibilities to other team members

Discontinued support for DJI Mobile SDK	Unable to run AI model on DJI drones	Unlikely	Catastrophic	High	Look for other drone alternatives to run AI models. DJI has other forms of SDK to remedy this issue
Drone Malfunction	Unable to integrate and test AI recognition model on drone	Moderate	Moderate	High	Borrow drones from supervisor. Consider price as part of drone selection criteria such that additional standby drones can be purchased.

X. Appendix B: Project Requirements and Design

10.1 Work Breakdown Structure & Gantt Chart

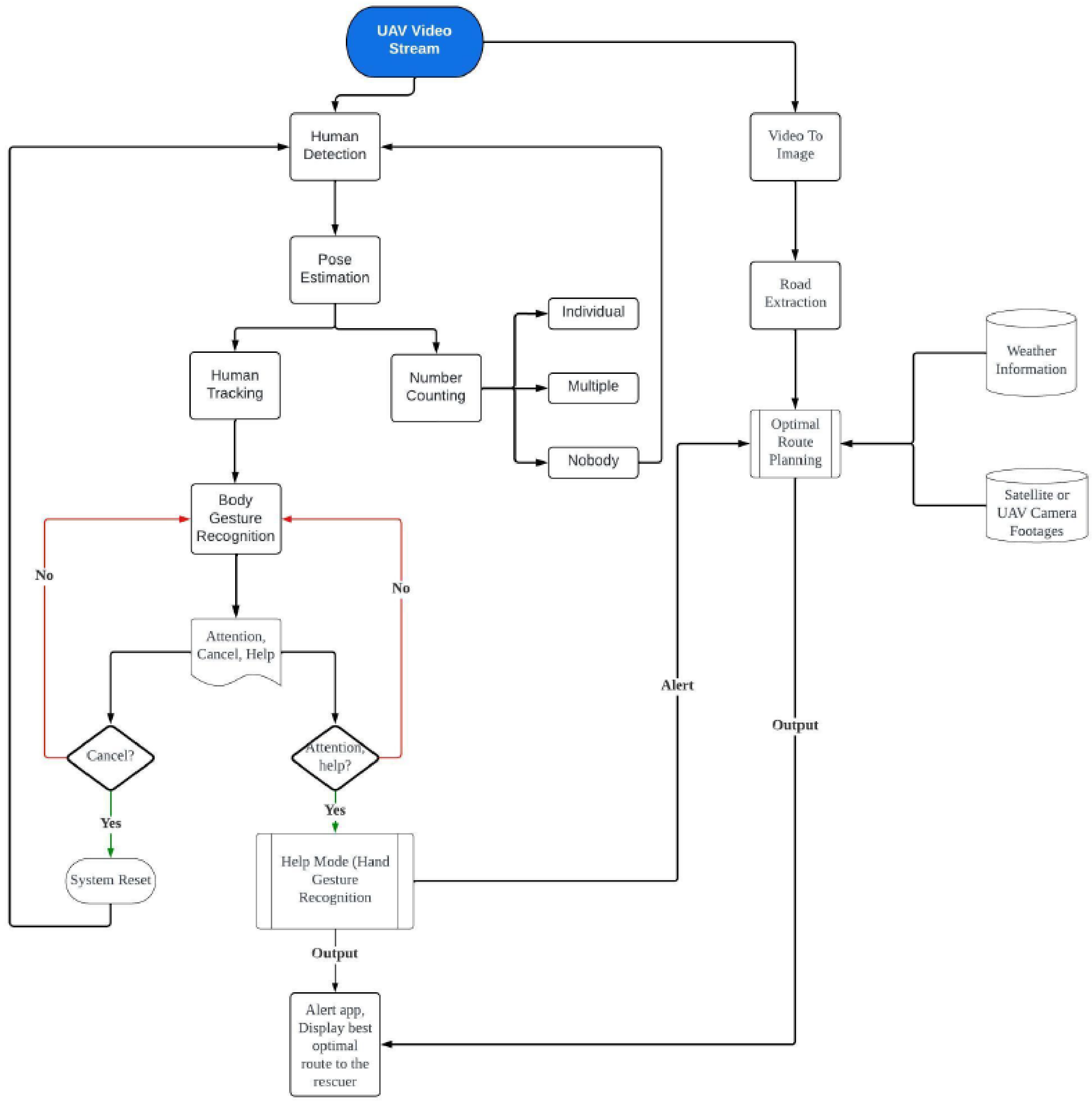
WBS NUMBER	TASK TITLE	TASK DEPENDENCY	SEMESTER TWO											
			1	2	3	4	5	6	7	8	9	10	11	12
1	Human Detection and Gesture Recognition													
1.1	Human Body Gesture Recognition	Finish to start 1.3												
1.2	Hand Gesture Recognition	Finish to start 1.3												
1.3	Training and validation	Finish to start 1.4												
1.4	Integrate AI model with TensorFlow Lite	Finish to start 2.1												
2	Optimal Route Calculation													
2.1	Acquiring pre-downloaded satellite imagery	Finish to start 2.2												
2.2	Train D-Link Net for road extraction	Finish to start 2.3												
2.3	Implement route planning algorithm	Finish to start 2.4												
2.4	Testing and validation	Finish to start 2.5												
2.5	Integrate AI model using TensorFlow Lite	Finish to start 3.1												
3	Android Application User Interface													
3.1	Implement main dashboard	Finish to start 3.4												
3.2	Implement video feed	Finish to start 3.4												
3.3	Implement performance metric bars	Finish to start 3.4												
3.4	Usability testing	Finish to start 4.1												
4	Monitoring and Improvements													
4.1	Field test	Finish to start 4.2												
4.2	Further tuning of AI parameters	Finish to start 4.3												
4.3	Consult professionals for improvements	Finish to start 5.1												
5	Project Closing													
5.1	Final presentation	Finish to start 5.2												
5.2	Evaluation and Reflection	N/A												

