Progress report marking sheet

Student's name: **Deborah Taylor**	Student's Reg: **100085169**	
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2nd marker:	Date:	Signed:
Title: **Designing, Building, Coding and Tracking a Mechanical Hand/Arm**		

	Agreed Marks
Description of project: aims, motivation	/10
Description and understanding of issues and problems addressed in the project	/20
Design and planning	/50
Evaluation of progress	/10
Appropriate use of LaTeX	/10
Overall mark	/100

Comments

Report and completed mark sheet should be returned to the LSO.

Designing, Building, Coding and Tracking a Mechanical Hand/Arm

Deborah Taylor

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1 Introduction

Since the first industrial arm was built in 1954, by George C. Devol[1], the majority have been claw based and aren't very dexterous or flexible. Due to their design restrictions they can only perform precise, repetitive tasks and are liable to fail if the claws are not aligned correctly, or one stops working. (Rosen, 2011), (Grigore and Scassellati, 2017).

To increase manoeuvrability and flexibility, while also reducing restrictions, the mechanical arm needs to be redesigned so it can replicate the majority of movement in a normal human hand, instead of using a claw.

The purpose of this project is to build a bespoke mechanical (robotic) human skeletal hand/arm, code[2] it to pick up and put down items using relevant fingers on the hand and track items or movement. This will enable the project to develop a flexible hand that will continue to work, even if one of the fingers is broken or not in alignment.

2 Motivation and Aims

2.1 Motivation

Prosthetic limbs have been an interest, ever since the author's school friend developed meningitis at an early age and ended up losing an arm. The author saw how difficult it was for that person to complete even the simplest task, such as dressing or tying a shoelace.

With current skill levels and the project time-frame, it will not be feasible to develop a fully functioning prosthetic limb, therefore, the author has shifted focus to commercial uses instead. Commercial arms are more straight forward to develop and are used in a multitude of industries from manufacturing to defusing bombs.

This project will enable the author to develop their skills (a possible precursor to moving forward into health research and prosthetics) while still producing a project that can be useful commercially.

2.2 Aims

The main aim of the project, as mentioned in the introduction, is to design and build a mechanical hand/arm, with coding that enables it to demonstrate the flexibility and functionality of a human hand.

The hardware will be able to complete basic tasks such as moving each finger, moving the hand/arm up, down, left and right, plus, picking up and putting down an item. It will,

[1] George Charles Devol, Jr. American Inventor born 20 Feb 1912 and died 11 Aug 2011

[2] Code and coding are other names for programming. Programming is a way of entering instructions into a machine to execute commands.

also, have more complex coding to play Rock, Paper, Scissors[3] or solve the Towers of Hanoi[4] (Ito et al., 2016), (Benditkis and Safro, 2006).

The author is still in the process of identifying which of these two options will be the most suitable for this project, so the design and build is being completed so either can be coded, at a later date. Whichever option is chosen, any missing movement from the other one can be incorporated into the basic coding, to ensure full flexibility is demonstrated.

3 Design and Hardware Build

An online Trello board has been created to log each task, within the project. This enables the author to continually monitor progress and ensure all tasks are completed correctly. To view this Trello board access: https://trello.com/b/cdHgyGX0.

This project involves both hardware and software so a Software Engineering Design Document is needed to show designs, development and testing[5]. This is the best way to make sure each stage of the design and build is completed correctly and efficiently (McElrath, 2007).

3.1 Design

The full Design Document is too large to include in this report, so an overview is covered here.

3.1.1 Similar Systems Analysis

One of the first stages in designing any hardware and software is to investigate and review similar products, to see which features are available and how they differ from the new one being designed.

This ensures there is no crossover of hardware or software already in existence and helps clarify specifications, requirements and scope. This is, also, a way to identify if there are any "off the shelf" hardware or software that can be used and, if not, whether there is anything currently in use that can be adapted for the new project.

See figure 1 below for analysis of five mechanical arms already in use:

[3] Played between two people. Each player forms one of three shapes with an outstretched hand. "Rock" is a closed fist, "Paper" is a flat hand and "Scissors" is a fist with the index and middle fingers extended. It has only two outcomes, either a tie or one of the players win.

[4] Object of the game is to move all the disks over to Tower 3 but you cannot place a larger disk onto a smaller disk

[5] A Design Document is a technical guide for Developers and includes Definitions, Requirements, Use Cases, etc.

