CE 903/CE913

TEAM 12

REDACTED

Software Requirements Specification

Document

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1. Abstract

This study tackles the optimization of computer network structures to mitigate the spread of a mutant, simulating the Moran process in a computerised environment. The resident network, modelled as the existing infrastructure, encounters the emergence of a “virus” with replication and alternative connection capabilities. Our research utilises computational simulations by varying key parameters, such as the virus transmission rate and network topology, to assess their impact on a mutant propagation. The results reveal network configurations that minimise the threat, identifying critical factors for computer security. The drawn conclusions provide valuable insights for network designers and security professionals, highlighting the importance of specific measures to prevent the expansion of computer threats. This work contributes to the field of network security by integrating evolutionary concepts into a computer context, offering practical applications to enhance the resilience of computer infrastructures against potential intrusions.

Keywords: *Moran process, computer networks, computer security, virus spread*

2. Introduction

2.1 Purpose

The purpose of this document is to present a comprehensive overview of a Python-based application aimed at modelling and simulating the Moran Process within a graph of interconnected nodes. The system's primary objective is to estimate the fixation probability of a given input graph, comparing it against a predetermined fixation probability characteristic of the Moran Process. Catering to students, scientists, professors, and scholars, the application provides a user-friendly interface for running simulations on both preset and custom network architectures. This introduction aims to elucidate the document's purpose by outlining the system's goals, target audience, and the significance of Moran Process simulation in the context of network dynamics.

2.2 Scope

The system is designed to be independent, implemented as a Python application. Users can interact with the system through a graphical user interface (GUI), choosing among preset network architectures or uploading custom architectures. The document delves into the system's interfaces, software requirements, and user characteristics, providing insights into the practical aspects of its usage. Additionally, it explores the input and output requirements, offering a glimpse into the system's functionality and the expected outcomes of Moran Process simulations. By defining the scope, this introduction sets the boundaries for understanding the system's features and capabilities.

2.3 Overview

This document provides a holistic overview of the Moran Process simulation system, offering detailed insights into its goals, functionality, user characteristics, and dependencies. It introduces the system's purpose, emphasising its role in estimating fixation probabilities and confirming adherence to the Moran Process. The document explores the scope of the system, from its implementation in Python to the user interaction through a GUI. Furthermore, it outlines the input and output requirements, shedding light on the essential components driving the Moran Process simulation. In addition to discussing the system itself, the document touches on project planning considerations, management structures, and the selection of tools like Trello and Jira for efficient project management. The overview sets the stage for a comprehensive understanding of the Moran Process simulation system and its broader implications in the field of network dynamics.

3. The Overall Description

The goal of the system is to successfully model and simulate the Moran Process in a graph of interconnected nodes. The system would be implemented in the form of a Python application with the capability of taking in the weight / adjacency matrix of a graph and running the Moran Process simulation on it multiple times. The application would be able to show the various changes that occur on each time step of the process for simple graphs. Larger graphs may have to be simulated behind the scenes to save memory on draw calls.

The main output from the implemented algorithm will be the estimated fixation probability of the input graph weight / adjacency matrix. This would then be compared against the predetermined fixation probability of the Moran Process to confirm whether or not the input graph follows the Moran Process.

Users who wish to use this system must have all necessary packages and tools installed. An understanding of the mathematical basis of the system is not required to use it.

3.1 Product Perspective

This project is independent and totally self-contained.

3.1.1 System Interfaces

This does not apply to the system as it is fully independent.

3.1.2 Interfaces

A GUI will be used to interact with the system, allowing users to choose among preset network architectures and offering the option to upload a custom architecture through a file.

3.1.3 Hardware Interfaces

The system has no hardware interface requirements.

3.1.4 Software Interfaces

The system will work using Python, so it is required to have installed Python 3.x or more recent versions.

3.1.5 Communications Interfaces

The system has no communication interface requirements

3.1.6 Memory Constraints

The system has no memory constraints

3.1.7 Operations

This does not apply to the system

3.1.8 Site Adaptation Requirements

This does not apply to the system

3.2 Product Functions

1. Run simulation on relevant preloaded network architectures
2. Upload new custom architecture using a weight matrix

3.3 User Characteristics

The intended users for the system are students, scientists, professors, and scholars. However, users are not required to understand the mathematical or computational background in the system to use the preloaded architectures, allowing for anyone with an interest to interact with it.

When it comes to uploading their own architectures, they must have a basic understanding of graphs and weight matrices, limiting the accessibility to the general public.

3.4 Constraints

There are no extra constraints due to the system being independent.

