ENGINEER 1C03 - Engineering Design & Graphics
Engineering 1 Cornerstone Design Project

Instructor: Dr. Nease

Technical Report

Team **6**

Lab Section**: L06**

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As a future member of the engineering profession, the student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University and the Code of Conduct of the Professional Engineers of Ontario.

Submitted by Madeline Coleman

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Submitted by Shiv Thakar

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Arnav

Submitted by Arnav Arora

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Submitted by Davies Umoh

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Introduction

Design Problem

This report outlines the design for a low-cost gripping apparatus for an advanced prosthetic for BME Devices. This apparatus is designed to be a full right hand, with working/moving fingers. The design was required to take an input speed of 67 RPM and, using a gearing mechanism, reduce the rotational rate of the finger and thumb to 15 RPM. The gearing mechanism also needed to be designed such that the forefingers and thumb rotate in opposite directions from one another on specified axises. Finally, the design needed to include a bracket which supported the gears but did not interfere with the given prosthetic frame.

Final Design

Our final design is composed entirely of spur gears. The design has a total of fourteen spur gears which reduce the given input speed of 67 RPM to 15.033 RPM, a rate which is within 0.5% of the desired speed. Our final design consists of the following gears: two 14 tooth gears, two 18 tooth gears, three 20 tooth gears, four 24 tooth gears, two 26 tooth gears, and one 28 tooth gear. All gears have a module of 1 mm/tooth except for two 20 tooth gears with a module of 1.0213 mm/tooth, and two 25 tooth gears with a module of 1.06 mm/tooth. The slightly different modules were used to ensure that the finger and thumb rotated about the appropriate locations. Our design also included a unique one piece axis that supports all of the gears and rods.

Overview

This technical report consists of our gear calculations, gear parameters table, simplified gearing mechanism drawing, as well as our CAD documentations. The gear calculations show how we achieved our final output speed as well as the rotational speed of each gear. The table of gear parameters is a summary table that shows the number of teeth, diameter, type of connection, speed, and direction of motion for each gear. The simplified gearing mechanism drawing is a simple diagram that shows the arrangement of all the gears. Additionally, drawings for all of our unique parts as well as pictures of our final assembly are included. Finally, this report contains a table of team contributions, meetings, and a Gantt chart.

Gear Calculations

Input Speed (ω_i): 67 RPM

Desired Output Speed (ω_o): 15 RPM $\pm$ 0.075 RPM

Achieved Output Speed (ω_{gear6}): 15.033 RPM

Gear Ratio Calculation:

$$GR = \frac{\omega_i}{\omega_o} = \frac{67}{15} = 4.46667$$

Gearing Solution:

Gear A = 20 teeth

Gear B = 28 teeth

Gear C = 14 teeth

Gear D = 24 teeth

Gear E = 14 teeth

Gear F = 26 teeth

$$GR = \frac{z_o}{z_i} = \frac{B}{A} * \frac{C}{D} * \frac{F}{E} = \frac{28}{20} * \frac{24}{14} * \frac{26}{14} = 4.45714$$

<u>Speed of Individual Gears:</u>

$$\omega_{gear\ A} = 67\ RPM$$

$$\omega_{gear\ B} = \frac{\omega_{gear\ A}}{GR_{AB}} = \frac{67}{1.4} = 47.857\ RPM$$

$$\omega_{gear\ C} = 47.857\ rpm$$

$$\omega_{gear\ D} = \frac{\omega_{gear\ C}}{GR_{CD}} = \frac{45.857}{1.71429} = 27.917\ RPM$$

$$\omega_{gear\ E} = 27.917\ RPM$$

$$\omega_{gear\ F} = \frac{\omega_{gear\ E}}{GR_{EF}} = \frac{27.917}{1.85714} = 15.033\ RPM$$

Note: the remainder of the gears have 1:1 ratios, resulting in all of them having a final RPM of 15.033.

