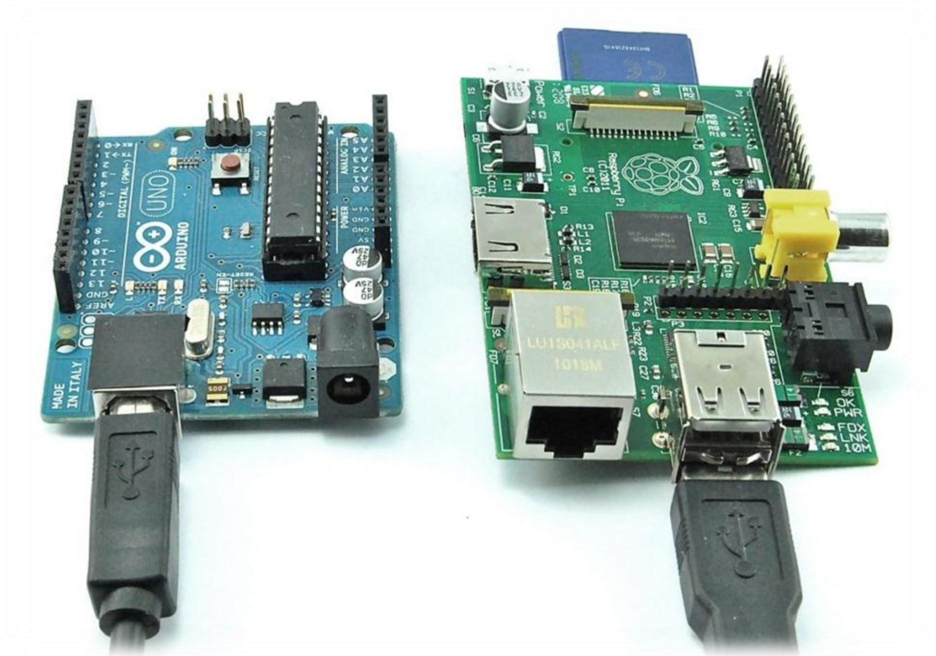
University of Strathclyde
Engineering

GROUP ACE
PHASE 1



24/10/12

CS413 Embedded Systems

Group 3
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I confirm and declare this report and the assignment work is entirely the product of my own efforts and I have not used or presented the work of others herein.

Signature____Date______________

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INTRODUCTION

The brief for this project was to plan, design, implement and document an embedded system ‘gadget’ made from an Arduino device and/or a Raspberry Pi.

After brainstorming it was decided that the gadget would be a remote control robot game, with firing mechanisms detected by ‘targets’ on the other robot. A ‘game-master’ will also be implemented that will take control of the entire game, including scoring and video streaming.

ASSESSMENT OF CAPABILITIES

The Arduino is an open-source electronics prototyping platform. It can receive input from a variety of sensors and can affect surroundings by controlling lights, motors and other actuators. It is low power and also has serial communication capability. It is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). The programming language is very similar to C/C++.

The Raspberry Pi is a single-board computer that is small in size (85.60 mm × 53.98 mm) and was developed to aid the teaching of basic computer science in schools. It uses the Linux operating system. The Pi has a Broadcom system on a chip which includes an ARM 700 MHz processor, a VideoCore IV GPU, and 256 Mb of RAM. There is not a built in hard disk but it has an SD card slot.

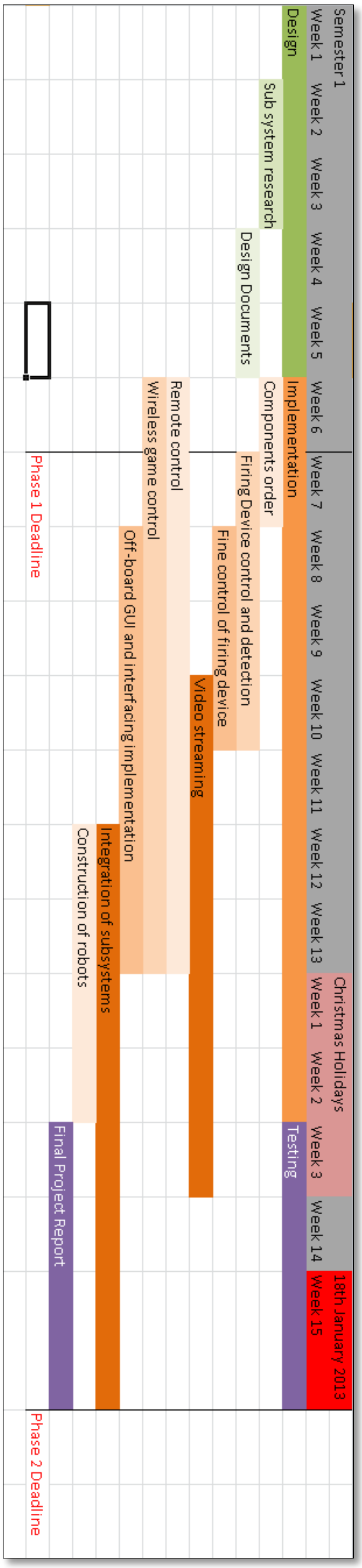
Due to the excellent sensor capabilities of the Arduino, it will be used on the robot to control the firing device and detect the targets. Due to the graphics processing capabilities of the Raspberry Pi, it will be used to stream video from the onboard cameras and display a GUI for the scoring system.