3.5 Assumptions and Dependencies

Network architectures for different real world phenomena exist, however, most consist of unweighted graphs, since estimating these weights is a difficult task. This could prove a challenge since it would mean estimating or generating these weights in order to run simulations, which could affect the outcome.

3.6 Apportioning of Requirements

Since this project is self-standing, the objective is to deliver everything by the assigned deadline

4. Requirements Analysis and Specification

4.1 Input Requirements

The Moran process simulation necessitates specific inputs to accurately model the dynamics of the resident-cell population:

4.1.1 Connected Graphs

The purpose of the graph input is to define the intricate connectivity of the resident-cell population. This involves representing the relationships between cells within the population. The scope of this requirement encompasses the inclusion of algorithms designed to generate synthetic graphs. These algorithms should provide flexibility in creating diverse graph structures to capture various resident-cell network scenarios.

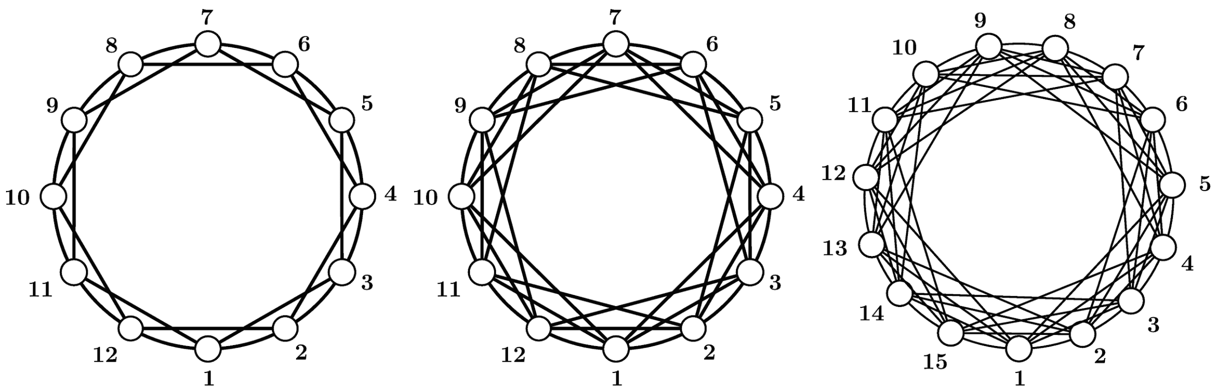
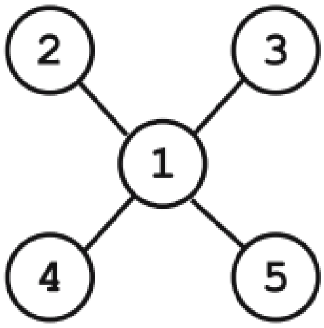


Figure 1. The classes of 4-regular, 6-regular and 8-regular undirected graphs CI4, CI6 and CI8. Here the number of nodes is 12,12 and 15 respectively.[1]

4.1.2 Weights Matrix

The weight matrix input serves the purpose of specifying the weights associated with connections in the network, providing a quantitative measure of the strength of interactions between cells. The scope extends to defining algorithms responsible for generating synthetic weight matrices. These algorithms should be adaptable to different scenarios, allowing for variations in the strength and influence of connections between cells. The overview emphasises the critical role of weight matrices in offering insights into the relative impact of intercellular connections within the resident-cell population.



$$W = \begin{bmatrix} 0.2 & 0.2 & 0.2 & 0.2 & 0.2 \\ 0.5 & 0.5 & 0 & 0 & 0 \\ 0.5 & 0 & 0.5 & 0 & 0 \\ 0.5 & 0 & 0 & 0.5 & 0 \\ 0.5 & 0 & 0 & 0 & 0.5 \end{bmatrix}$$

Figure 2. The star structure graph with population (N=5) and its associated weighted adjacency matrix (W).[2]

4.1.3 Real Network Data

The purpose of integrating real-world network data into the simulation is to enhance the model's realism and applicability. The scope of this requirement involves documenting the sources of real-world network data and outlining methods for adapting this data into the simulation framework. Ensuring compatibility between real and synthetic inputs is crucial for conducting a thorough comparative analysis. The overview underscores the importance of incorporating real-world network data to improve the simulation's relevance to actual biological scenarios and foster a more accurate understanding of the Moran process dynamics.