Gear Train Parameters

Gear Name	Type of Gear	Connection to Procedding Gear		Pitch Diameter	Module	Number of Teeth	Speed (RPM)	Direction of Motion	Facew idth
		Type	Name						
A	Spur	N/A	N/A	20	1	20	67.00	CW	5
B	Spur	Mesh	A	28	1	28	47.86	CCW	5
C	Spur	Axial	B	24	1	24	45.86	CCW	5
D	Spur	Mesh	C	24	1	24	27.92	CW	5
E	Spur	Axial	D	14	1	14	27.92	CW	5
F	Spur	Mesh	E	26	1	26	15.03	CCW	5
G	Spur	Axial	F	14	1	14	15.03	CCW	5
H	Spur	Mesh	G	26	1	26	15.03	CW	5
I	Spur	Axial	H	20.2426	1.01213	20	15.03	CW	5
J	Spur	Mesh	I	20.426	1.0213	20	15.03	CCW	5
K	Spur	Axial	I	18	1	18	15.03	CW	5
L	Spur	Mesh	K	18	1	18	15.03	CCW	5
M	Spur	Axial	L	25.44	1.06	24	15.03	CWW	5
N	Spur	Mesh	M	25.44	1.06	24	15.03	CW	5

<u>Figure 1: Gear Parameters Worksheet</u>

Final Design Parameters	
Input Speed of G1 (RPM)	67
Output Speed of Final Gear (RPM)	15
Gear Ratio of Spur Gears	4.466666667

<u>Figure 2: Final Design Parameters</u>

Simplified Gearing Mechanism

The simplified gearing mechanisms below show the top view and the side view of our gearing mechanism. These gearing mechanisms are based on the number of teeth of each gear, not the pitch diameters.

