UAV aid for Search and Rescue missions

Planning Report

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1 Introduction

1.1 Background

Unmanned Aerial Vehicles (UAVs) are and have been prominent within both military and government organizations throughout the modern years. The possibility of being able to survey areas without the need for a pilot is evidently compelling in modern warfare. However, as these systems are becoming cheaper, the interest in the surveillance tool is spreading to other applications. The ability to search and map large areas autonomously have several functions outside warfare, such as mapping, surveilling and search and rescue missions.

Using UAVs for search and rescue has advantages in both response time and need for manpower compared to piloted aircrafts. These are qualifications that suits companies such as the Swedish Sea Rescue Society (SSRS), hence, they have taken an interest in the idea. Obtaining information early about an accident out at sea would ease decisions such as; what boat to choose, equipment to bring and how many crew members that are needed. By the use of UAVs, an aircraft could be deployed as soon as a location is received. The UAV would autonomously travel to the coordinates and be able to give a live video feed of the situation. This information would aid in decisions and also allow the rescue mission to be supervised.

By having UAVs on standby at several locations around the Swedish seaboard, SSRS would have the ability to get visual aid at every coordinate close to the coast. By the use of such a system, a live video feed of the accident could be provided within minutes of an emergency call. Moreover, if the location of the accident is not completely established, the UAV could autonomously scout the area and locate the person in distress.

This thesis aims to initiate the idea by designing an UAV that autonomously travels to a location given specified coordinates. By forming the system for one UAV that covers an area within its radius, the system can be implemented in additional UAVs in order to together cover larger areas. The UAV is intended to, given some coordinates, autonomously launch from a specialized housing and travel to the specified location. During travel, a video camera is used to send live footage from the flight. When the aircraft reaches its destination it should circulate the accident autonomously while constantly streaming a live video feed of the scenario.

At any point of the flight, the UAV should be able to receive new directives from the ground control station. Instead of using Radio Control (RC) which is the most commonly used communication medium, this thesis aims to explore the possibility of exploiting the mobile network (3G/4G). If successful, the UAV would not be restricted to operate within a certain radius, only the wireless internet coverage would constrain the communication. This would also allow the UAV to be controlled from all over the globe under the assumption that the user has access to the internet.

In recent years extensive research have been conducted regarding the design of control algorithms for UAVs using modern control theory. A vast amount of these methods are also successful in the sense that they are all able to stabilize and control the aircraft. Amongst the more famous methods there are Linear Quadratic Regulator (LQR) [1], machine learning methods [2], Model Predictive Control (MPC) [3], Vector-Feld based control, Nonlinear Guidance Law (NLGL) algorithms [4] etc. Although these nonlinear methods are optimal in the sense of performance, not many have been implemented in real applications. The reason for this lies in their complexity, nonlinear nature and computational cost [5]. The commonly used and most implemented method is the Poportional-Integral-Derivative (PID) controller due to its low complexity and adequate performance.

The performance of the PID controller can be significantly enhanced by combining the method with various extensions. Rhee et al. [6] presents an easy but sophisticated PID controller with a feed-forward term. Their work is also mentioned by Sujit et al. [4] as a PID solution with high robustness against wind disturbance that is comparable with the nonlinear control methods. The kalman filter is also a valid option for disturbance rejection and increased robustness. The Extended Kalman Filter (EKF) and PID combination have been analyzed by Warsi et al. [7] and they conclude that the system works well and successfully suppress the impact of noise. Furthermore, the competitor of EKF known as Unscented Kalman Filter (UKF) have also been suggested as a replacement for the EKF. The UKF have been implemented in UAVs and compared with the EKF by Wanli et al. [8] and de Marina et al. [9]. Both the papers conclude that the UKF gives better performance with equal computation complexity.

1.2 Objective

The objective of the project is to aid in search and rescue missions using autonomous UAVs. An UAV is to be built, modeled and controlled and the finished product should be able to autonomously travel to a location given its coordinates. At arrival the UAV is also supposed to circulate and capture a scenario using a video camera. The footage is to be streamed to a server using the mobile network.