DEVELOPMENT ENVIRONMENT

The development environment of the Arduino is Arduino Sketches.

The development environment of the Raspberry Pi is any IDE compatible with Linux.

PLAN


Semester 1
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Week 11
Week 12
Week 13
Christmas Holidays
Week 1
Week 2
Week 3
Week 14
18th January 2013
Week 15
Design
Sub system research
Design Documents
Implementation
Components order
Firing Device control and detection
Fine control of firing device
Video streaming
Remote control
Wireless game control
Off-board GUI and interfacing implementation
Integration of subsystems
Construction of robots
Testing
Final Project Report
Phase 1 Deadline
Phase 2 Deadline

ADDITIONAL RESOURCES

Below is a summary of the costs incurred in the design of the game.

Component Required	Reason	Unit Cost	Number Required	Total Cost
Optek Technology OPV380 Laser Diode	Firing Device	£6.99	2	£13.98
Optek Technology OP550A phototransistor	Firing Detection	£0.64	2 min	£1.28
Futaba S3003 Standard Servo	Fine Control	£8.70	2	£17.40
Tower Pro Analog Servo	Fine Control	£1.98	2	£3.96
iWebcamera App	Video Streaming	£3.00	1	£3.00
Xbee Modules	Wireless Comms	£27.94	2 (possibly zero)	£0 - £55.88
USB Wi-Fi dongle for Raspberry Pi	Wireless Comms	£7	1	£7
Tamiya Tracked Vehicle	Platform	£19	2	£38

Total cost: £84.62 (not including cost of Xbees)

DESIGN

FIRING SYSTEM AND DETECTION

FUNCTION

The firing system is what the robot uses to shoot at the other robot. A robot will have one firing device and multiple targets which will detect the shots fired.

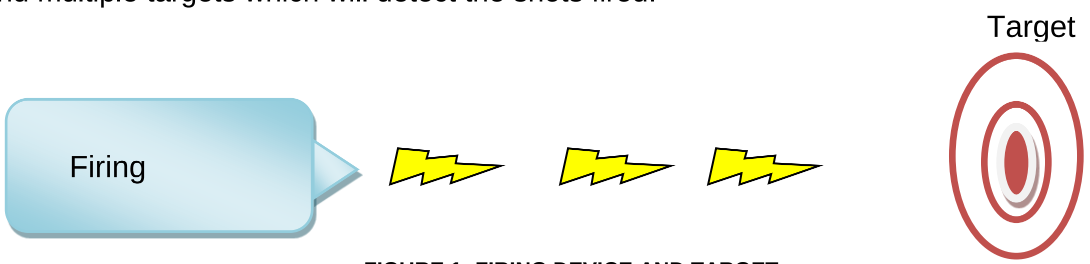


FIGURE 1: FIRING DEVICE AND TARGET

DESIGN

The firing device will be made from a laser diode. A laser diode has a small emission angle meaning that it is very accurate. To detect the laser, a photo transistor will be used. This detects the light and converts it to an electrical signal. The laser diode and photo transistors will be connected to the Arduino, as the Arduino is very good at receiving input from a variety of sensors and also controlling emitters.

Laser Diode

The laser diode that has been chosen is the Optek Technology OPV380 Laser Diode. Below is a table of the specifications of this device along with a picture of the diode.

TABLE 1: SPECIFICATIONS OF LASER DIODE

SPECIFICATIONS	VALUES
Wavelength	580nm
Current Rating	12mA
Output Power	1.5mW
Forward Voltage	2.2V
Reverse Current	100nA
Maximum Series Resistance	55Ω
Minimum Series Resistance	20Ω
Maximum Reverse Voltage	5V
Diode Case Style	Flat lens
No. Of Pins	2

FIGURE 2: OPTEK TECHNOLOGY LASER DIODE

Maximum Operating Temperature	85°C
Minimum Operating Temperature	0°C
Beam Divergence	20°
Laser Class	1M

This laser was chosen as it requires very low drive currents to obtain the same amount of output power as LEDs. This feature allows the laser diode to be used in low power consumption applications such as battery operated equipment, which makes it perfect for use in the robot. The price of this laser diode is £6.99.

Phototransistor

To detect this laser diode, the Optek Technology OP550A phototransistor has been chosen. It consists of NPN silicon phototransistors moulded in clear epoxy packages. It has a wide receiving angle that provides relatively even reception over a large area. Below is a table of specifications and a picture of the phototransistor.

TABLE 2: SPECIFICATIONS OF PHOTOTRANSISTOR

SPECIFICATIONS	VALUES
Wavelength	935nm
Power Consumption	100mW
Power Dissipation	100mW
Collector Emitter Voltage	0.4V
Current	2.55mA
Dark Current	100nA
Voltage	5V
Nom Sensitivity @ mW/cm^2	2.55mA @ 1mW/cm^2
Transistor Type	NPN
Maximum Operating Temperature	100°C
Minimum Operating	-40°C

FIGURE 3: OPTEK TECHNOLOGY PHOTOTRANSISTOR

Temperature	
External Depth	2.28mm
External Length/Height	5.71mm
External Width	4.45mm
Package/Case	Side Emitting

The phototransistor is priced at £0.64, making it very cheap to buy several to have different targets across the robot.