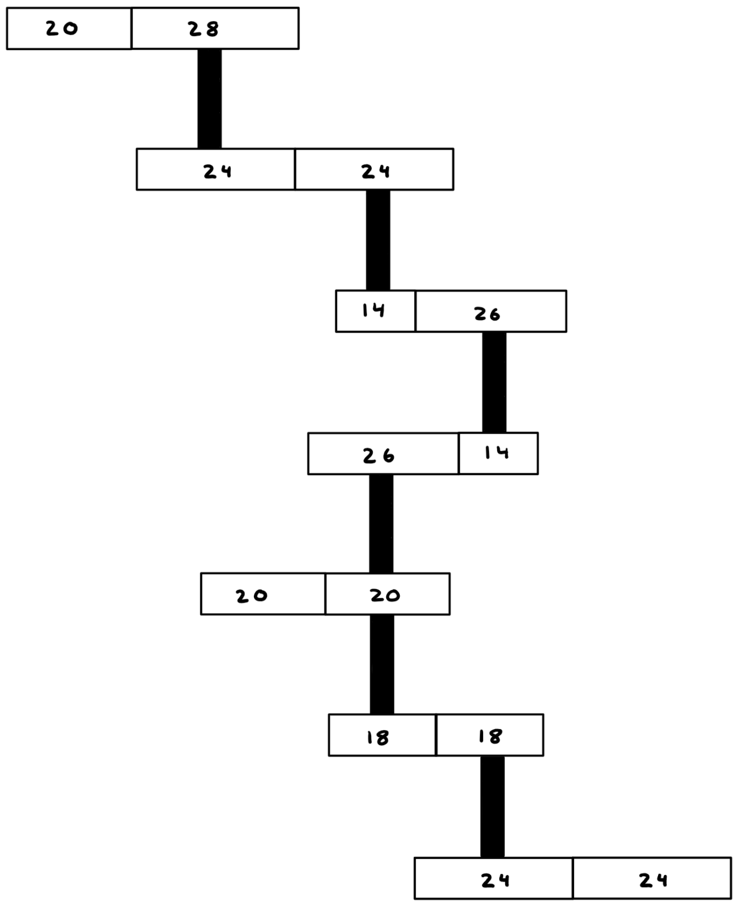

Figure 3: Simplified Gearing Mechanism Top View

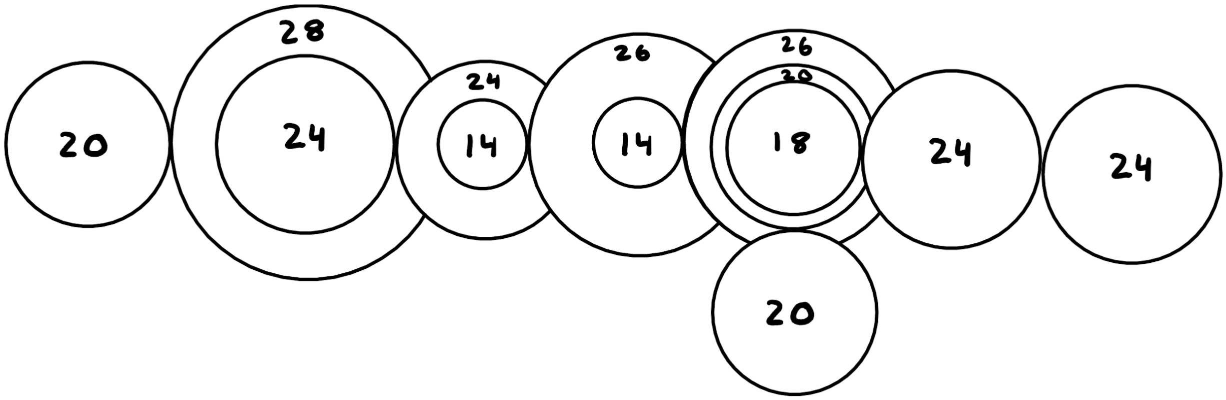

Figure 4: Simplified Gearing Mechanism Side View

Our Design

Final Assembly

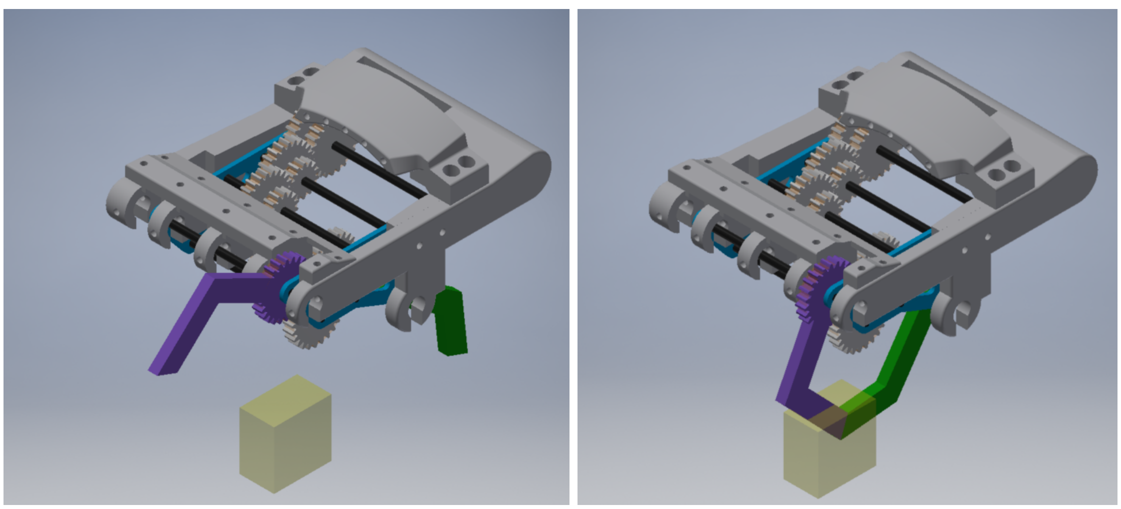
Figure 17 & 18: Assembly Screenshots

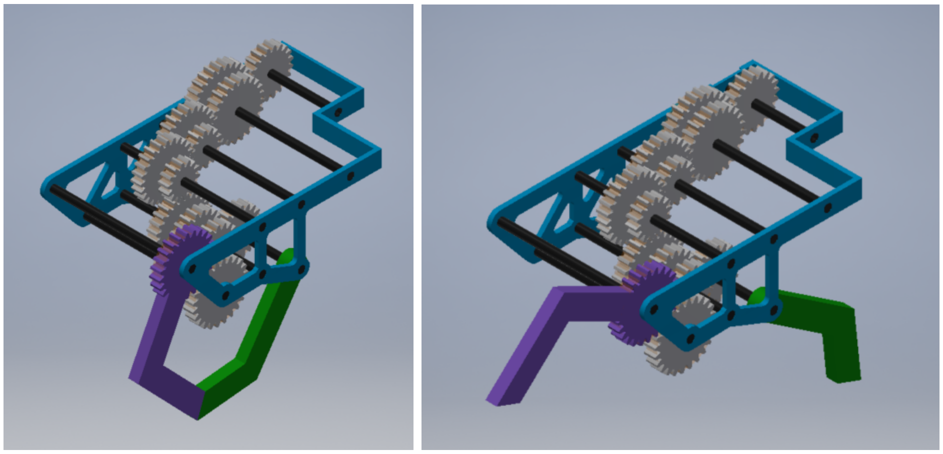

Figure 19 & 20: Assembly Screenshots without Frame

Dynamic Simulation Graph

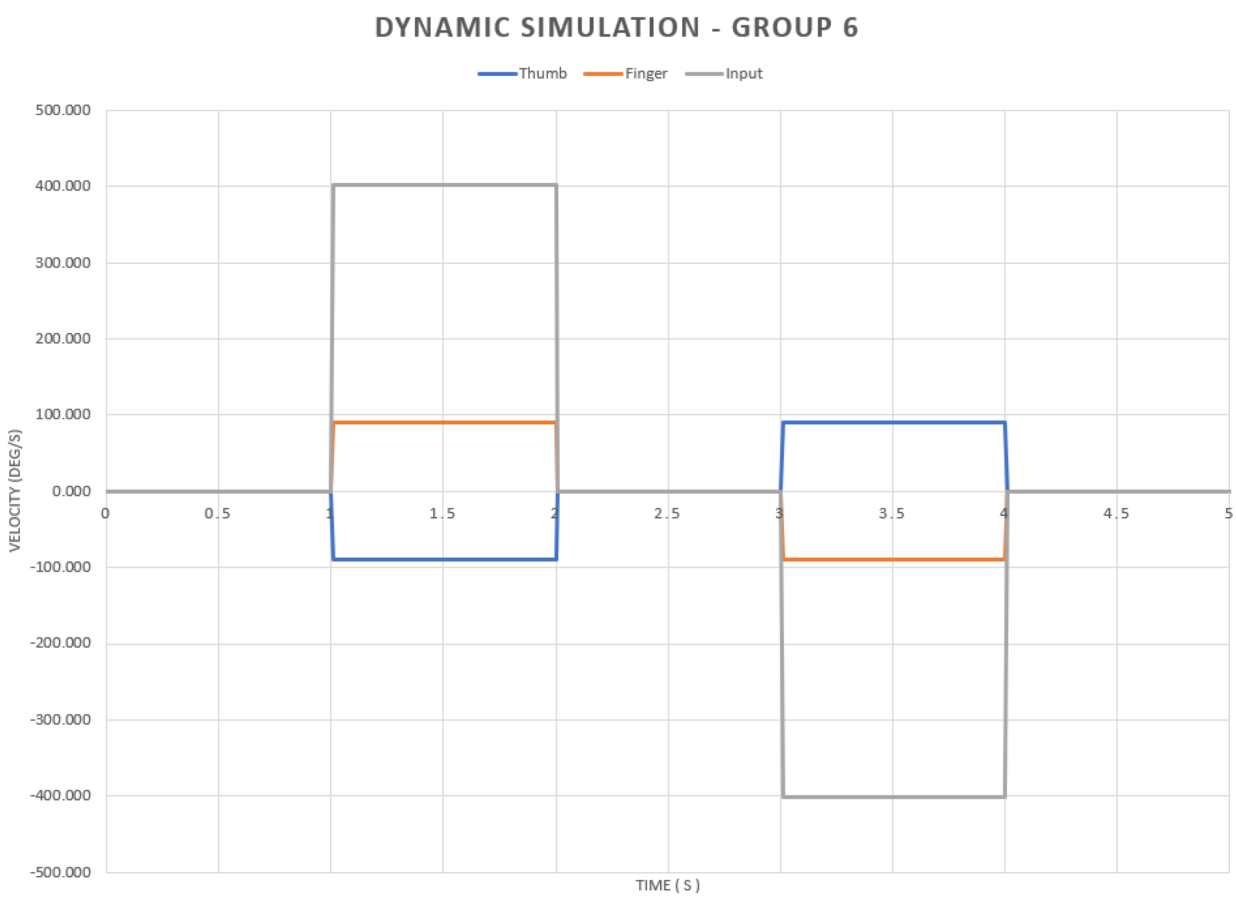

Figure 23: Dynamic Simulation Graph

Prototype Explanation

Our prototype consists of 14 spur gears supported by 8 shafts and a single bracket. It is designed to take an input speed of 67 RPM and reduce it such that the finger and thumb rotate at a rate of 15.033 RPM. The biggest challenge we encountered during the design process was selecting the appropriate gears to ensure that our finger and thumb were in the appropriate place. We went through many different gear combinations before we found one with the appropriate center distances. Our final design has two unique features - a one piece bracket and a finger that is integrated with a spur gear. We decided to make our bracket one piece and to combine our finger with a spur gear because we thought it would make the assembly processes easier. The shafts would be easier to line up with only one bracket and we would not have to worry about spacing between the final spur gear and the finger if they were integrated together as one part. Additionally, both of these pieces reduce the number of components we need to 3D print, which makes for a faster manufacturing process.

