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iVER: Intelligent Unmanned Aerial Vehicle to Assist Flood Search and Rescue

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Abstract: Flood is a natural disaster that can disrupt large area for a long period of time. Many people are affected by it and it can cause major damage towards society and economy. The main cause of fatality during flood is drowning. This may be due to difficulties to find flood victims in short period of time. This research introduces intelligent Vehicle for Emergency Response (iVER), an unmanned aerial vehicle that can assist search and rescue during flood by providing live-feed of bird-eye-view videos of the surrounding area to the rescuers. iVER's design, materials and features are all designed to be easy to handle by rescuers during emergency and under harsh weather. iVER's features such easy take-off, auto-landing and fully autonomous flight optimisations are also discussed in this paper.

Key words: Autonomous Vehicle · Emergency · UAV · Search and Rescue · Flood

INTRODUCTION

Flood has massive and devastating impacts on economy, society and causes fatalities [1]. There are several natural and human factors that caused floods, such as abundant number of rainfall, deforestation, tidal effect, inadequate river maintenance and shortage of drainage in urban areas [2]. Rescue department have very limited communication and coordination during mega flood emergency thus rely on independent perception especially when scouting using boat in an isolated area [3]. Independent perception based on physical observation assisted by binoculars and close-proximity radio communication could only cover some fraction of the affected population area especially at hills and valleys.

Major cause of flood deaths is drowning [4]. The inability for rescuers to locate victims early and accurately for safe extraction is one of the reason of flood fatalities. Robotics have been used to assist in search, lifesaving and drowning prevention missions. One of the product, Emergency Integrated Lifesaving Lanyard (EMILY), allows rescuers to send floatation device to victims using a radio-controlled boat. There are also several autonomous marine surface robots that can be used for search and rescue support [5].

Nevertheless, robots that move on water surface could not cover large areas due to strong water current and abundance of debris caused by flood. Furthermore, observations from water level are low altitude which limit the visibility due to the camera angle and it can be easily obstructed by the surroundings. The development of Intelligent Unmanned Aerial Vehicle for Flood Emergency Rescue (iVER) was aimed in providing the rescue department with reliable and robust aerial platform to provide bird-eye-view for detection of isolated victims.

Design: Application concept of iVER is intended to allow rescue personnel to have aerial view of the emergency scenario in order to effectively and accurately locate victims. The proposed aerial platform should be mobile, easy to carry and fit within the backpack of the rescue personnel. As shown in Figure 1, iVER could be launch autonomously from the boat thus it should have very short take off distance to achieve sustained flight and start providing real-time video stream of aerial view to the rescuer. iVER will maintain circular flight pattern with the rescuer as the centre of the circle. Radius and altitude of flight will be customizable on the rescue personnel's smartphone or tablet. Once mission is

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completed, instruction of auto-landing procedure could be transmitted to iVER with just one click of a button in the provided apps.

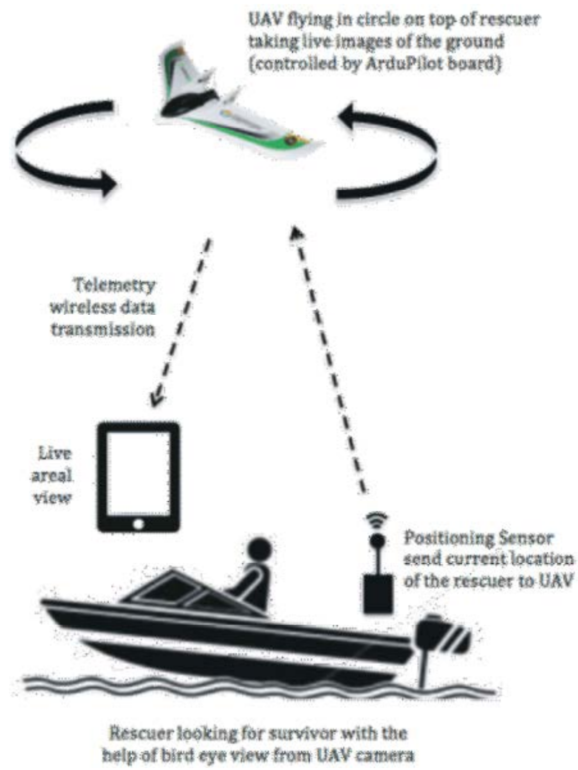

Fig. 1: Application Concept of iVER in Search and Rescue Situation.

