Towards a Reliable, Cost Effective and Easy to Operate Unmanned Aerial Vehicle for Technology Education

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***Abstract*—With the increasing difficulty for many universities to find students willing to invest in a career in technology, it becomes a necessity to attract those capable students whom might not consider technology in the first place. Often the reasons for not choosing an education in technology are fear of the difficulty of the subject, unclear picture of what technology education really entails, or still the perception of technology being boring. A possible way to eliminate some of these reasons in the minds of prospective students is to develop interesting and meaningful yet exciting projects which clearly demonstrate the various aspects of the field. Ideally, these projects should contain a social and/or business oriented relevance in order to attract funding and support from companies or funds.**

In this paper we present one of those projects currently on the way to implement a cost effective and reliable unmanned aerial vehicle (UAV). One of the goals of the project is ease of use, so that prospective or first year students can operate the system with minimal training, while clearly able to observe three main technological fields in practice: embedded systems engineering, software engineering and telecommunications.

The project is headed by the Vaasa University of Applied Sciences, Finland (http://www.puv.fi) in cooperation with, and funded for the most part by, WRD Systems, a young British technology company (http://www.wrdsystems.co.uk). The goal for WRD Systems is to apply the results of this project in areas which can benefit from aerial observations such as crop yield estimation, forest monitoring, wildlife tracking and search and rescue.

I. Introduction

In the past, the Vaasa University of Applied Sciences has developed a range of projects which aim at motivating students, even before they begin their academic career. The best known of these past endeavours is probably the RoboCup Soccer Project [1]. While this still ongoing project provides a rich environment for both research and education in a variety of fields, it also presents substantial financial, technological and infrastructural challenges to keep the project running. The complex nature of the project also means the barrier to entry for new team members is relatively high. This can scare potential students away, worried about the daunting task of comprehending, and contributing to, the project.

In order to tackle these and other problems, a set of requirements for future projects was created. The first requirement is the need for external financing. With time, financing large projects with departmental or university funds becomes more and more problematic. Therefore, external sponsorship or financing can alleviate some, if not all, of the financial burdens. A second requirement is one of manpower. It should be possible to run the entire project with a minimal of staff and students, while still measuring overall progress. As a third requirement, the infrastructural needs should be kept to a minimum, not only because of lack of project rooms, but also to make the system portable in order to give on location demonstrations without too much problems. Lastly, the social and/or industrial relevance should be highlighted in order to give students as well as visitors a clear picture of the relevance of the project.

The first project to follow these guidelines is the Unmanned Aerial vehicle presented in this paper.

II. The Idea

Things that fly have always been a stimulus to the imagination, for youngsters and adults alike, and are fascinating to work with. Radio controlled planes have in the past been prohibitively expensive. With the advent of better batteries, more advanced yet cheaper electronics and brushless motors, prices have come down remarkably, and building a UAV has recently come within reach of even the lowest budgets.

A. The Plane

Selecting the plane is not always easy. There are a large amount of model planes available, starting from the very small all the way to the very large. For starter UAV projects, it is important to choose stability over agility. While ducted air jets provide for a fast and exciting flight, they are more difficult to fly and chances are that crashes result in a large amount of damage. Therefore, one rather starts with a slow flying plane with a lot of wing area for stability.
Deciding between fuel or electric powered models is substantially easier, as the cost and maintenance of fuel

powered planes is substantially higher than electric powered models. An added advantage one has with electric powered craft is the reduced noise level compared to fuel powered airplanes.

In our case, we decided to go for the Sig Kadet shown in Fig. 1. Some of the deciding factors were its big wing area for stability and the fact that it came with a powerful brushless motor to make it easier to take up extra payload. The plane itself is lightweight (about 700g), and not unimportant, was semi-ready to fly. This last aspect makes it easier for starting pilots, as not balsa woodwork is required, and no special tools or materials are needed for assembly.