Discussion Questions

1. Briefly explain your design decisions, outlining any unique decisions regarding gears or the support from that had to be made, DFM/DFA considerations you took into account, and anything else you deem worthy of mention.

Some design decisions we made early in the design process were that we wanted our design to consist entirely of spur gears, all the pitch diameters of the gears should be less than 30 mm, and all the modules should be approximately 1 mm. We wanted our design to consist of entirely spur gears because the EPIC Lab IAI mentioned that spur gears were easier to print than worm gears. We decided that the pitch diameters should be less than 30 mm because we found that smaller gears could be placed more freely and were less likely to interfere with the frame. Finally, we decided the modules for all the gears should be about 1 mm because in our first round of 3D printed gears, that module worked well.

One unique decision that we made was that we wanted our bracket to be one piece. We did not want our bracket to have multiple pieces because we thought that it would be difficult to assemble. We thought that a one piece bracket would take out all the difficulty in lining up opposite shaft holes and streamline the assembly process.

One major DFM consideration we took into account was the ability to 3D print all of our components. Our design consisted of entirely spur gears because they are very easy to 3D print. Additionally, the top of our bracket is entirely flat so that it could easily be 3D printed. One DFA consideration we took into account was the size of the holes in our bracket and gears. The provided shafts were 8-32 so the hole sizes were designed to be 3.53mm so that they could be easily tapped during assembly.

2. Does your design meet the design objectives? If so, briefly explain (with evidence) how you know this is the case. If not, briefly explain the particular challenges you faced that prevented you from achieving your design objectives.

Our design meets all of the design objectives.To begin, the finger and thumb rotate at the within $\pm 0.5\%$ of the desired rate. Calculations for the rate of rotation is included on page 4 and can also be seen in the dynamic simulation graph. Additionally, our gears and bracket do not interfere with the frame. While we did not get to 3D print our prototype to prove this, an interference analysis on our inventor model showed no issues and the finger and thumb only contacted in the designated box. Finally, out finger and thumb contact within the desired area. Again, we did not get to manufacture our prototype to test this physically, but our inventor model shows them contacting appropriately.

3. What was the greatest design challenge you faced as a team when completing this project?

The greatest design challenge we faced as a team when completing this project was determining the correct gear calculations. While we determined the gears needed to achieve the proper speed easily, we had a difficult time determining the gears needed to ensure that our thumb and finger rotated about the correct axis. We had to try many different gear combinations before settling on a combination that had the appropriate center distances.

4. Provide at least two assumptions that were made of this project related to the prosthetic hand. Then, briefly describe how you might relax those assumptions to make your design more "realistic."

One assumption we made was that the finger and thumb only rotate about one joint. In reality, that would not make a very effective prothstetic hand. To make a more realistic design, each finger could have an additional joint that would mimic the proximal interphalangeal joint on the finger and the metacarpophalangeal joint on the thumb. This joint could be driven by a series of pulleys and belts. The addition of this joint would help the prototype to behave more like a hand.

Another assumption that we made was that the thumb and finger should always move together. There are many different tasks that require the finger and the thumb to rotate independently (e.g. using a mouse). To make a design behave more like a real hand, it should include some sort of mechanism that allows the user to engage one or both of the fingers in motion.

Group Contributions

Table of Contributions

Name	Contributions
Madeline	- Milestone 0 - Milestone 1 - Milestone 2 - Gear Calculations - CAD - Exploded View - Gantt Chart - Dynamic simulation - Bracket Drawing
Shiv	- Milestone 0 - Milestone 1 - Milestone 2 - Technical Report - Printing - Gear CAD Drawings - Gear Parameters

Arnav	- Milestone 0 - Milestone 2 - Technical Report - Printing - Gear CAD Drawings - Simplified Gear Mechanism
Davies	- Milestone 0 - Milestone 1 - Finger/Thumb CAD Drawings - Printing - Technical Report

Team Meetings

The following table breaks down each meeting and printing session that we have had. It shows the topics covered in the meetings. This table also keeps track of the attendance of group members at each meeting.