10.2 Requirement Traceability Matrix

ID	Ass. ID	Requirement Description	Project Need, Justification	WBS Element
1	1.1	Human Detection and Gesture Recognition	To ensure the object detected is a human; not a random object, i.e. Tree, Rock, Animal	1
1	1.1.1	Body Recognition	Enhancement on human detection, to further ensure that the object detected has the common human actions, i.e. walking, kicking, punching, rolling	1.1
1	1.1.2	Hand Gesture Recognition	Dynamic hand gestures to allow rescue operators to check if a hiker may need assistance	1.2
1	1.1.3	Integrate AI model with TensorFlow Lite	Used in conjunction with optimal route calculation algorithm to find shortest rescue path to victim	1.3
2	2.1	Optimal Route Calculation Algorithm	Calculate the most optimal path from rescuer to victim based on the road extraction outcomes, estimated pedestrian speeds, and road throughput	2
2	2.1.1	Acquire satellite images	Processed and used for training the D-Link Net	2.1
2	2.1.2	Train D-Link Net	A neural network used extract road graph from RGB images	2.2
2	2.1.3	Implement A* algorithm	Algorithm to calculate shortest path from one point to another point using a heuristic function	2.3
2	2.1.4	Integrate algorithm into application	Used in conjunction with AI recognition model to find shortest rescue path to victim	2.5
3	3.1	Android Application Interface	For interacting and testing AI model on drone	3
3	3.1.1	Main Dashboard	Provide users information about the drone's status, including its current location, battery life, and connectivity.	3.1
3	3.1.2	Video Feed	Allow operators to visually assess the surroundings.	3.2

3	3.1.3	Performance Metric Bar	Allow users access to performance metrics such as the drone's speed, altitude, and distance covered during the mission	3.3

10.3 Flowchart from Assignment 3: Project Initial Concept & Design and Presentation



XI.Appendix C : Test Planning

11.1 Test Coverage

Test Case ID	Test Description	Testing Stage	Components Involved
1	Test if the user interface functions are correct and the user interface is user-friendly.	Acceptance testing	UI
2	Ensure that the software can accurately detect humans in real-time using the drone's camera.	Functional Testing	UI, Drone, Software Backend
3	Ensure the software is able to recognize specific hand gestures, such as "Stop" or "Attention,", and “Cancel” made by the detected humans.	Functional Testing	Drone, Software Backend
4	Ensure the software can extract road information from satellite images and determine road conditions.	Functional Testing	Drone, Satellite Images, Software Backend
5	Evaluate the software's capability to plan optimal rescue routes for rescuers based on road conditions and other factors.	Functional Testing	UI, Software Backend
6	Verify the software's ability to facilitate communication between rescue operators and the drone.	Functional Testing	Drone, UI, Software Backend
7	Ensure the software is compatible with various devices and versions	Compatibility Testing	UI, Software Backend
8	Evaluate the software performance under different loads.	Performance Testing	Software Backend
9	Identify and mitigate vulnerabilities that could compromise system security	Security Testing	Software Backend
10	Feedback regarding user experience and usability of software UI	Usability Testing	UI, Users

11	Test the integration of satellite data and weather condition in optimal route planning	Integration Testing	Software Backend
12	Ensure changes in optimal route planning algorithm will not introduce defects	Regression Testing	Software Backend