1.3 Scope and Boundaries

The thesis is focused on the design of an autopilot attached to a Zephyr XL [10] aircraft. A mathematical model is to be formulated and a control method is to be established. The implemented system should be able to follow a path trajectory that is generated from provided coordinates. Path planning and optimization is not studied in this thesis, and will be produced using existing software. Developing a control method for the attached camera is outside the scope of this thesis, instead an existing gimbal control solution will be used. The UAV is to receive instructions and send video footage via the cellular internet. This communication should be handled through a user interface. Furthermore, the launch and the landing of the UAV is not considered. This infers that the housing will not be designed and the UAV is to land using a parachute.

1.4 Purpose and Aims

The goal is to initiate a large scale search and rescue system that utilizes autonomous UAVs in order to quickly obtain live video footage of an accident at sea. By successfully designing a system that only involves *one* UAV, the arrangement could be replicated into additional UAVs to cover larger areas. When a distress call is received, the location of the accident should be communicated to the system through the user interface. Given some coordinates, the closest UAV (only one for this project) is launched and travels to the provided position. At arrival it should circulate the scene until commanded to land using the parachute.

To achieve the goals of this project, there are several problems that needs to be analyzed:

- Establish necessary hardware for the UAV
  - What autopilot should be used and what specifications are required?
  - What hardware needed to connect to the mobile internet?
  - What properties does the camera need in order to retrieve acceptable video?
  - What is needed for suitable gimbal control and disturbance rejection?
- Conduct comparative research on control methods for UAVs
  - Nonlinear controllers
  - PID controllers
  - Tuning methods
  - Filters for disturbance rejection
- Construct mathematical model
  - How should the attachments be positioned for a stable model?
  - How accurate should the mathematical model be? What assumptions can be made?
- Design and simulation
  - Determine suitable programming language and simulation environment
  - Evaluate the mathematical model and control method
  - Test various wind conditions
- Implementation and path following
  - Choose path planning method
  - Conduct tests using manual controller and pre-determined trajectories
- Video footage and camera control
  - Assess the quality of the footage, what needs to be improved? How?
  - Is there a need for manual control of the camera?

- Data communication and video streaming
  - How is the data transfer rate? Is it acceptable?
  - How should the UAV behave if there is no connection?
  - What directives should be communicated?
- User Interface
  - What software is to be used for the interface?
  - What options should be presented?