Meeting Date	Tasks Done/Discussed	Attendance
February 11th, 2020 - Team Meeting	Milestone 0: - Cover Page - Signed Academic Integrity Statement - Outline of Team Responsibilities - Gantt Chart	Madeline, Shiv, Arnav, Davies
February 27th, 2020 - Team Meeting	Milestone 1: - Preliminary Sketches - Proposed Gear Mechanism - Hand Calculations - Gear Design Parameters	Madeline, Shiv, Davies
March 5th, 2020 - Printing Session	- Gear Printing	Shiv, Arnav, Davies
March 10th, 2020 - Team Meeting	- Technical Report - Update Gear Parameters	Madeline, Shiv, Arnav, Davies

	- CADing Bracket and Gears	
March 11th, 2020 - Printing Session	- Gear Printing	Shiv, Arnav, Davies
March 12th, 2020 - Printing Session	- Gear Printing	Shiv
April 4th, 2020 - Team Meeting	- Discussed tasks that need to be done before final submission - Dynamic Simulation - Assembly Drawings - Gantt Chart - Gear Drawings - Technical Report	Madeline, Shiv, Arnav
April 6th, 2020 - Team Meetings	- Finishing Technical Report - Discussion Questions - Prototype Explanation	Madeline, Shiv, Arnav, Davies

Gantt Chart

The Gantt chart displays a breakdown of each step of the project leading up to the final submission. It shows who is responsible for what portion of the project and when it should be started and completed by.

Group 6 (L06)

Engineering 1C03

Project Start: Fri, 1-31-2020

Display Week: 01-Jan

TASK	ASSIGNED TO	PROGRESS	START	END
Milestone 0				
Team Contract	Arnav, Davies	100%	1-31-20	2-14-20
Cover Page	Shiv	100%	1-31-20	2-14-20
Gantt Chart	Maddy	100%	1-31-20	2-14-20
Milestone 1				
Cover Page	Shiv	100%	1-31-20	1-31-20
Preliminary Design Sk	Arnav	100%	2-4-20	2-28-20
Labelled Sketches	Davies	100%	2-4-20	2-28-20
Hand Calculations	Maddy	100%	2-4-20	2-28-20
Table of Gear Design	Shiv	100%	2-4-20	2-28-20
Milestone 2				
Solid Modelling	Maddy, Davies	100%	2-24-20	3-1-20
3D Print Gears	Shiv, Arnav	100%	3-1-20	3-13-20
Final Submission				
Technical Report	Shiv, Arnav	100%	3-10-20	4-7-20
Working Drawings	Shiv, Arnav, Maddy	100%	3-13-20	4-7-20
Software Models	Maddy, Davies	100%	3-5-20	3-16-20
Dynamic Simulation	Maddy	100%	3-15-20	4-7-20

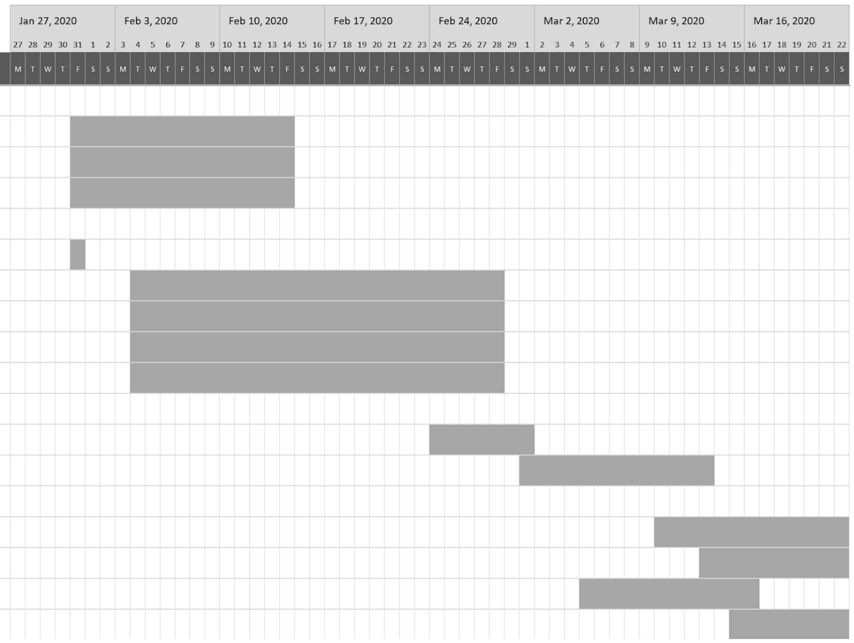

Figure 24: Gantt Chart