THE UNIVERSITY OF NOTTINGHAM

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

Project Outline and Plan

Hands Free Control of a Quadcopter

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Introduction
The popularity of the small flying vehicle known as the quadcopter has dramatically increased over recent years. The vehicle, which consists of four rotating blades, is normally controlled by a handheld radio controller. Using the handheld device to control flight can prove somewhat challenging for unskilled users. This project looks at replacing the physical need to operate the handheld controller and instead uses gesture recognition to control the flight, hence offering 'hands free' control for the user.

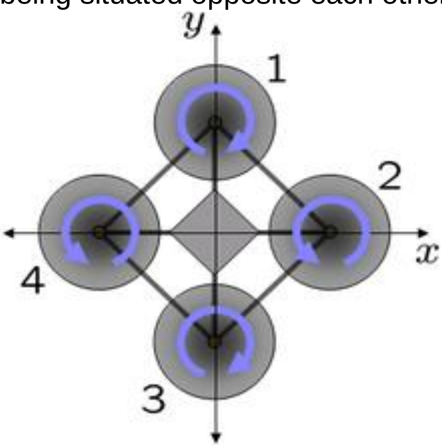
This report outlines the some background, design theory, aims, objectives and deliverables of the project. It also discusses the industrial relevance and gives a time plan.

Gesture Recognition
As humans, we understand gestures as a means of communication and expression. One obvious example of this is with use in sign language (which uses manual communication and body expression to convey meaning). Gestures thus can convey information in a nonverbal way which is recognised and interpreted by other humans. The study of this nonverbal communication is known as Kinesics [1]. This idea can be transferred to computers and as such, gesture recognition is the interpretation of movements and gestures of a human by a computer, using mathematical algorithms.

Gesture recognition plays a big part in computer science and robotics since it allows easier human – machine interaction than traditional graphical user interfaces (GUIs). Many parts of the body can be used in gesture recognition such as the head, face, hands, joints and body. These gestures are captured and used as inputs to a system and as such, different input devices exist. These include wired gloves, depth-aware cameras, stereo cameras, single cameras and controller – based gestures [2]. More recently, the use of radar has been used to capture gestures [3]. Most of these input systems rely on the temporal (time related) and spatial (space related) behaviour of the gestures [4].

Gesture recognition has a few technical challenges to overcome. These include the ability to be accurate and precise, and to distinguish between useful gestures and unwanted gestures or background interference. Noise can also be an issue if the type of gesture recognition is image based. There are also social challenges related to gesture recognition since gestures need to be simple, easy to understand and universally accepted [5].

Quadcopter
A quadcopter is a multirotor vehicle with four rotors in total. Each rotor has a blade of fixed pitch and the vehicle has a rotor in each corner, making it symmetrical. Two rotors spin clockwise, whilst two spin anticlockwise; with each pair that rotates in the same direction being situated opposite each other. The configuration is show in Figure 1.



Each rotor creates a thrust and torque about the centre of its rotation. Due to the configuration of the rotors, each torque cancels out if the rotors are spinning with the same angular velocity. In this case, the quadcopter has zero yaw rotation (rotation about the z-axis in figure 1). If a rotor pair is spinning faster than the pair spinning in the opposite direction; the quadcopter will rotate (i.e. if rotors 1 and 3 in Figure 1 were spinning faster than rotors 2 and 4).
If all four rotor speeds were increased equally, the quadcopter would thrust upwards and gain altitude. The opposite is true if all four rotor speeds were decreased.

Figure 1: Arrangement of quadcopter rotors [6]

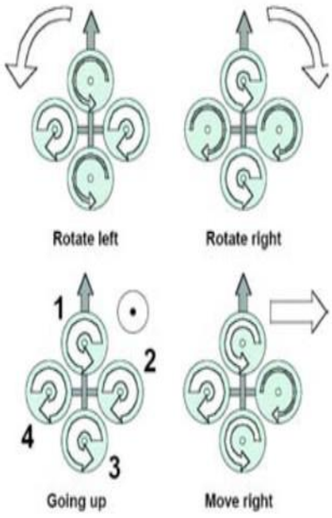


Figure 2: Quadcopter movement [7]

More movement options are seen in Figure 2 (note that this quadcopter has rotors spinning in the opposite direction to Figure 1). Rotation and gaining altitude (going up) has already been discussed above.