Figure 1: Analysis of 5 different mechanical arms

Website	Included Features	Difference to project Mechanical Hand	Other Notes
Universal Robots: UR3 Robot https://www.universal-robots.com/products/ur3-robot/	360 Degree Rotation on wrist joint Infinite rotation on other joints	270 Degree extra rotation as project will only have 90 Degrees on all joints Claw rather than Hand based No camera for tracking software	Commercial only but some design specifications could be adapted for use in non-commercial design
Fast Picker TP80 Robot https://www.staubli.com/en/robotics/6-axis-scara-industrial-robot/low-payload-6-axis-scara-robot/fast-picker-tp80/	Sturdy Design Simple Mounting High Speed Does not interfere with the line of vision of the camera 0.5 kg load capacity	Claw rather than Hand based Project will move at slower pace for more flexibility.	Camera option can be included in project for tracking software Commercial only but some design specifications could be adapted for use in non-commercial design
ST Robotics R17 5-Axis Robot Arm https://uk.rs-online.com/web/p/industrial-robots/1242698/	Vertically articulated robot arm Hand terminates in a mounting plate to which can be mounted one of ST Robotics low-cost grippers Easy to program Fully enclosed (wiring goes through the arm)	Claw rather than Hand based Wiring on project will be outside the arm.	Could adapt the mounting plate process into the project to enable stability
DIY Robotic Hand Controlled by a Glove and Arduino http://www.instructables.com/id/DIY-Robotic-Hand-Controlled-by-a-Glove-and-Arduino/	Hand and glove linked Glove is mounted with flex sensors Arduino reads the voltage change when the sensors are bent and triggers the servos to move Servos pull strings that act as tendons, allowing the fingers to move	Project hand will not be linked to a glove. Hand and Arm will work independently once coded	Arduino parts could be used within the project
Brunel Hand https://www.openbionics.com/shop/brunel-hand	Fully articulated robot hand 9 degrees of freedom (DOF) Programmed using the Arduino programming environment	Project hand will have fewer DOF Cost of £1,499.00 too high for project	Use of Arduino environment could be used for project. Basic design look could be adapted into project

3.1.2 MoSCoW Analysis:

Once the *Similar Systems Analysis* is completed the next stage is the *MoSCoW Analysis*.

This process determines the different requirements that will be in and out of scope for the project, along with how they should be prioritised for development.

This analysis is made up of *Must Have, Should Have, Could Have, Won't Have* tasks.

Must Have:

The ***Must Have*** tasks are identified as absolutely crucial, at base level, for the project to work. These will be prioritised within development and the *Should Have* section will not be started until these are fully completed and tested.

- *Skeletal hand design and arm (up to the equivalent of an elbow)*
- *Fingers and thumb that can move independently and/or together*
- *Movement rotation of 90 degrees, up, down, left and right*
- *Basic coding to enable movement of the arm: up, down, left and right*
- *Basic coding to enable the hand to pick up, hold and put down an item*

Should Have:

The ***Should Have*** tasks are identified as necessary to the project to increase effectiveness within the design. These are the second stage of a development and will only be started, completed and tested, once the *Must Have* tasks are working correctly.

- *Complex coding to enable hardware to play Rock, Paper, Scissors or solve Towers of Hanoi puzzle*
- *Sensor or Camera connected to the hardware (with or without a wire) to identify items or movement*

Could Have:

The ***Could Have*** tasks are identified as nice to have, but not necessary for the project to be successful. These are tasks which are desired and may be implemented, depending on cost and the time-frame available.

- *Ability to move independently of a PC or laptop (utilising a servo controller mounted on the arm)*
- *Haptic sensors to enable feedback on how the hand grips an item*

Won't Have:

The ***Won't Have*** tasks are identified as out of scope for the project and will not be implemented. If the project were to continue into a future development stage, these could be implemented then.