Fig. 1. Sig Kadet Plane

Some problems however became apparent with the choice of this airframe, the most important one being that it is actually too lightweight. This means that flying the plane becomes extremely dependent on weather conditions, especially wind speed. Vaasa is known to be the sunniest, but also windiest city in Finland.

While good enough as initial testing platform, it is clear that this is not the way to go forward. We developed a co-operation with the University of Joensuu, Finland which is doing forest engineering. They have been using remote controlled airplanes since 2007 to monitor forest and find suitable areas for cutting. The planes they are using are extremely cheap, build with off the shelf materials. This is a requirement for them, since landing in rough forest areas means they break their planes often.

One of the planes used by the University of Joensuu is shown in Fig. 2. This plane will be the base of our next UAV, as the University has been so kind to donate one of their planes to us. The fact that the plane is easy to repair in case of damage, or indeed to rebuild completely, makes it a much better choice for the aim of this project. Furthermore, the plane is capable of carrying a payload of 1 kilogram, and is itself much heavier than our testplatform, and is therefore much less susceptible to weather conditions.

B. The Electronics

The actual autopilot consists of a system derived from the Open Source Paparazzi autopilot system[2], developed by the

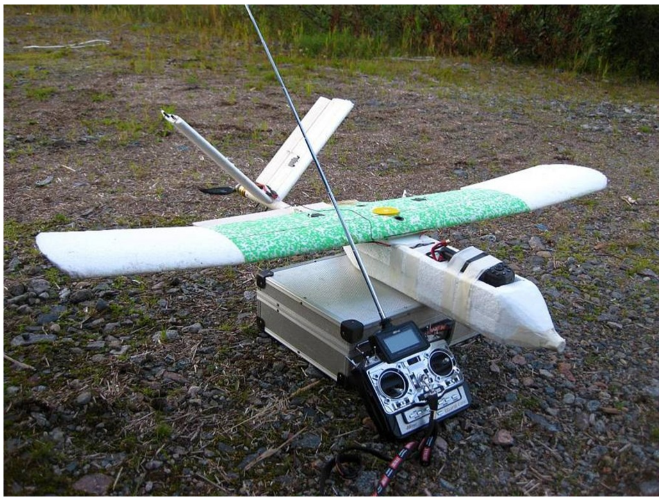

Fig. 2. Plane for Forest Monitoring from the University of Joensuu

École Nationale de l'Aviation Civile. It contains a ground control station (GCS) and an onboard autopilot based on an ARM microcontroller. The GCA and autopilot communicate through a radio link, in our case two AC4790 900MHz peer-to-peer modules.

The complete electronics as shown in 3 below contain:

1) ARM based Autopilot
2) Vertical infra-red sensor
3) Horizontal infra-red sensor
4) USB programming interface
5) Base station USB/Serial interface (FTDI)
6) HITEC HFS-05MS receiver
7) Telemetry datalink AC4790
8) GPS module
9) Base station AC4790

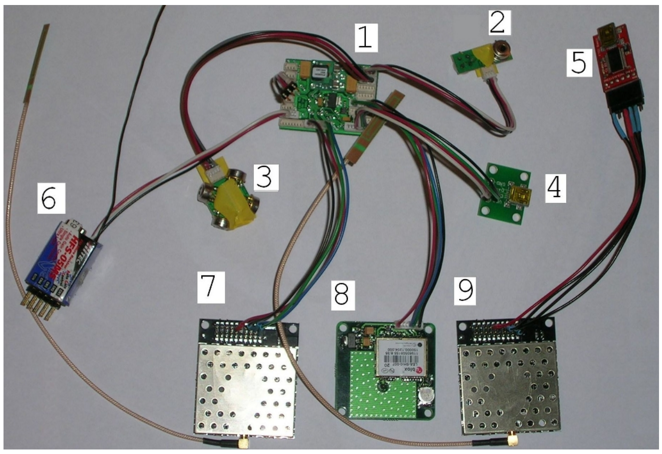

Fig. 3. Electronics

The ARM itself is used to control the servo's for the ailerons, rudder and elevator, and the Electronic Speed Controller (ESC) for the motor. This means that the servo control from the standard receiver is bypassed, and this requires a modification to the receiver as shown in Fig. 4.