11.2 Test Methods

Test Name	Description	Methods	Scheduling
Functional Testing	Validate the software core functions. Test the main features of the user interface and their interaction with external APIs and hardware.	Functional testing will be carried out through manual testing, automated testing, and user acceptance testing (UAT). Manual testing: systematically verifying that each function behaves as intended. Automated testing: Include the use of testing frameworks to execute repetitive and complex test scenarios. UAT: Involve potential end-users to evaluate the software's usability.	Functional testing will be conducted throughout the development process. There will also be dedicated testing before each release. User acceptance testing will only be done in the final development phase.
Performance Testing	Evaluate the software's speed, responsiveness and resource utilisation.	Evaluate through load testing, stress testing, and latency testing.	Performance testing will be done before and after the software's major updates and before deployment
Usability Testing	Evaluate the software for user friendliness, communication.	Conduct through end-users feedback sessions and surveys.	During the final user acceptance testing phase.
Security Testing	Identify and mitigate vulnerabilities that could compromise the safety and integrity of SAR operation.	Simulate real world attacks to identify weaknesses. Identify vulnerabilities in software and code analysis.	Integrate in each testing phase and comprehensively security assessment before deployment.
Integration Testing	Assess the interoperability of the software with external packages, APIs, and devices.	Interfacing the software with all the softwares, hardwares, and APIs.	Conduct during the final testing phase and everytime a new external component is integrated.

Regression Testing	Ensure new code or extension will not affect existing functionalities.	Test by running predetermined test cases.	Continuously conducted throughout the development process and before each major release.
Compatibility Testing	Assess software's compatibility with various devices, OS versions.	Test the software on multiple different devices and different OS versions.	Conduct in every testing phase.
Acceptance Testing	Ensure the software meets end users' requirements and defined acceptance.	Feedback from real end-users by using the software in real-world scenarios.	Conduct in the final phase of development.

XII. References

Circumstances and causes of death of hikers at different altitudes: A retrospective analysis of hiking fatalities from 2003–2018. Forensic Science International. https://www.sciencedirect.com/science/article/pii/S0379073820301146

Hayat, Yanmaz, E., Brown, T. X., & Bettstetter, C. (2017). *Multi-objective UAV path planning for search and rescue*. IEEE Conference Publication | IEEE Xplore. https://ieeexplore.ieee.org/document/7989656

Hayat, S., Yanmaz, E., Bettstetter, C., & Brown, T. X. (2020a). Multi-objective drone path planning for search and rescue with quality-of-service requirements. *Autonomous Robots*, *44*(7), 1183–1198. https://doi.org/10.1007/s10514-020-09926-9

Laghari, A. A., Jumani, A. K., Laghari, R. A., & Nawaz, H. (2023). Unmanned aerial vehicles: A review. *Cognitive Robotics*, *3*, 8–22. https://doi.org/10.1016/j.cogr.2022.12.004

Liu, C., & Szirányi, T. (2021). *Real-time human detection and gesture recognition for on-board UAV rescue*. MDPI. https://www.mdpi.com/1424-8220/21/6/2180

Liu, C., & Szirányi, T. (2022). *Road condition detection and emergency rescue recognition using on-board UAV in the wilderness*. MDPI. https://www.mdpi.com/2072-4292/14/17/4355

Lyu, M., Zhao, Y., Huang, C., & Huang, H. (2023). *Unmanned aerial vehicles for search and rescue: A survey*. MDPI. https://www.mdpi.com/2072-4292/15/13/3266

Published by Statista Research Department, & 24, M. (2023). *U.S. Americans who went hiking 2021*. Statista. https://www.statista.com/statistics/191240/participants-in-hiking-in-the-us-since-2006/

Rao, B., Mulloth, B., & Harrison, A. J. (2019). *Integrating AI Capabilities into Existing Technology Platforms: Drones as a Case in Point*. IEEE Conference Publication | IEEE Xplore. https://ieeexplore.ieee.org/abstract/document/8893858

Ricketts, I. (1998). *Managing your software project*. SpringerLink. https://link.springer.com/book/10.1007/978-1-4471-0599-2

RIIS LLC. (2023). *Counting Sheep with Drones and AI (whitepaper) - RIIS*. RIIS. https://riis.com/contact/counting-sheep-with-drones-and-ai-whitepaper/

Xie, L., & Guo, X. (2019). *Object detection and analysis of human body postures based on tensorflow*. IEEE Xplore . https://ieeexplore.ieee.org/document/8896402

Zhang, C., Zhou, W., Qin, W., & Tang, W. (2023). *A novel UAV path planning approach: Heuristic crossing search and rescue optimization algorithm*. Expert Systems With Applications. https://doi.org/10.1016/j.eswa.2022.119243