To move left or right, a rotor pair spinning in the same direction must have different angular velocities. An example of this is shown in Figure 2: rotor 4 has been accelerated and rotor 2 has been decelerated, hence the vehicle would move to the right. It should be noted that rotors 1 and 3 need to be kept constant during this process. Thus vehicle movement is achieved through varying rotor speeds.

Quadcopters have gained such popularity because they have big advantages over fixed wing aircraft and the conventional helicopter. The quadcopter is relatively small and omnidirectional. This means it has much greater manoeuvrability than both the fixed wing aircraft and helicopters [8]. It is also much cheaper and less complex to construct, which only adds to its appeal. Compared with the helicopter, it doesn't need any yaw compensation since, as explained above; it has zero yaw rotation when rotors are of the same angular velocity. Due to the fixed pitch rotors and vehicle control through variable speeds of them rotors, design is better and maintenance is lower than a normal helicopter. It also has much smaller rotors, resulting in significantly less kinetic energy present; which is a lot safer should a collision occur [9]. This is complemented by the fact that some quadcopters have guards over their rotors. These safety features explain why the quadcopter is so attractive for hobbyists and researchers, both for indoor and outdoor use. Cameras and other equipment can be easily fixed onto the vehicle and so this is why they are also used in imaging and military applications. When used in military or imaging applications, they are sometimes known as unmanned aerial vehicles (UAVs) or drones.

The conventional handheld controller uses two joysticks which move in four different directions each. Typically, one stick controls the pitch and roll whilst the other controls the throttle and yaw. An example of this configuration is shown in Figure 3.

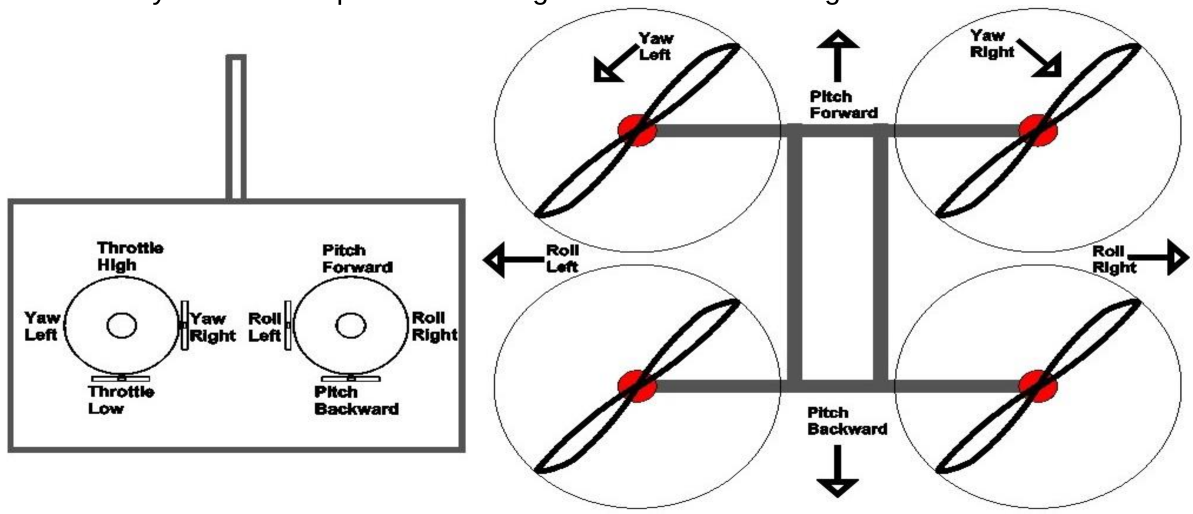


Figure 3: A typical handheld controller set up with quadcopter motion [10]

In Figure 3, the throttle would make the quadcopter lose or gain altitude. The use of the handheld controller is not trivial and is relatively difficult to master. This is because the two sticks need to be operated simultaneously to ensure smooth flight. Advanced flying requires a lot of skill and precision with the sticks, since it is hard to vary the rotor speeds manually quickly. The quadcopter is also relatively unstable to sharp and sudden movements. An additional challenge is that the pilot is not present on the vehicle. This means situational awareness can be hindered since the pilot is likely present on the ground whilst controlling the quadcopter [11]. The quadcopter is also prone to going out of sight if not careful.

Design Theory

The physical use of the sticks can be replaced with a system which captures gestures from a human user. These gestures can be captured using a motion sensor device, which one will need investigation. This device can be interfaced with a PC. The gesture inputs can then be translated into commands to activate controls on the handheld transmitter, allowing the user to control the quadcopter flight. The basic system is shown in Figure 4.