OTHER DESIGN OPTIONS CONSIDERED

Infra-red emitters were considered instead of the laser. An infra-red emitter is a lot cheaper than a laser. However, the beam from an infra-red emitter is not as accurate, and cannot be seen so that the user can aim. A laser can be seen and therefore aimed at a target. Also, the laser diode that was chosen uses a much lower drive current than infra-red LEDs.

Projectiles were also considered to be the firing device but were disregarded due to their complexity to construct and detect electronically.

FINE CONTROL OF FIRING DEVICE

FUNCTION

This system should allow the user to move the firing device in small increments after positioning the robot. An illustration of the movement can be seen in figure 4. This movement can either be on the x axis or on the y axis, turning the device horizontally or vertically.

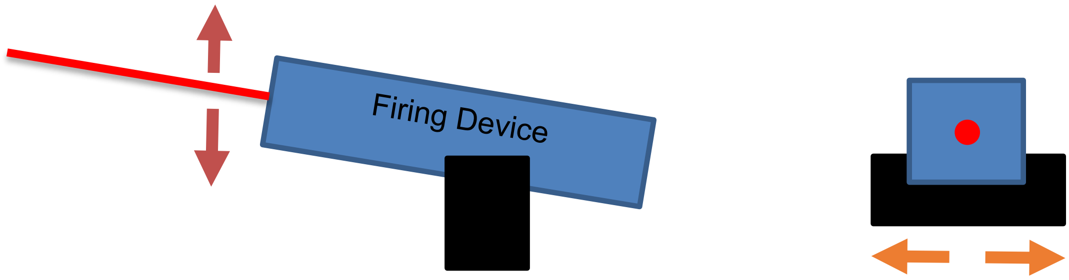


FIGURE 4 | INDICATION OF MOVEMENT OF FIRING DEVICE

Using this system it will be possible to alter difficulty by limiting range of movement therefore forcing user to move robot, or speed of movement.

CHOSEN DESIGN

Most solutions involved using servos to move the firing device. These servos are often used in RC cars to move throttle arms and steering position. They usually have low power consumption due to their portable use, and are small in size. This makes them ideal for our application. They also tend to be low cost.

FIGURE 5 | EXAMPLE OF A SMALL LOW COST SERVO

Many designs use two servos, one for the x axis, and one for the y axis.

The y axis servo is to have the firing device attached to it, with that mechanism mounted on top of a servo that controls the x axis. This design will mean that the lower servo does not have to lift the weight of the second servo and the firing device, just rotate it, meaning it will require less power/torque rating.

The servos can be controlled with Pulse Width Modulation from an Arduino’s digital output, giving a faux analogue voltage. This voltage can be fed into the control line (the other two being power).

Components

- **Lower (x axis) servo:**
  - Name: Futaba S3003 – Standard Servo
  - Price: £8.70
  - Voltage: 4.8V/6V
  - Speed: 0.19 sec/60°
  - Weight: 37.2g
  - URL: http://www.wheelspinmodels.co.uk/i/35787/
- **Upper (y axis) servo:**
  - Name: Tower Pro Analog Servo
  - Price: £1.96
  - Voltage: 4.8V/6V
  - Speed: 0.12 sec/60°
  - Weight: 9g
  - URL: http://www.rc-fever.com/tower-pro-analog-servo-9g-12kg-012s-w-servo-arm-sg90.html

Lower servo was chosen as standard solid option, with favourable reviews among RC community at (http://www.servodatabase.com/servo/futaba/s3003). Upper servo was chosen due to extremely low cost and weight, if it doesn't work or is not suitable, not much loss. Also has been used in similar applications (http://vimeo.com/18837811).

OTHER OPTIONS

Suggestion 1

This was to create a mounting for both the camera and the firing device. This would cause the mounting to be much more complicated and heavier – requiring heavier, more powerful and more expensive servos. The advantage would be that the camera would move with the firing device, helping the user to aim, however it could become confusing with the robot moving too.

A simpler solution could be to mount the camera behind the firing mechanism, so the user can see the position of it through the video feed.

Suggestion 2

Cost could be cut by having the firing mechanism just move in one direction, so the x or y axis. This issue with fixing the y axis is it places the onus on the designer to get the height of the target correct, as the user cannot adjust this.

Fixing the x axis is possible, as the user can adjust by moving the robot. It is suggested that this is used as a fall back if the mounting for the two servos proves too time consuming. The flexibility that the two servos give for changing difficulty etc. outweighs the disadvantages of the complicated mounting.

ONBOARD VIDEO

FUNCTION

The On-board Video system should capture a live feed from each robot and display both feeds on a screen on the off-board device. The video stream should be good enough quality to be able to facilitate both the movement of the device and determine how much to adjust the fine firing control.