- *Independent thought and movement eg Artificial Intelligence*

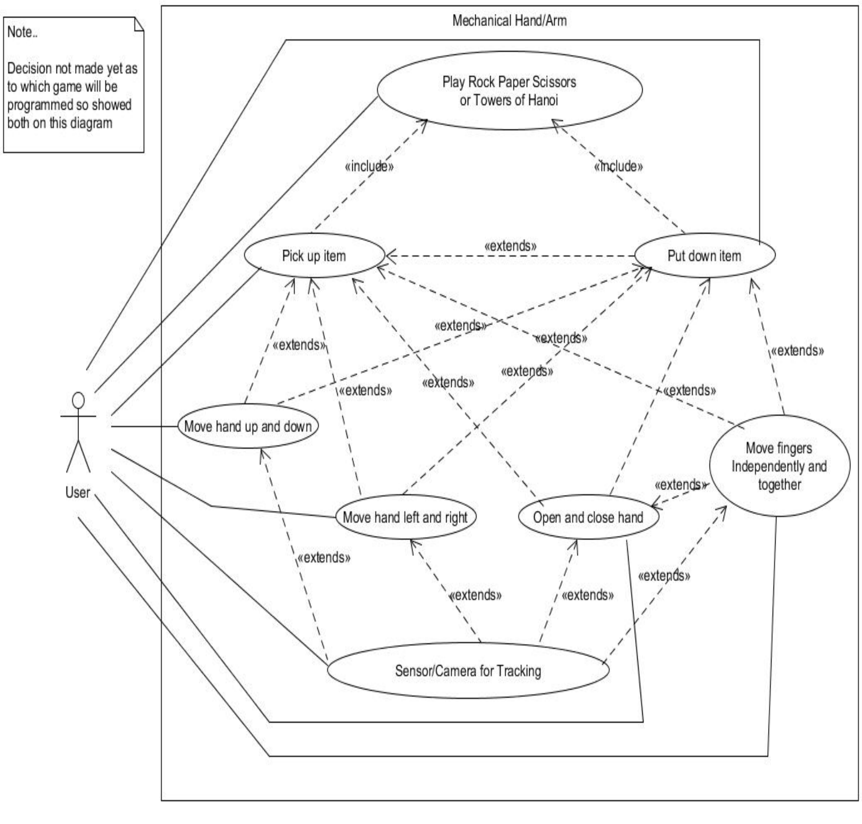
3.1.3 Use Case (UML) Diagram:

Once the *MoSCoW* analysis is completed a *Use Case (UML) Diagram*[6] is designed to show User interaction with the hardware (Aljamaan et al., 2014). From the above *MoSCoW Analysis*, the priorities (to enable the hand to play either Rock, Paper, Scissors or solve the Towers of Hanoi) are identified as:

- *Move hand/arm up, down, left, right and open, close the hand*
- *Move fingers independently and/or together so items can be picked up and put down*
- *Use a sensor or camera to track items and/or movement*

As these priorities are necessary to the project, they need to be added to the *Use Case UML Diagram*, to show how they interact and link together. See figure 2 below:

Figure 2: Use Case UML Diagram



[6]Unified Modelling language (UML) is a standard modelling language for developers to visualize and document tasks

3.1.4 Use Case Descriptions:

Following completion of the *Use Case UML Diagram*, *Use Case Descriptions* are written, for each of the tasks shown on the diagram. See below for an example:

- *Use Case 3 Open Hand: describes the process of connecting the laptop signal to the Hand hardware and enabling the Hand to open. This is a basic command that will be fundamental to the Hand movement for later, more complex, coding.*

3.1.5 Detailed Use Case:

The descriptions are then expanded into *Detailed Use Cases*. These show steps required to achieve each task eg triggers, frequency, release schedules and provide information needed for development. See figure 3 below for an example:

Figure 3: Use Case3: Open Hand Example

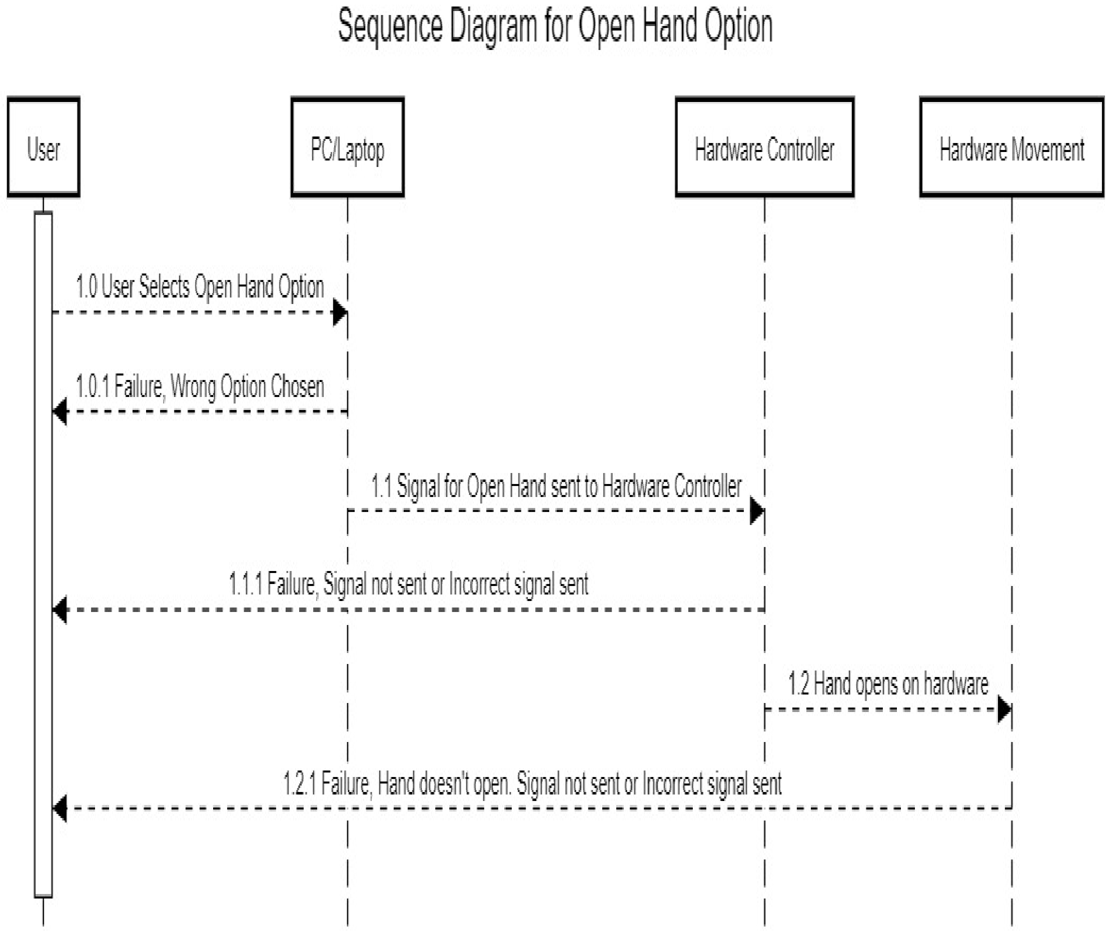
Use Case 3 (Open Hand)

USE CASE NAME	Open Hand	
Goal in Context	To allow a user to open the Hand	
Scope & Level	Overall system	
Preconditions	System is running and hardware is turned on	
Success End Condition	The User is able to open the Hand	
Failed End Condition	The User is unable to open the Hand	
Primary Actor	User	
Trigger	User selects option to open the hand via choice on a laptop	
SUCCESS SCENARIO	**Step**	**Action**
	1	**The User selects the Open Hand option**
	2	**The System sends signal to the Hardware to open the Hand**
	3	**Hardware opens the Hand**
ALTERNATIVE SCENARIO	**Step**	**Branching Action**
	1a	**The User selects the wrong option**
	1b	**The Hand moves in different way than expected**
	2a	**System doesn't send the signal as Hardware not connected correctly**
	2b	**System sends signal but Hardware isn't connected properly so no movement**
	3a	**Hardware doesn't interpret signal correctly, so Hand doesn't open**
RELATED INFORMATION		
Priority	High	
Frequency	Frequent, as several Hand movements will involve opening the Hand	
Subordinate Use Cases	N/A	
Channel to Primary Actor	User Interface	
Secondary Actors	N/A	
Channel to Secondary Actors	N/A	
OPEN ISSUES		
SCHEDULE	Due date is version 1.0.	
AUTHOR	Debbie Taylor	

3.1.6 Sequence Diagram:

Once the *Detailed Use Cases* are completed the final stage[7] is to create *Sequence Diagrams*. These show step by step representations of specific scenarios. See figure 4 below for an example:

Figure 4: Sequence Diagram Example



Completing this Design Document confirms there is no "off the shelf" skeletal hand/arm hardware available, so a bespoke build is required for this project.