Figure 4: Basic design proposal

The positions of the two sticks on the handheld controller can be modelled as four variable voltages (one for pitch, roll, throttle and yaw respectively). These voltages can be given via digital potentiometers, the driving of which needs investigation. Interfacing the PC commands to the handled radio transmitter is not trivial and a few options can be explored. One option is to connect the PC commands first to a microcontroller, such as an Arduino or other microcontroller, and then to connect the microcontroller to the digital potentiometers. This configuration is shown in Figure 5.

Figure 5: An option for PC interfacing with digital potentiometer

A second option essentially skips the microcontroller and interfaces directly to the digital potentiometer via USB. With both options, the interfacing of the motion sensor to the PC will be done via USB.

Motion Sensing Devices

A range of motion sensing devices exist which could be suitable for the gesture recognition required. The most commonly known gesture recognition devices are used as controllers for video games. For example the Nintendo Wii Remote uses accelerometers and optical sensors to achieve gesture recognition. This is similar to the ASUS Eee stick. The feasibility of this type of gesture recognition device will be investigated.

Devices which detect the body are of more interest, since they will allow for better skeletal recognition. This will be useful since limb or hand movements could be used for this project. The devices under consideration are the Xbox Kinect, ASUS Xtion and the Leap Motion device. All three of these devices rely on camera and infrared light to recognise gestures. The ASUS Xtion and the Xbox Kinect both use a depth map to process the gestures [12], whereas the Leap Motion applies different algorithms to reconstruct a 3D representation of what is sees [13]. A review of these devices will take place and one chosen for the gesture recognition input to the system. The three devices are shown in Figure 6 below.

Figure 6: Xbox Kinect [12], Leap Motion [14] and ASUS Xtion [12]

Aims

The aims of the project are outlined below:

- To determine whether hands free control via gesture recognition is possible for something as complex as quadcopter flight
- To investigate different ways of implementing the interfaces of the system
- To provide an easier human interface than the conventional radio controller
- To implement a quadcopter flight control system using gesture recognition
- To push boundaries of hands free control

Objectives

The main objectives of the project are outlined below:

- Select suitable motion sensing device and capture movement through example programmes
- Select suitable digital potentiometers and method of driving them
- Interface PC to radio controller and ensure it is working
- Develop code to allow gestures as control inputs to system
- Interface the motion device and code into control system
- Have working quadcopter control
- Write Thesis

If all these objectives are achieved, then there is an option to improve the graphical interface on screen for the human. For example, a visual representation of the quadcopter flight path could be added on screen to aid navigation and situational awareness. It should be noted that this is an optional objective and is proposed as scope for expansion.

Proposed Deliverables

- Working potentiometer network which allows for full voltage swing of radio controller sticks
- Working interface between PC and radio controller
- Working code to manipulate gesture recognition information and produce outputs
- System controlling simulation quadcopter
- Fully operating system which implements correct gesture controls on quadcopter
- Final Thesis

Industrial Relevance

The quadcopter is a very commercially available vehicle with use for leisure, research and military purposes. It is also a relatively difficult to fly for the average unskilled person due to its complex flight. If hands free control can be demonstrated for a vehicle such as the quadcopter, then it could in theory be applied to less complex vehicles and machines. Hands free control can allow an unskilled person to fly the quadcopter much easier and so would have an even bigger appeal to the wider community. It would also make it easier for amputees and people with a disability to control a quadcopter, since they may not be capable of even using the handheld controller. It would also lessen the need for training to use drone type vehicles, which would be particularly useful in military applications. Hands free control could help mitigate the instability of the quadcopter to sharp manual movements by only processing gestures of a lower frequency.

Some motion sensors are also widely commercially available and are already used with great success as a controller for video games. Most development kits are free to download for these devices and so if more capabilities and applications are demonstrated; it could lead to more people trying it for themselves. This makes motion sensors more appealing and profitable and could further research into them. Gesture recognition as a whole is a growing field and is already prevalent in the gaming world. The market predictions state a lot of potential in this area [15] [16] and research is already on going in medical applications. For example; eye movement, head gestures and facial expressions are being captured to control devices such as intelligent wheelchairs [17] and even to control quadcopters [18]. Gesture recognition is likely to have more applications in military in future and is predicted to reach the automotive industry, which is being recognised by some companies [19].