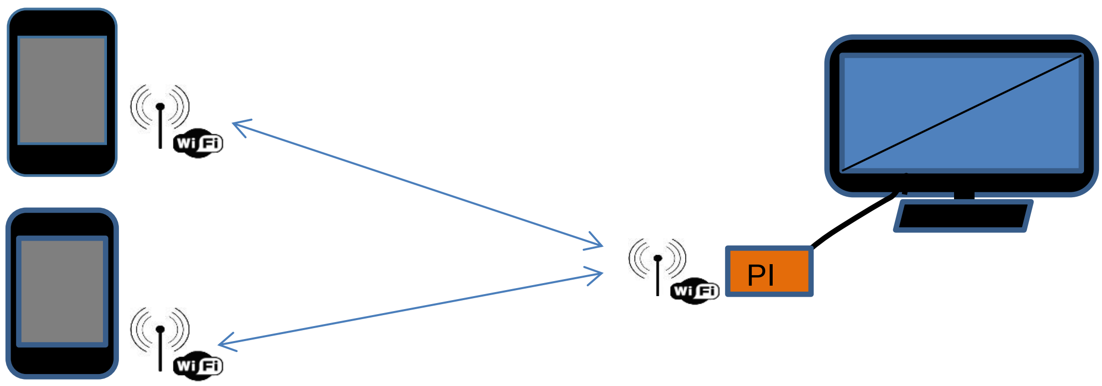


FIGURE 6: VIDEO SUBSYSTEM

CHOSEN DESIGN - IWEBCAMERA - £6.00

FIGURE 7: IWEBCAMERA

Description

This provides a virtual webcam to your computer by connecting to an iPhone/iPod touch running iWebcamera. This will provide us with two webcam streams on the Raspberry Pi, one each from an iPhone/iPad on each robot.

Components

- 2 compatible iPhones/ iPod touches - Requires iOS 4.0 or later.
- A copy of iWebcamera - £2.99
- Network connection between the two iPhones and the Raspberry Pi.

Justification

This design was chosen due to the availability of the hardware, the group already has access to two iPod touches that can be utilised in the project. The other solutions although possibly providing a neater more concise solution to the project, fell far outside of the project budget and so would not have been possible.

OTHER DESIGNS

1. Wireless Analogue Camera - £22.98

The wireless analogue camera is a fairly good solution to our problem, it uses fairly old technology so is available surprisingly inexpensively. It still gives us the problem of having to input an analogue signal into the game controller but this can be accomplished in the same was as described before with the usb camera capture device for around £6 per video input. We would need to ensure that the software for these would be compatible with the operating system used on the game controller. If a Raspberry Pi used likely to be some variation of Linux.

2. Wi-Fi IP Webcam - £35.74

The Wi-Fi IP camera seems to solve a lot of the problems with the previous options presented. It displays the video stream in an http window on a networked device.

It also offers remote pan and tilt which we could utilise for the firing device. It even has infa-red LED's built in which could possibly be focussed and used in the firing system.

It is compatible with 802.11g networks which means we would need to set up either an ad-hoc or preferably a network with a router to facilitate the connection to the game controller. Also works with different types of security although probably net an issue for the current use of the project is something that could be important if the device was used for other purposes.

OFFBOARD SYSTEM

FUNCTION

The offboard system refers to the scoring system of the game, and the smart phone app that will allow the user to drive the robot.

Scoring System

When a robot fires at the other robot and hits a target, they will be awarded a point. The point value will depend on how easy or hard the target was to hit. When the sensor is hit, a message will be sent to the main game master to increment the score of the robot who shot the target. This score will then be displayed on a screen in the form of a GUI. The figure below demonstrates this.

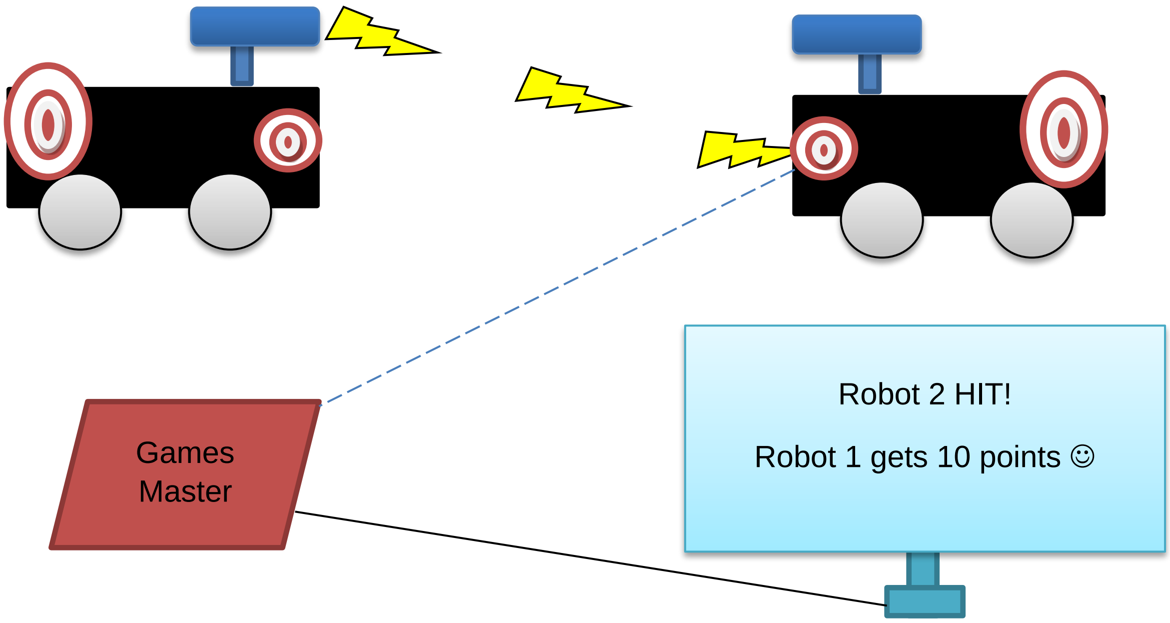


FIGURE8: SCORING SYSTEM

Smart Phone App

An app will be created to allow the user to control the robot. It will have buttons for the motion of the robot (left, right, forward, backward) and it will also have buttons to control the firing device (pan left/right, pan up/down, fire). A basic diagram can be seen below.