3.2 Hardware Build

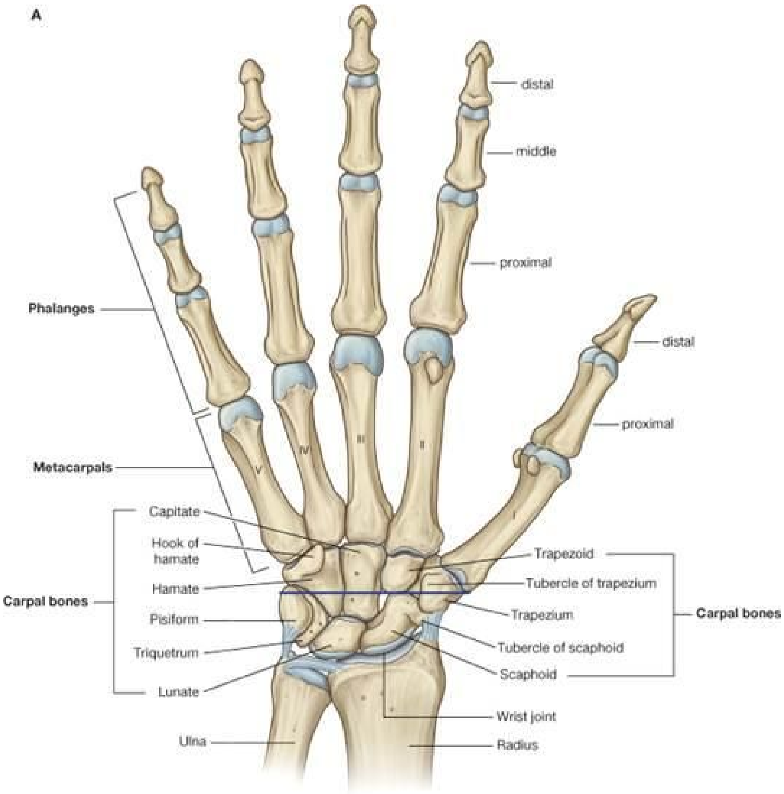
The first stage of the build involves identifying how a human hand works.

[7] As this is a hardware and software design there is no need for Architecture diagrams

3.2.1 Skeletal Human Hand Investigation:

In order for a hand to open, close, move each finger, hold items etc, a combination of the fingers and thumb need to be working in sequence (Freivalds, 2011). The author investigates the skeletal structure, by reading up on human anatomy and learning the names and connections for each section of a hand[8].

Figure 5: Human Hand Skeleton



This identifies exactly which metal shapes need to be cut and how many servos, joints etc are needed to build the hardware.

A friend (who is a machinist) supplies the bespoke metal skeleton "bone" parts, from specifications provided, using figure 5 as a template.

The rest of the equipment (eg servos, wiring, sensors, servo controller unit etc) are obtained separately "off the shelf", using some of the ideas obtained from the *Similar Systems Analysis*.

The author originally decided to keep the build specific to a single brand name (eg Arduino) but a more cost effective approach, found while researching the schematic, is to buy "mix and match" parts from several different manufacturers.

3.2.2 Hardware Build Progress:

Due to the hardware being fundamental to the project, the build starts during the summer holidays and continues until the middle of Semester 1. Multiple photographs are taken showing step by step progress.

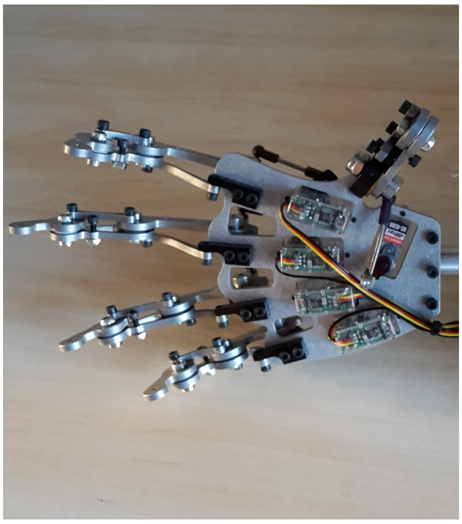
[8]Figure 5 Source: http://visual.merriam-webster.com/human-being/anatomy/skeleton/hand.php

See figure 6 below for a selection of four photographs showing the build as it progresses:

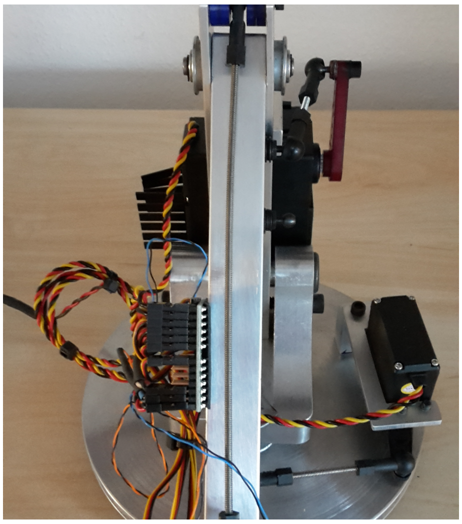
Figure 6: Build Progress from start to complete

(a) Start

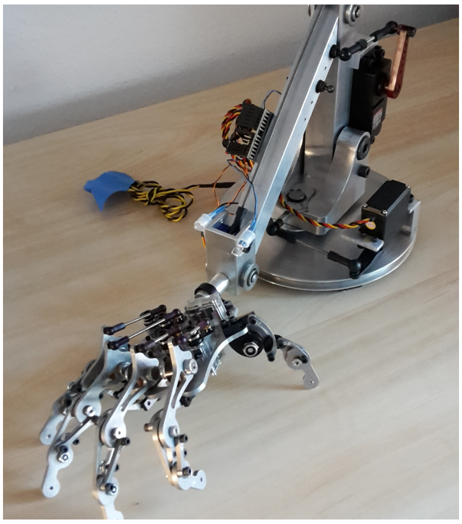
(b) Hand built



(c) Arm built



(d) Complete-Hand/Arm connected



The build does not go completely to plan, as the author originally estimates it will take about three full weeks, however it ends up taking just over seven. The hand and arm itself are more complex than expected and there are several welding issues before the parts are fully positioned.

Also, when testing the basic coding, the original servos are found to be too strong and cause some movement issues, so new ones have to be ordered and re-inserted onto the hand.

4 Issues and Contingencies

The main issue, so far, is the hardware build and basic coding taking much longer, and being more complicated, than originally considered when the project was proposed. Some of the parts also take longer than expected to arrive and, as stated above, some have to be re-ordered and re-inserted into the hardware due mistakes by the author.

The build, however, is fully completed half way through Semester 1 and the basic coding script is written and tested. The hand can currently move up, down, left, right, hold a paper coffee cup, move it and put it down.

This means the ***Must Have*** section of the *MoSCoW Analysis* is fully completed and tested, leaving the more complex tracking coding (***Should Have*** section) ready to be started.

Unfortunately, due to a personal family bereavement, the project has to be placed on hold for several weeks, causing an unexpected delay. Due to this delay the author has identified a few potential issues going forward into the next stage of development. They are:

- *Bereavement continuing to impact productivity and efficiency*
- *Investigation of complex coding taking longer than expected*
- *Hardware breakdowns*
- *Combining complex coding with the basic coding script already written*

These are considered carefully, along with the delays already occurring, so contingencies can be put in place, to ensure the project is completed on time.

At the end of this report are two project Gantt Charts. The first (figure 8) shows the original version included in the Project Proposal. Due to the issues and delay stated above, this plan needs to be changed.

The Christmas holidays are originally unused so, from a contingency viewpoint, this holiday is now being included in the revised plan. The remaining tasks have also been revised, with new time-lines, to ensure the project remains on target and take into account the first two potential issues identified above. See the second Gantt chart (figure 9) for the revised plan.

The potential hardware breakdown issue is being covered by the author ordering spare backup parts (eg sensors, servos etc) so any breakdowns can be fixed immediately, rather than having to order and wait for new parts at a later date.

And finally the potential coding issue is being dealt with by the author writing the complex code separately and testing it each time a movement, or tracking process, is written.

This will ensure it does not interact with the basic coding, so will not cause any problems to the code already written. A decision will be made, at the end of development, as to whether this should be integrated into the basic coding script, or left as a separate process.

5 Evaluation

Following careful reflection and evaluation the author feels that, even with the unexpected delay, good progress is being achieved with this project.

The skill level of the author, for electronics and understanding how software code interacts with hardware, is increasing considerably and all mistakes are being learnt from and will not happen again.

The Design Document, also, turns out to be more important than originally expected. It not only ensures the hardware is built to cover all the critical movements in a human hand but, also, identifies the build as quite complex and will probably take longer than originally estimated.