This project will help to evaluate how fine the control can be implemented using gesture recognition, where there are a wide range of movements and high precision is needed. The control system will need to be accurate, but also capable of removing high frequency movement such as someone shaking constantly, possibly through illness. It tries to focus instead on the low frequency movement i.e. of moving a limb from one position to another.

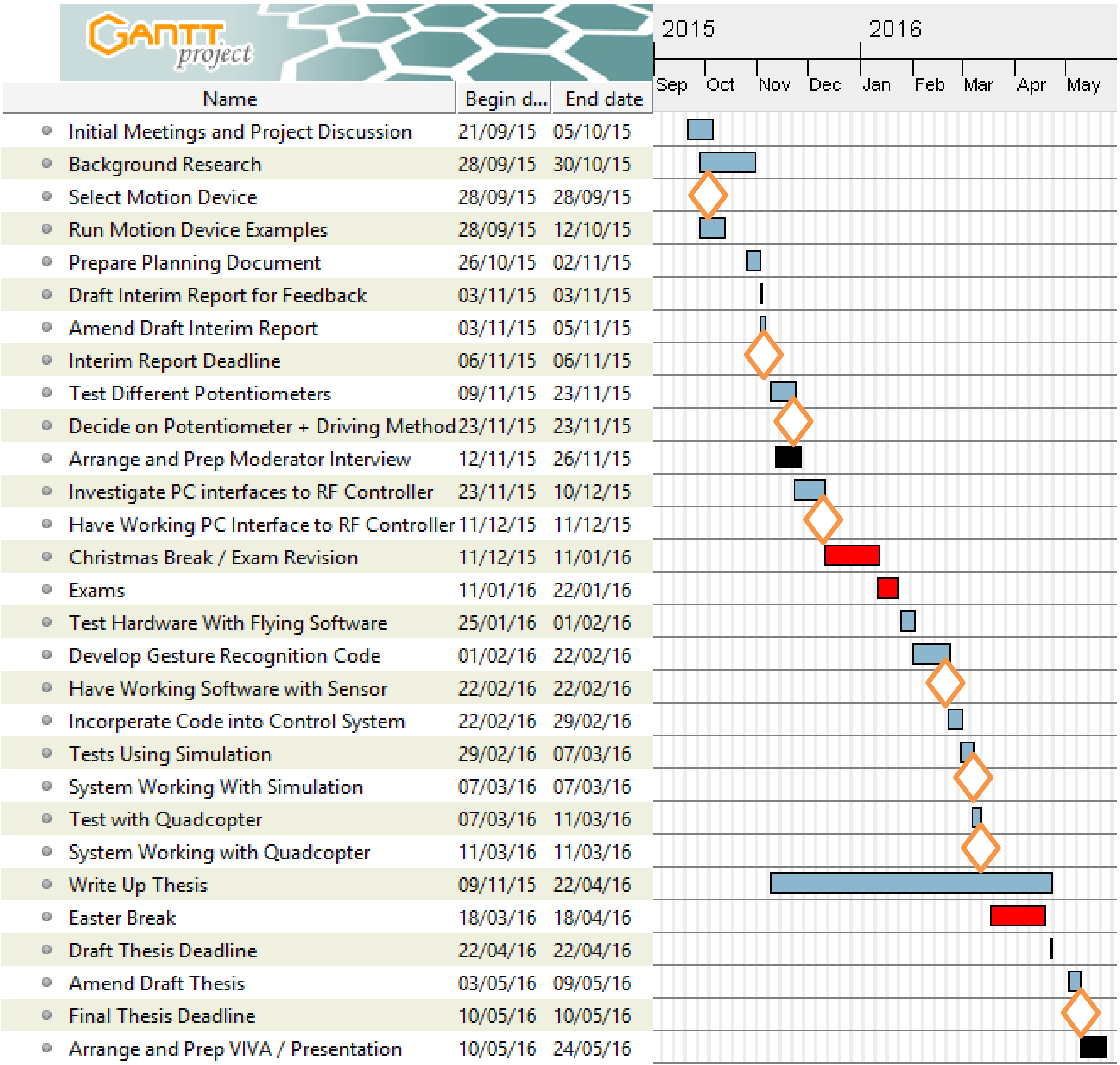
The project will also help to investigate different methods of interfacing PC's to robots and machines via USB or with the use of a microcontroller.