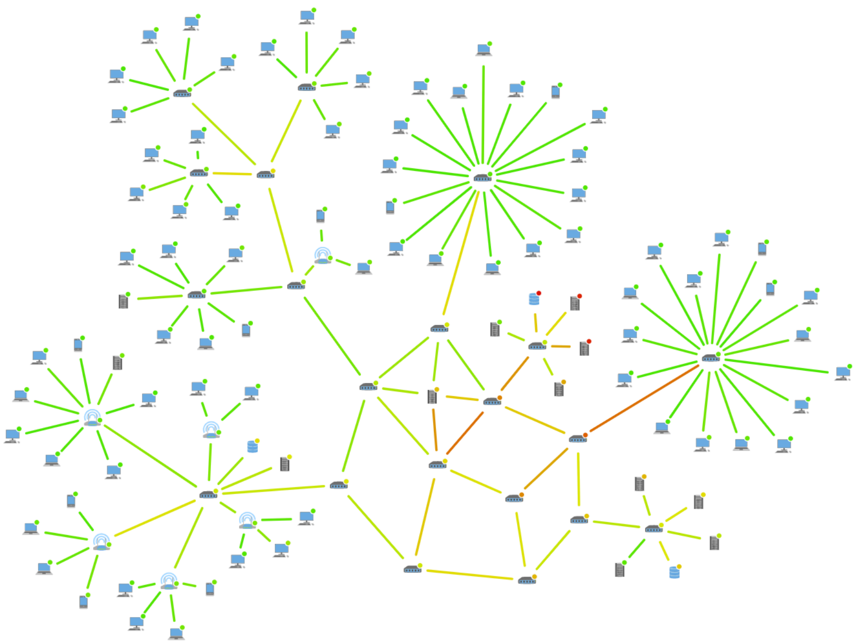


Figure 3. An example graph of computer network
https://www.yworks.com/pages/network-monitoring-visualization

4.2 Output Requirements

Complementary to the input requirements, the Moran process simulation produces specific outputs:

4.2.1 Simulation Results

The purpose of the simulation results output is to capture and analyse the outcomes of the Moran process, including fixation probability, mutation occurrences, spread dynamics, and final states. The scope includes designing data structures that systematically store relevant simulation metrics to facilitate efficient analysis. The overview emphasises the significance of simulation results in providing valuable insights into the dynamics of the Moran process, aiding in the evaluation of mutation spread and network evolution.

5. Project Planning

5.1 Management Structure

A management structure is a set of guidelines and procedures that help a project development cycle be efficient. There are many types of Management Structures each having uses in different types of projects and environments, finding a structure that suits the project and team the best is extremely important because if it doesn't fit it can result in a waste of resources and time for the project and can end up affecting the overall quality of the end result. Having all of this in mind we decided to look into a couple of different Structures to find the correct one.

Waterfall

The waterfall method is a sequential development process that requires all steps to be completed in order without the possibility of going back to previous steps to change aspects of them, it follows the “measure twice, cut once" ideology. The quality of the project depends on the amount and quality of work that is put into each of the steps that are in it. Some of the most common steps in waterfall method are:

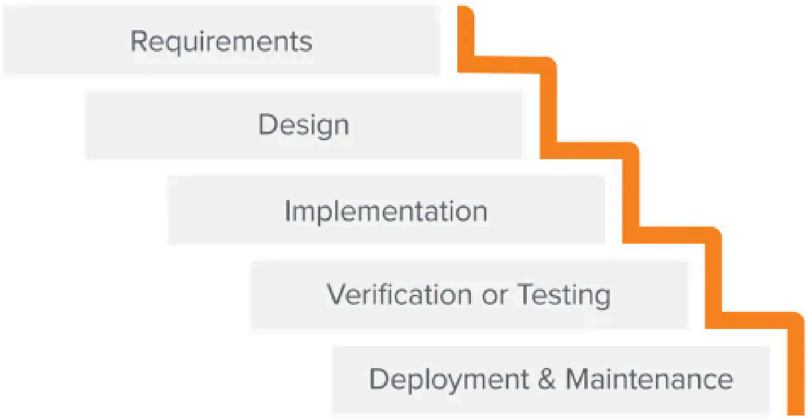


Figure 4. Example of a waterfall development process.

All of these steps must be completed in the order that they’re shown and cant be modified after going to the next step so they require extremely good planning before starting the development process to avoid problems.

Some of the advantages of the waterfall method include:

- Developers can catch design errors during the analysis and design stages, avoiding problems in the implementation.
- The total cost of the project can be accurately estimated, as can the timeline, after the requirements have been defined.
- It is easier to measure progress according to clearly defined milestones.
- Customers aren’t always adding new requirements to the project.

However there are some disadvantages coming with this methodology but the main ones are these:

- Projects can take longer to deliver with this chronological approach.
- Clients are not involved in the design and implementation stages.

- Deadline creep — when one phase in the process is delayed, all the other phases are delayed.