To help mitigate this issue, the build is started during the summer holidays, instead of being left until the Semester starts in September. If this were left until September the unexpected delay, mentioned above in the Issues and Contingencies section, will have fallen during the *Must Have* stage of development and will have caused a major disruption.

Instead the delay will cost the project time, but the revised Gantt chart (figure 9) shows it is still possible to accomplish the original completion date, by including Christmas and working longer hours during Semester 2.

To ensure no further delays occur, and any potential issues are dealt with quickly and efficiently, progress will continue to be closely monitored during the second half of the project.

This will be achieved by the author using Trello to keep tasks on target, having regular meetings with their project supervisor and with careful project management of their available time during Semester 2.

Overall, with the revisions stated above, this project should be completed on time and provide all the requirement needed for a successful delivery.

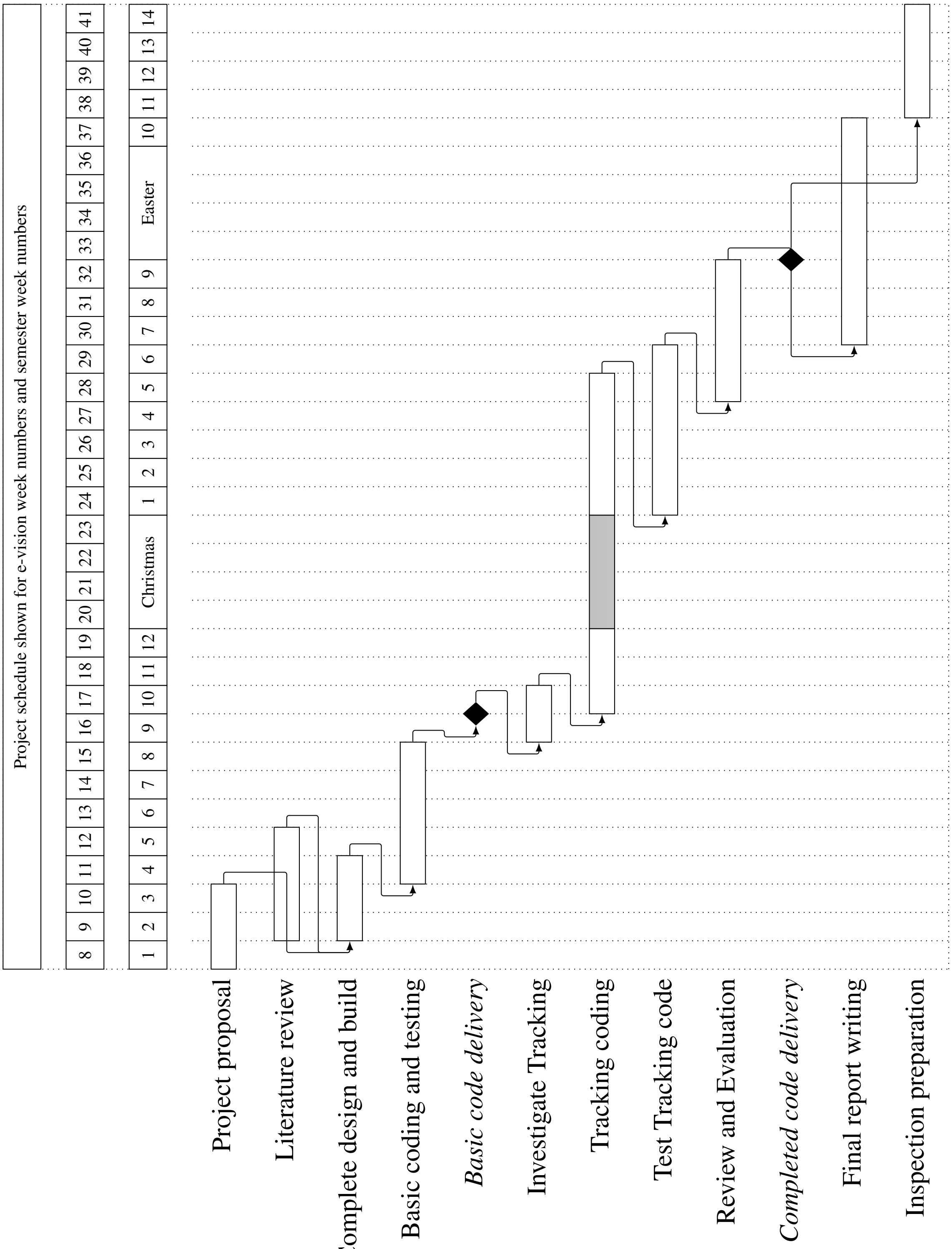


Figure 8: Original Project Gantt chart time-table

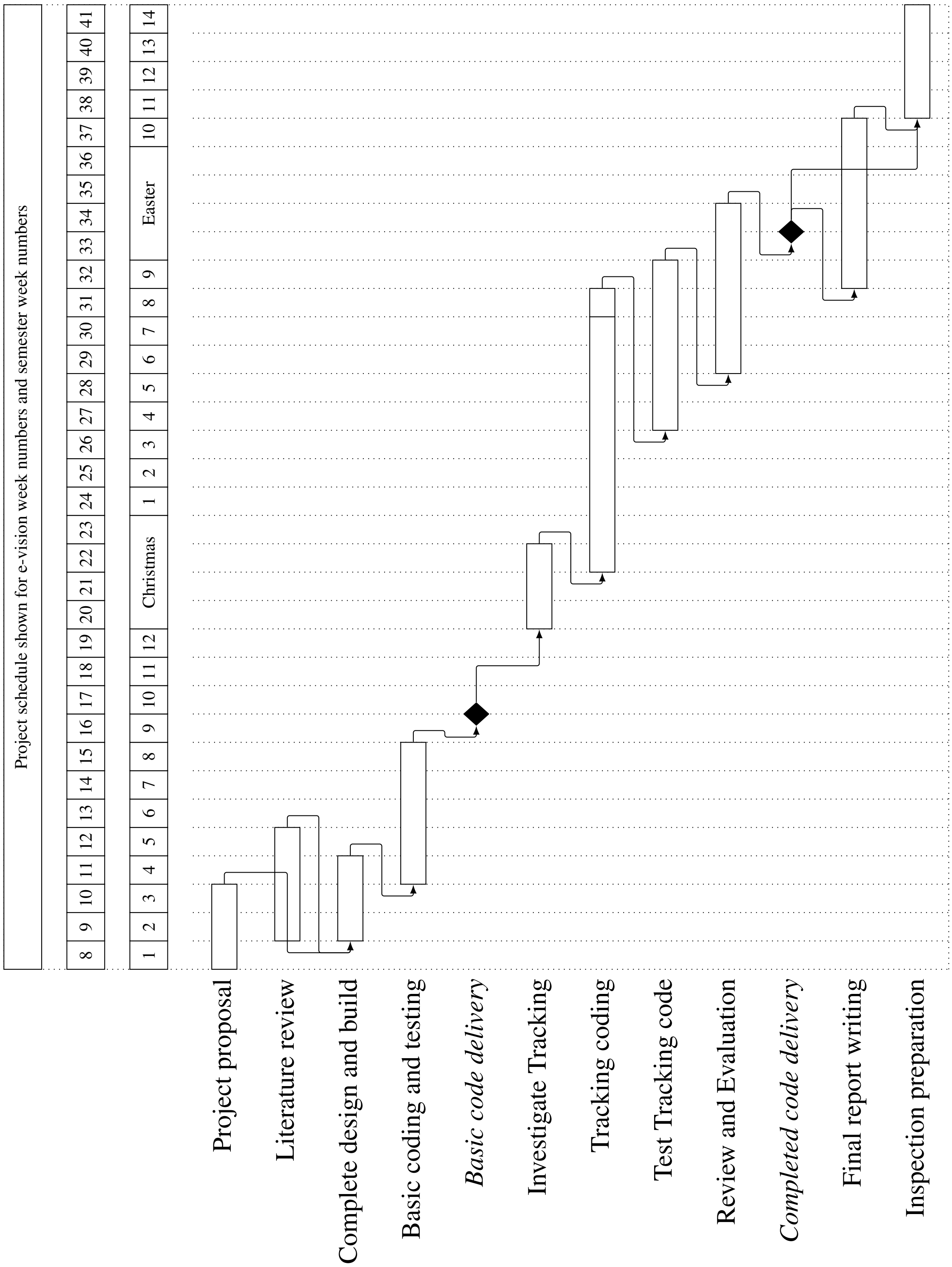


Figure 9: Revised Project Gantt chart time-table

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