MATERIALS AND METHODS

In this study, the platform of autonomous aerial platform was developed with the objective of low-cost aerial surveying system for search and rescue personnel. In order to achieve low-cost manufacturing and fabrication of the system, an open-source flight control from MAVlink was adopted complemented with in-house fabrication of the aircraft body from inexpensive material such as expanded poly-olefin (EPO) and thin fiberglass coating. In order to allow successful autonomous flight capability, the aerial platform is required to be optimised especially regarding their PIDs setting [6]. The relation among PIDs value is shown in Figure 2.

PIDs optimisation is difficult for small aerial platform. Hence, the scale-down of the platform was performed by adapting the PIDs value of initial scale platform. Initially for the establishment and tuning of the UAV, a relatively wide wing platform was adopted with a wingspan of 1200mm which is then reduced to 500mm as the programming matured. In addition, the potential of the

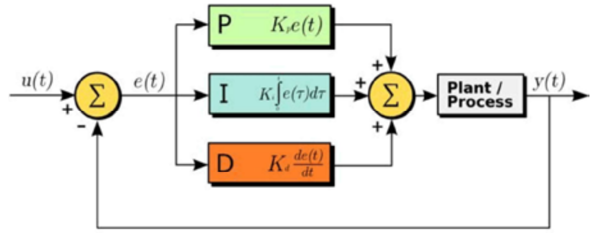

Fig. 2: Algorithm of the Relation of P, I and D in Flight Control [6].

flight control and various radio link protocol was also investigated during the study. The type of radio link protocol selected was based on its robustness to weather condition and data bandwidth transfer.

RESULTS

Optimisation of Autonomous Aerial Platform: Relatively large platform as shown in Figure 3 was chosen initially to assist the programming of the flight controller especially for the PIDs parameter. The use of EPO was favoured over the material of expanded polypropylene (EPP) and expanded polystyrene (EPS) because of its flexible and recoverable structure. The first prototype utilised a flying wing EPO aerial platform with 1200mm wingspan. Flying wing was selected as the type of aerial platform for iVER. The absence of fuselage such as in conventional airplane body would reduce air drag and increase survivability of the plane during crash landing.

Fig. 3: First Prototype of iVER Utilising Aerial Platform with 1200 mm Wingspan.

Second prototype was made also based on EPO however significantly narrow wingspan of 500mm. Optimised PIDs setting from the first prototype was adopted to the second prototype with additional optimisation due to the scale down factor. Figure 4 shows the third prototype of iVER with the purpose for autonomous flight experimentation and optimisation.

Fig. 4: Second Prototype of iVER with Actual Scale of 500 mm Wingspan.

This prototype was constructed based on the actual scale intended for real world iVER applications. The length of its wingspan is suitable for mobility and fits within the backpack of rescue personnel. The final prototype and also the production unit of iVER is shown in Figure 5. As the last stage of prototyping, the production unit of iVER was made using thin fiberglass with ABS reinforcement structure. Clear polycarbonate was chosen for its observation dome located at the anterior of the aerial platform.