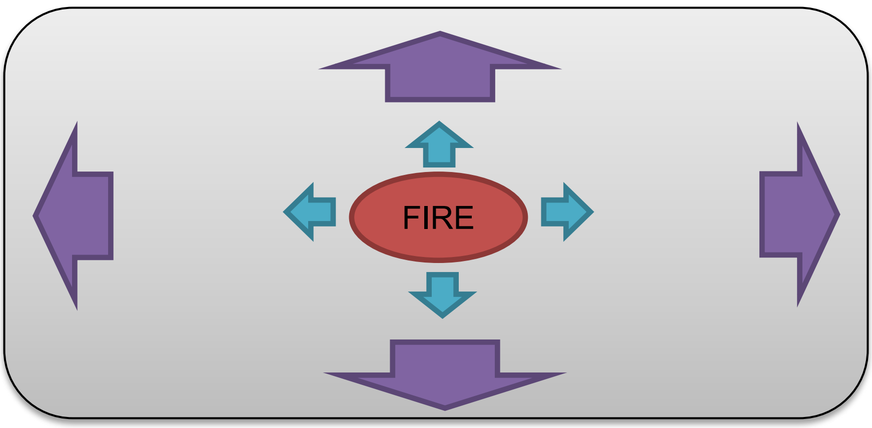


FIGURE 9: SMART PHONE APP

DESIGN

Scoring System

The scoring system will be programmed using Java, as GUI's are very easy to make in Java. Below is a class diagram showing the intended classes that are to be made. The GUI has the possibility of displaying the score in many ways. One option is to have a picture of the robot with the targets and when a target is hit, the target could flash to show it has been damaged. Another option is to display the different targets with a tally system, showing how many times each target has been hit.

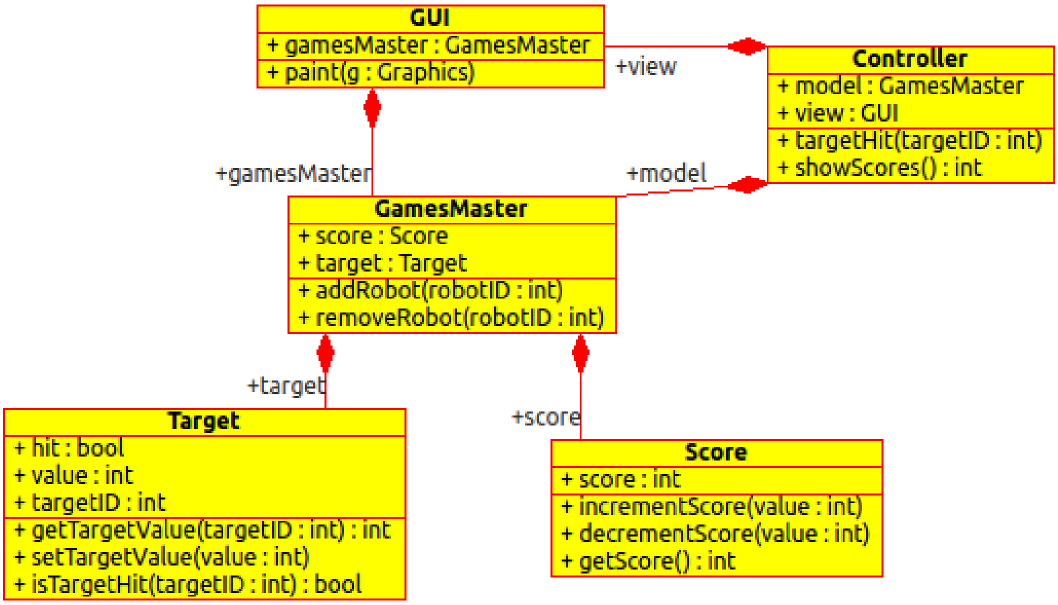


FIGURE 10: BASIC CLASS DIAGRAM

Smart Phone App

The app will be designed as simple as possible. It will have buttons to move the robot, to move the firing device and to fire the device. Figure 9: Smart Phone App shows one option for the layout of the app. Another option is to have the controls for moving the robot on one screen, and then the controls for moving and firing the laser on another, switching between the two by pressing a button. This is shown below.

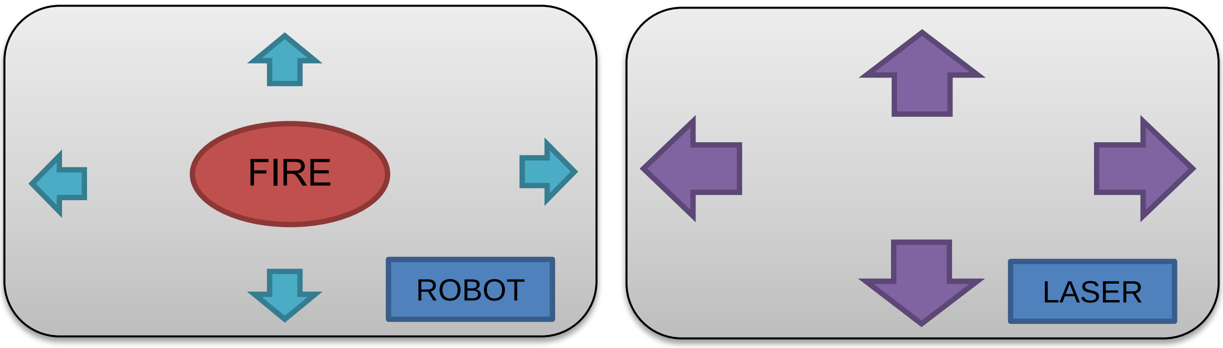


FIGURE 11: ALTERNATIVE IDEA FOR SMART PHONE APP

OTHER DESIGN OPTIONS CONSIDERED

Scoring System

The scoring system could be made by simply printing the scores to a console, but this does not look very impressive and is quite boring. Therefore, a GUI is going to be made. The Raspberry Pi was chosen to host the scoring system as it is very powerful and it is good at graphics. The Arduino, while suitable for sensing the shots being fired, would not have been suitable for hosting this programme.