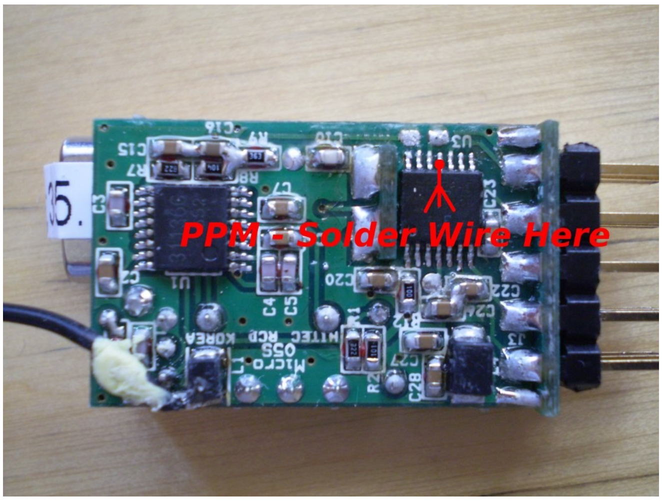

Fig. 4. Receiver PPM Bypass

This means that the ARM is also be used to do the Pulse Position Modulation (PPM) decoding, which allows us to have a cheap 3 or 5 channel receiver while still being able to decode up to 8 channels. The HITEC HFS-05MS receiver, which is a 5 channel receiver was included in the kit, yet, we can decode the full 6 channels needed from the transmitter, and more if needed in the future for e.g., camera control.

The infra-red sensors provide a cheap and durable alternative to inertial sensors for attitude control. The disadvantage of using infra-red sensors is that in agile aircraft, the slow response time of these sensors can lead to oscillations. This effect does not present any problems for our project.
The transmitter used in this project is a HITEC Optic 6 SPORT, a cheaper version of the HITEC Optic 6. It is used only for take-off and landing, and as a safety link. A switch on the transmitter allows for switching between autopilot and manual control. Paparazzi contains two autopilot modes, the first one (AUTO1) is used to test some of the autopilot settings, and is used in combination with manual control. The second auto mode (AUTO2) is full autopilot mode, and bypasses manual control completely. The normal way of switching between these modes is using a three position switch on the transmitter. The HITEC optic 6 SPORT does not have a three position switch, but does contain a 2 position switch to control the landing gear in some aircraft. The autopilot was adapted to cycle through the autopilot modes using this switch, using the sequence MANUAL → AUTO1 → MANUAL → AUTO2. This way, a cheaper transmitter can still be used, and no hardware modifications are needed to add a three position switch.

C. The Software

The main function of the Paparazzi GCS is to manage waypoints and track the position of the plane on an interactive map. Furthermore, it checks plane parameters such as battery condition, attitude, and radio link quality through messages sent by the onboard autopilot. It also contains powerful capabilities to record the entire flight data such as altitude, speed, etc. and to represent those in graph form.

The GCS is written mostly in OCaml. While this presents some challenges to find students able to understand this language, as a teaching tool it allows to demonstrate some of the uses of a functional programming language which might not be seen in the normal curriculum. The software itself is very well written and extending the base software with additional modules is easy. One of the main additions currently being integrated is a video monitor and control plug-in to control and view video from an onboard camera.

Simplification of the user interface is currently in planning stages. Since the system is intended to be used by people not necessarily used to flying model aircraft, let alone using a UAV, we intend to scale back the functionality of the GCS to the bare minimum for each intended application. This will hopefully allow for a wide range of people to use the system, with minimal training requirements.