Time Plan

The time plan for the project is given below in Figure 7.

Milestones are as follows (in order seen in Figure 7):

1. Motion device selected
2. Interim report submitted
3. Working potentiometer network
4. Working PC interface with RF controller
5. Working software with gesture capture device
6. System controlling simulation software
7. System controlling actual quadcopter
8. Thesis completed



Name	Begin d...	End date
Initial Meetings and Project Discussion	21/09/15	05/10/15
Background Research	28/09/15	30/10/15
Select Motion Device	28/09/15	28/09/15
Run Motion Device Examples	28/09/15	12/10/15
Prepare Planning Document	26/10/15	02/11/15
Draft Interim Report for Feedback	03/11/15	03/11/15
Amend Draft Interim Report	03/11/15	05/11/15
Interim Report Deadline	06/11/15	06/11/15
Test Different Potentiometers	09/11/15	23/11/15
Decide on Potentiometer + Driving Method	23/11/15	23/11/15
Arrange and Prep Moderator Interview	12/11/15	26/11/15
Investigate PC interfaces to RF Controller	23/11/15	10/12/15
Have Working PC Interface to RF Controller	11/12/15	11/12/15
Christmas Break / Exam Revision	11/12/15	11/01/16
Exams	11/01/16	22/01/16
Test Hardware With Flying Software	25/01/16	01/02/16
Develop Gesture Recognition Code	01/02/16	22/02/16
Have Working Software with Sensor	22/02/16	22/02/16
Incorperate Code into Control System	22/02/16	29/02/16
Tests Using Simulation	29/02/16	07/03/16
System Working With Simulation	07/03/16	07/03/16
Test with Quadcopter	07/03/16	11/03/16
System Working with Quadcopter	11/03/16	11/03/16
Write Up Thesis	09/11/15	22/04/16
Easter Break	18/03/16	18/04/16
Draft Thesis Deadline	22/04/16	22/04/16
Amend Draft Thesis	03/05/16	09/05/16
Final Thesis Deadline	10/05/16	10/05/16
Arrange and Prep VIVA / Presentation	10/05/16	24/05/16

Figure 7: Gant chart for project

Gant Chart Key: **= Milestone** **Red = Exams / Break**

Blue = Normal Work **Black = Contact with Moderator / Report Deadline**

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Appendix: Supervisor Project Description

'Hands Free' Control of a Quadcopter

A quadcopter is a multi-rotor vehicle that has, as its name suggests, four rotors. The popularity of the vehicle has increased in recent years and is used extensively by hobbyists and research institutions interested in unmanned aerial vehicles.
For this project the vehicle is to be supplied as a kit of parts, which is to be built and its operation demonstrated by initially flying the vehicle in the traditional manner via the use of a hand held radio controller. The vehicle supplied uses an Arduino based flight controller whose features and capabilities extend beyond those of a traditional hand-held radio and vehicles using this controller are generically known as Arducopters [1]. The focus of this project is to take advantage of the enhanced capabilities of the flight controller and develop systems to communicate with the flight controller to control all or part of the vehicles flight. These systems are to be PC based, avoiding the requirement for the traditional manual/hand-held controller. The ultimate aim is to design and develop a system that allows the user to control all or part of the vehicles flight via an Xbox Kinect device[2]. The Kinect is a motion sensing device intended to allow users to interact with games running on an Xbox 360. Microsoft have released a software development kit (SDK) that allows the functionality of the Kinect device to be accessed when connected to a PC and allow developers to build PC based applications using common e.g. C++ or Visual Basic. Using the Kinect the user's gestures (or speech) can be translated into commands that are in turn transmitted to the vehicle, via a PC, without the user having to physically touch a controller.

Tasks:
1. Assemble the quad copter vehicle, detailing the steps necessary to provide a vehicle that is ready to fly.
2. Investigate flight capabilities of the Arduino autopilot and demonstrate via a simple figure of 8 flight path at fixed altitude.
3. Investigate methods of transmitting control signals from a PC to the vehicle.
4. Design a system capable of controlling the flight of the vehicle; this may be as simple as controlling lift off, to set altitude, prior to flying a predetermined flight path.
5. Acquire an understanding of the MS Xbox Kinect device and its SDK and develop an application to track simple body/limb movements.
6. Design and develop an interface that allows control of the quadcopter via the Kinect device; this again may be as simple as controlling lift off, to set altitude, prior to flying a predetermined flight path.

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