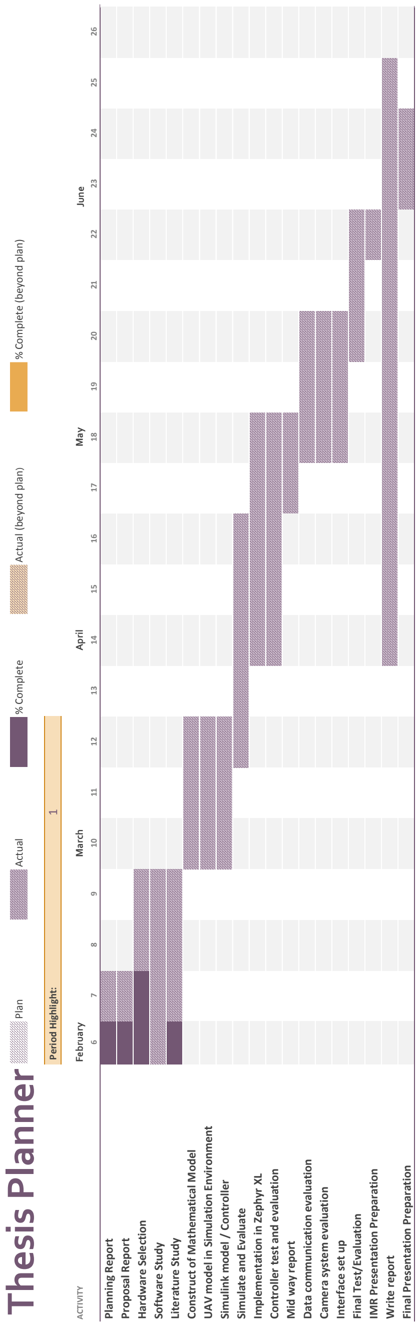
2 Method

The preliminary objective is to implement a control system that succeeds to stabilize the UAV. This is accomplished by obtaining an mathematical model and a controller. The model needs to be calculated after the construction of the UAV. In parallell with this work relevant control methods should be thoroughly investigated. Once a controller and model is retrieved, their performance needs to be tested in a flight simulator. Finding an appropriate controller can be an iterative process if the performance is not satisfactory in the simulations. The simulation stage should be extensive and verify trajectory tracking, wind rejection, stability etc. This is to avoid damage to the real UAV if the system fails.

Once the implementation is successful and the UAV is capable of being airborne, the movement and flight paths needs to be controlled. Existing path planning software is to be used to generate trajectories from coordinates. Such a program can be used to pre-determine a flight path or possibly feed the UAV continuously with a trajectory. If the autopilot successfully follows the generated paths, the hovering feature could also be obtained using the path planning software.

There are two components needed to successfully send relevant information back to the control station. First, the camera should qualitatively capture the scenario by the use of gimbal control and stabilization. These features are obtainable through existing target tracking technology or alternatively a 360 degrees camera could be employed. Secondly, a stable data communication link is needed to smoothly stream the video.

3 Time Plan



Schedule is presented in weeks. The project starts at week 6 , beginning of February.

References

[1] J. Shao, Q. Fei, Q. Hu, and Q. Geng, "Multi-model control design for longitudinal dynamics of fixed-wing uav," in *Control Conference (CCC), 2014 33rd Chinese*, July 2014, pp. 8826–8830.

[2] Furqan, J. Iqbal, A. Malik, and W. Haider, "Neural network based aircraft control," in *Research and Development (SCOReD), 2010 IEEE Student Conference on*, Dec 2010, pp. 262–266.

[3] Y. Kang and J. Hedrick, "Linear tracking for a fixed-wing uav using nonlinear model predictive control," *Control Systems Technology, IEEE Transactions on*, vol. 17, no. 5, pp. 1202–1210, Sept 2009.

[4] P. Sujit, S. Saripalli, and J. Borges Sousa, "Unmanned aerial vehicle path following: A survey and analysis of algorithms for fixed-wing unmanned aerial vehicless," *Control Systems, IEEE*, vol. 34, no. 1, pp. 42–59, Feb 2014.

[5] B. Kada and Y. Ghazzawi, "Robust pid controller design for an uav flight control system," in *Proceedings of the World Congress on Engineering and Computer Science 2011 Vol II*, Oct 2011, pp. 945–950.

[6] I. Rhee, S. Park, and C.-K. Ryoo, "A tight path following algorithm of an uas based on pid control," in *SICE Annual Conference 2010, Proceedings of*, Aug 2010, pp. 1270–1273.

[7] F. Warsi, D. Hazry, S. Ahmed, M. Joyo, M. Tanveer, H. Kamarudin, and Z. Razlan, "Yaw, pitch and roll controller design for fixed-wing uav under uncertainty and perturbed condition," in *Signal Processing its Applications (CSPA), 2014 IEEE 10th International Colloquium on*, March 2014, pp. 151–156.

[8] X. Wanli, B. Shuo, and L. Zhun, "The state estimation of uav based on ukf," in *Advanced Research and Technology in Industry Applications (WARTIA), 2014 IEEE Workshop on*, Sept 2014, pp. 402–405.

[9] H. de Marina, F. Pereda, J. Giron-Sierra, and F. Espinosa, "Uav attitude estimation using unscented kalman filter and triad," *Industrial Electronics, IEEE Transactions on*, vol. 59, no. 11, pp. 4465–4474, Nov 2012.

[10] Ritewing, "Products," feb 2015. [Online]. Available: http://www.ritewingrc.com/products.html