Smart Phone App

The robot was considered to just be controlled via a remote controller. However, this is very basic. A smart phone app is up to date and can be changed over time to include new features or a different style set. Also, remote controllers can easily be lost or broken while an app is simply download to any device that you have handy at that moment in time.

COMMUNICATIONS

FUNCTION

This system involves controlling the robots through a smartphone and notifying the games master when game events happen, such as a robot being hit, game start/stop etc.

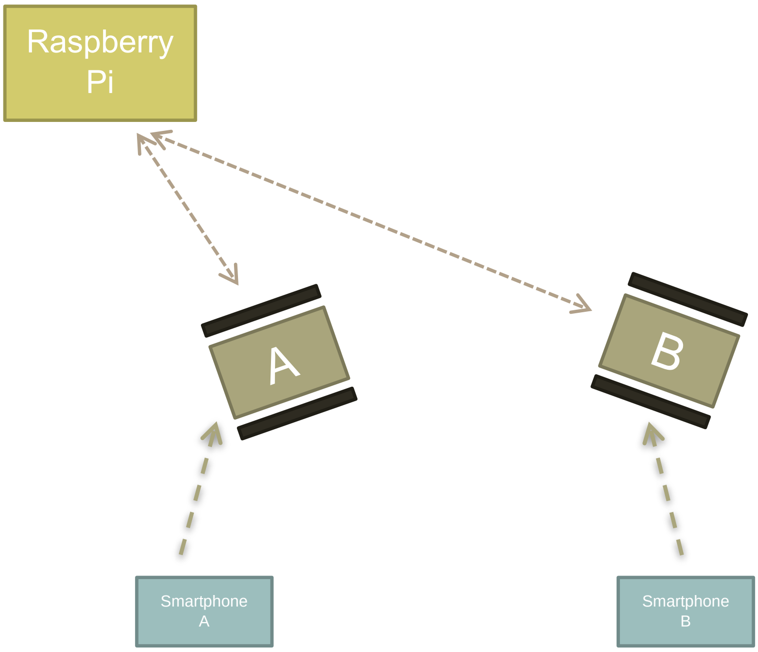


FIGURE 12 | OUTLINE OF COMMUNICATION LINKS REQUIRED

Different communication options and configurations were considered in terms of cost and ease of implementation.

CHOSEN DESIGN

Description

It was decided to use Wi-Fi as the main communications technology due to ease of implementation, as there are small modules available called Xbees. These modules interface easily with the Arduinos, and allow two-way communications over IP. There is much documentation online about using these devices, and most of the group has some experience with network programming so this was a clear choice.

In terms of configuration, it was discussed and a preliminary design is to use the games master as a server, so the smartphones communicate with that, and then that passes on the commands to the robots. This keeps the data streams tidy, and means that the Arduino programming has to only deal with one recipient/transmitter rather than keeping track of two devices. It should be simpler to deal with this functionality in the games master. A block diagram of this configuration can be seen in figure 13.