One extra advantage the GCS has, is its ability to send out airplane control commands to the open source FlightGear flight simulator[3]. This allows testing of the programmed flight plans in a fully simulated environment before use in the real UAV. Accidental misconfiguration or errors can be easily spotted in this way, preventing unneeded and potentially costly crashes. The GCS together with a simulation using FlightGear is shown in Fig. 5.

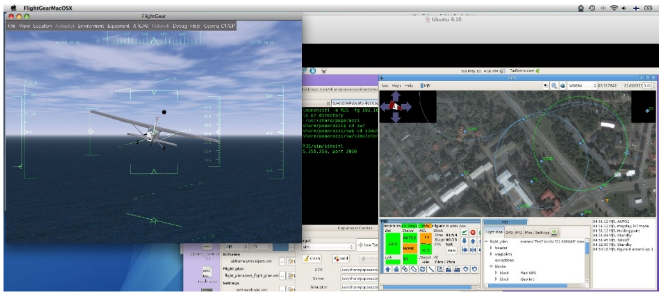

Fig. 5. GCS and Simulation

III. The Applications

Possible applications for UAV systems are vast. The problems with existing systems is usually the cost and the complexity, or are simply not available. Our main goal which we hope to accomplish is the ability to have a cheap UAV available for schools, both secondary and higher education, to inspire students in the fields of technology. Together with

WRD Systems, we also have some other target applications in mind which are briefly presented in the next sections.

A. Wildlife Monitoring

Planning is currently on the way to use the UAV project to track eagles and other wildlife in remote area's of Scotland. The animals often reside in very difficult to access regions and mountain areas, making accurate tracking difficult. UAV's could assist in locating and photographing animals, such as the golden eagle shown in Fig. 6, which can provide information on nesting locations and identification of individual birds. The UAV can be combined with existing GPS tracking methods to get better results, while also preventing too much interference with the birds themselves, e.g., humans can keep more distance and less birds would have to be equipped with GPS location equipment.

Fig. 6. Golden Eagle in Scotland (Source: Roy Dennis, http://www.roydennis.org/)

B. Crop Yield Estimation and Crop Monitoring

While crop monitoring has been done using radio controlled aircraft in the past, the systems on the market today are expensive. The idea is to use a UAV to do crop monitoring and, by use of machine vision techniques such as texture recognition, allow for crop yield estimation. The target area for this project is primarily developing countries. Local people would get training in how to use the technology to track damage to crops due to too little or too much irrigation or recognise damage by diseases and pests. Crop yield estimation could provide accurate numbers on the amount of food a crop can deliver, allowing for early actions in case of over- or underproduction.

C. Others

Perhaps the most obvious use of a UAV is research. Aerial observations and measurements can provide valuable information in a wide range of fields such as geography ad cartography. When equipped with meteorological sensors, information on geophysical conditions can be gathered with much more control than traditional means such as weather balloons.

One more area which is currently under investigation is disaster management. We are looking into the possibility of using the UAV to detect forest fires at an early stage. This could hopefully help the prevention of large scale fires which cost many lives ever year in places all over the world. Also, the possibility of using the UAV in search and rescue operations is currently being investigated.

IV. Conclusion

While currently not yet completed, we have managed to create a project that fulfils the requirements given in the introduction. The project is funded by an external source, it does not require a lot of resource dedication from the department, both in terms of manpower and that of infrastructure. Furthermore, we have demonstrated the social relevance of the project with regard to its applications as well as the relevance of the process of running the project from an educational point of view.

We have also noticed that students are interested in this project, and are willing to put substantial amounts of their free time and effort into the UAV project. At least one student started radio controlled aircraft as a hobby through this project, and has bought his own plane.

Acknowledgement

First of all, we would like to thank WRD Systems for their financial support and the initiative, without which this project would not have started.

We would also like to thank the University of Joensuu, Finland, for their donation of one of their planes. We look forward to continue further in this co-operation, applying the use of an autopilot to their forest engineering requirements.

Finally, we would like to express our thanks to the people on the Paparazzi IRC channel for their help.

References

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