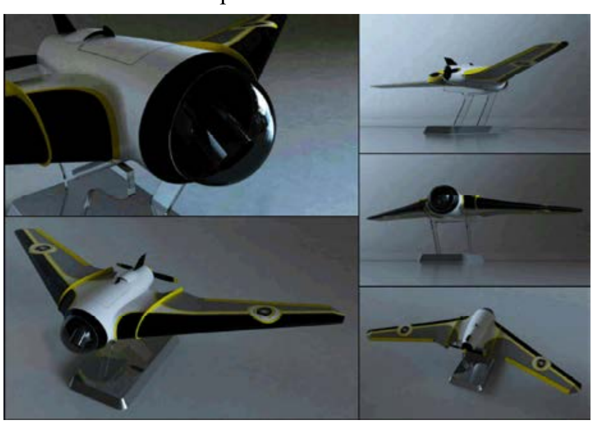

Fig. 5: Production Unit of iVER with Wingspan of 500 mm.

Autonomous Navigation Utilising Open-Source Mavlink Platform: Utilisation of MAVLink protocol assist in equipping iVER with various advanced features that can be accessed via mission commands. Some of them are automatic take-off, automatic landing, stall prevention and geo-fencing. These advanced features could speed-up the integration of iVER with the rescue department where only basic training is required.

Automatic take-off is done by automatically launch the iVER from boat without requiring human control. Example of automatic take-off by second prototype of iVER is shown in Figure 6. The basic idea of automatic take-off is where the iVER navigation system set the throttle to maximum and climb until the designated altitude is reached. As part of the mission plan or when instructed, iVER could automatically land itself safely. During landing procedure, iVER will shut down its throttle and hold the current heading until it reaches the flare point. Flare is the final stage of landing when the iVER navigation system cuts the throttle and raised the pitch, increasing the drag and slowing the aircraft to sink onto the ground [7].

Fig. 6: iVER Autonomous Take-Off.

In addition, iVER also has a logic to prevent stall. This feature is named stall prevention. One of the most common ways of plane crash is through a stall. A stall happens when the airflow over the wing is not sufficient to hold the aircraft in the air. Stalls can happen at any speed, but the most common type of stall is a low speed stall, where the airflow is too slow to provide enough lift [8]. The amount of airflow needed over the wing to hold the aircraft in the air depends on the bank angle iVER are flying at. If iVER are banked over hard then its navigation system will control it to fly faster to get enough lift to stay in the air. This is because the lift is produced perpendicular to the wing, so when the wing is rolled over it provides only part of the lift to holding the aircraft up and the rest of the lift goes into making the aircraft turn. Stall prevention could ensure the operability and longevity of iVER during bad weather conditions.

Another feature of autonomous capability of iVER is geo-fencing. The geo-fencing support in iVER allows the operator to set a virtual ‘fence’ around the area of survey, specified as an enclosed polygon of GPS positions plus a minimum and maximum altitude [9]. Geo-fencing will ensure the recovery of iVER in bad weather condition preventing it from flying beyond the target area. When geo-fencing is enabled, if iVER goes outside the fenced area then it will automatically switch to guided mode and will fly back to a pre-defined return point and loiter there ready for the next survey command or automatic landing.

Live Feedback Establishment Using Various Radio Link Protocol: The APM MAVLink platform worked with three radio frequency namely 2.4 GHz, 5.8 GHz and 951 MHz respectively for manual flight control, HD low-latency video streaming and flight data telemetry. The complete setup of ground control for the PIDs optimisation and autonomous flight experiment is shown in Figure 7.

Fig. 7: Ground Control Setup for PIDs Optimisation and Flight Experiment.

Selection of 2.4GHz provides the high resolution and proportional digital control of the aircraft manoeuvre with enough error-correction and weather-proof capability [10]. For video transmission, the choice of 5.8GHz had provide enough bandwidth for high definition video-streaming for the identification of victims and state of condition of the emergency. As compared to both frequency, a relatively low frequency of 951 MHz for flight data telemetry is sufficient for seamless duplex data transfer between the UAV and ground control with excellent weatherproof capabilities [11].

CONCLUSION

The prototype development of intelligent unmanned aerial vehicle for flood emergency rescue was elucidated in this paper. Utilisation of flying wing platform with complete suite of intelligent flight characteristics provides a robust and reliable system in assisting rescuersto locateflood victims effectively using bird-eye-view live video streaming.

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