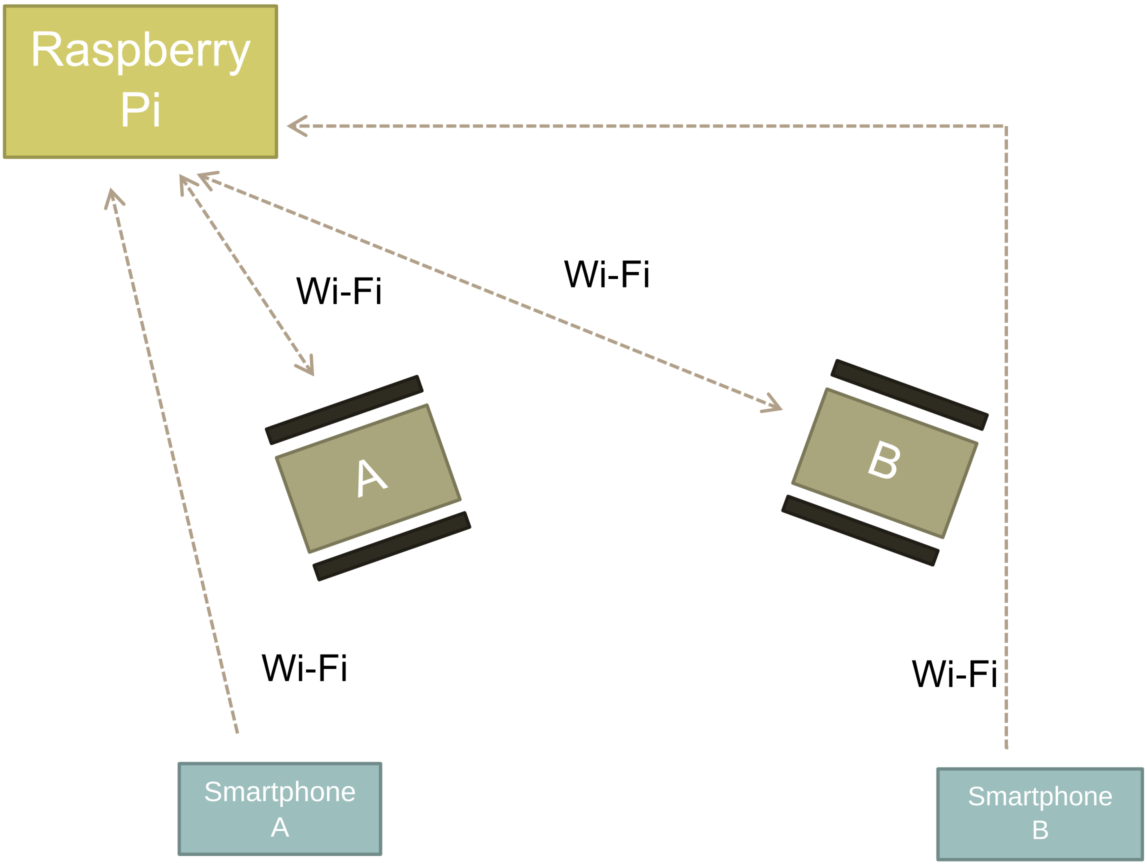


FIGURE 13 | DIAGRAM OF CHOSEN CONFIGURATION

Components

The main components required are Xbee modules. We would require two of these; however Duncan has indicated that some may be available from previous years projects.

FIGURE 14 | XBEE MODULE

Price: £27.84

URL: http://uk.farnell.com/digi-international/xb24-bwit-004/module-zigbee-xbee-znet-2-5-1mw/dp/1546390

Shields can be used as a quick, easy and neat way to connect Xbees to the Arduinos. Again, two would be required.

FIGURE 15 | XBEE SHIELD

Price: £16.80

URL: http://uk.farnell.com/jsp/displayProduct.jsp?sku=1848697

In addition to these devices, it will be necessary to connect the Raspberry Pi to a wireless connection. USB dongles are available to do this.

Price: £6-£7

URL: https://www.adafruit.com/products/814

OTHER OPTIONS

Suggestion 1

This was to replace the Wi-Fi connection with Bluetooth. This would be made possible as smartphones have Bluetooth built in, and a module attached to the Arduino.

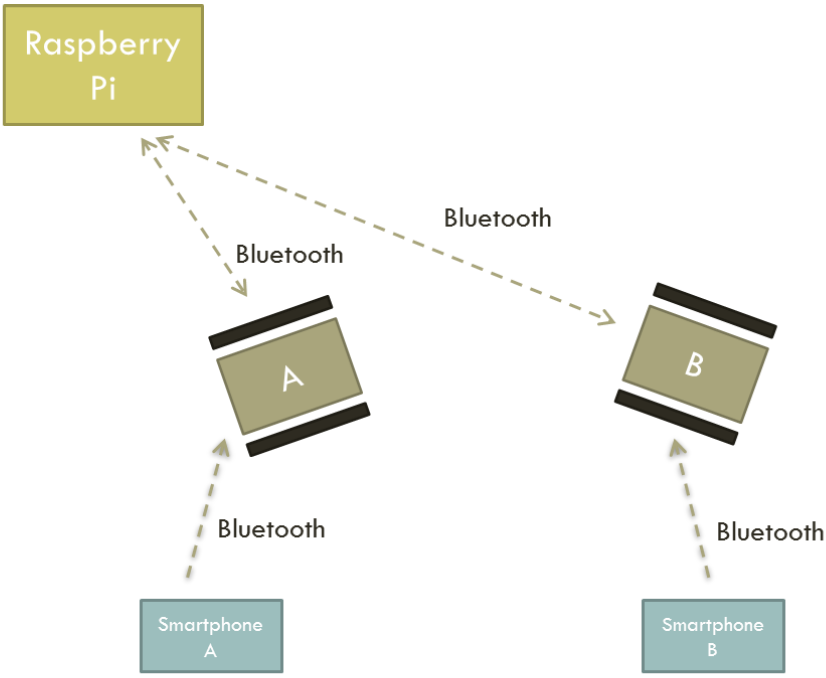


FIGURE 16 | BLOCK DIAGRAM OF BLUETOOTH CONFIGURATION

An example Bluetooth module is:

- Name: Bluetooth Moto Silver
- Price: £26.94
- URL: http://proto-pic.co.uk/bluetooth-mate-silver/

However controlling Arduinos straight from smartphones is not particularly simple, and using iOS is not possible without jailbreaking. There has been some success reported using Android (http://myrobotlab.org/content/connecting-android-phone-arduino-using-bluetooth) however there are not two Android smartphones available within the group. In addition to this we would need to connect the Arduinos to the Raspberry Pi via Bluetooth, which could cause issues with multiple streams etc.

Advantages:

- Standalone (no local network required)
- Range + Power is appropriate for application

Disadvantages:

- Inexperience with Bluetooth protocol gives uncertainty as to ease of implementation
- Could be expensive compared to Wi-Fi, as ZigBee modules possibly already available for use.

Suggestion 2

The last option was to use Bluetooth for control of the robots, and Wi-Fi used for game events. This was dismissed due to the need to have both Wi-Fi and Bluetooth available on the robots, leading to a complex and costly design, when one or the other or the technologies would be suitable by themselves.

PLATFORM

FUNCTION

The Platform of the device should provide a mobile platform to base all the electronics on-board. It should be able to be manoeuvred relatively easily as well as being big enough to hold all the electronics equipment and associated power supplies. Manoeuvring the device should be able to be controlled using a number of digital outputs from the Arduino. The power needed for the device should be able to be supplied using an on-board battery although this may be different from the one used to power the electronics.

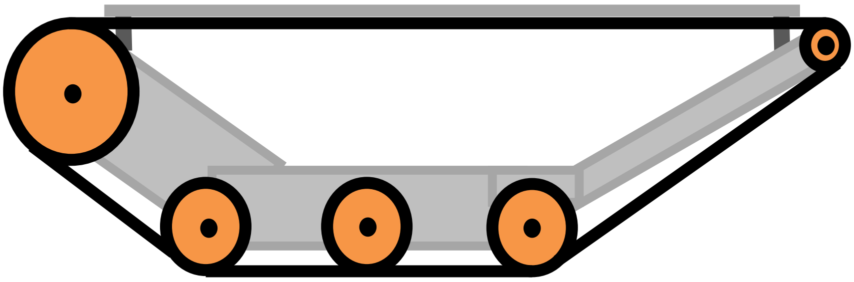


FIGURE 16 | DIAGRAM OF PLATFORM

CHOSEN DESIGN – Tamiya Tracked Vehicle - £19.00

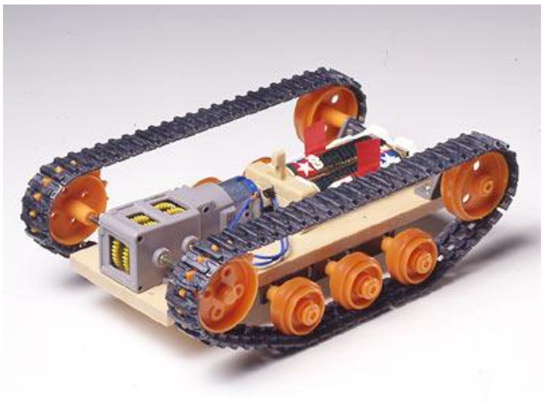


FIGURE 17| TAMIYA TRACKED VEHICLE

Description

The Tamiya tracked vehicle kit contains all the components we should need to build the base for our robotic device

Size: 8.5 x 5.6 x 2.4 inches

Components

Need the chassis kit as well as a dual motor gearbox so the robot can be manoeuvred left and right as well as the forward and back functionality offered by the single gearbox that comes with the chassis.

http://www.tamiya-model.co.uk/shop/tamiya/tracked/vehicle/chassis/kit-p-5751.html

http://www.tamiya-model.co.uk/shop/tamiya/double/gear/box/leftriight/independent/4/speed-p-6477.html

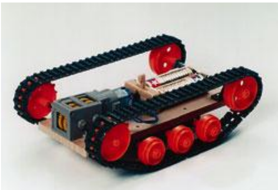


FIGURE 18| PLATFORM


FIGURE 19| GEARBOX

Two possible gear ratios Standard: 203.7:1 or High Speed 8.2:1.

Justification

This design was chosen due to the simplicity and cost of the hardware, the Tamiya chassis comes as a kit and should be relatively easy to assemble . A lot of the other solutions were also a lot more complex and would have taken a lot more fine adjustment after construction to do things like coordinate motors. A lot of them also fell far outside of the project budget and so wouldn't have been possible.

OTHER DESIGN OPTIONS CONSIDERED

1. DAGU MR. BASIC MOBILE ROBOTIC PLATFORM- £18.60

FIGURE 20| DAGU MR. BASIC MOBILE ROBOTIC PLATFORM

The Dagu Mr. Basic Mobile Robotic Platform is a simple 4WD robot chassis with an aluminium base, 2 motors/gearboxes and a 3xAA battery holder. The prototype PCB on top is double sided with plate through holes. The motors are rated 4.5V-6V with a no-load current of 250mA and a stall current of 1.8A @ 4.5V each. The main issue with this product is it seems to be only supplied for the US market.

- Aluminium based 4WD robot chassis
- 2 motors/gearboxes and a 3xAA battery holder
- Double sided PCB with plate through holes
- Motors are rated 4.5V-6V with a no load current of 250mA
- Robot Dimensions: 13cm (long) x ~9cm (wide)

2. 4WD ALUMINIUM MOBILE ROBOT PLATFORM - £45.00

FIGURE 21| 4WD ALUMINIUM MOBILE ROBOT PLATFROM

The 2012 latest 4WD aluminium mobile robot platform. It can hold many controllers, drivers, sensors and RFmodules. It has a support plate with controller mounting holes, 2 dof pan and tilt holddown groove, a collision switch mounting hole, and can have sensors added. It is light weight, high strength and has no deformation characteristics. It is a unique design and colour, with elastic rubber tyres that have damping, are wear-resisting and have a strong grip.

1.Robot kit
2. No-load speed: 120rpm
3. Wheel diameter: 120mm
4. Wheel width: 60mm
5. Platform length: 1280g

OVERALL CONCEPT

CHOSEN DESIGN

Below is a diagram of what the overal design of the gaget look likes.