Agile (SCRUM)

The agile method is an iterative process that requires multiple iterations of the set process to achieve a better product. The agile development process is a process that's created to be flexible and allow the team to make changes to the project on the fly. This method goes with the principle of continuous improvement, which means that with each iteration the product is being upgraded and changed.

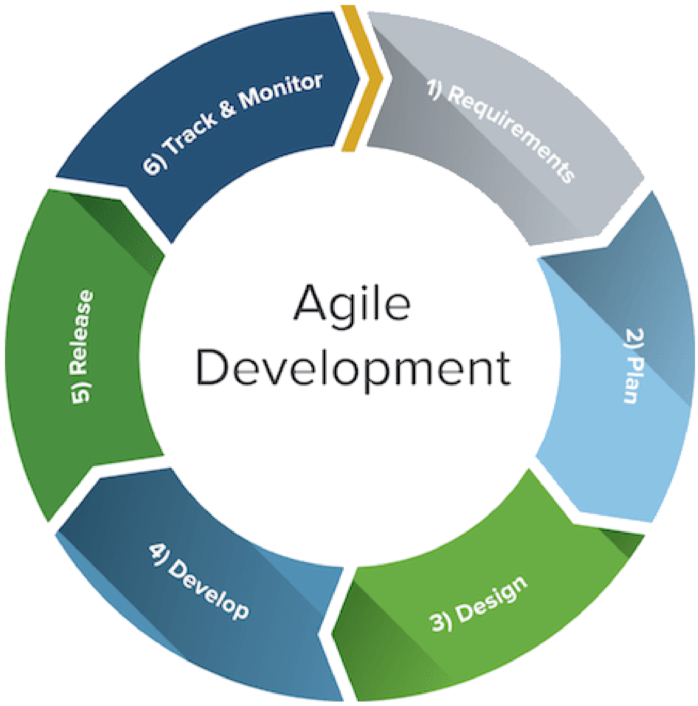


Figure 5. Example of an Agile development process.

However getting to that point for a team is extremely difficult because it requires that the whole team is able to coordinate themselves and change their ways of thinking constantly, that is why the SCRUM framework is used. The scrum framework outlines a set of values, principles, and practices that scrum teams follow to deliver a product or service.The scrum framework is based on continuous learning and adjustment to fluctuating factors. It acknowledges that the team doesn't know everything at the start of a project and will evolve through experience. Scrum works through a type of iteration known as Sprints, sprints are short periods of time in which the development team implements and delivers a product which has an achievable milestone set.

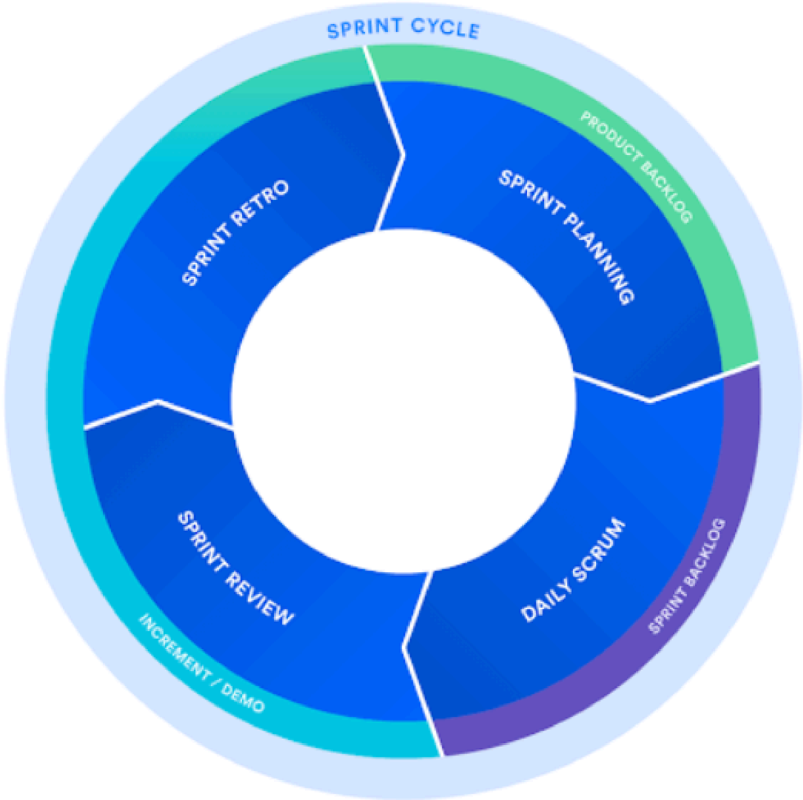


Figure 6. Example of a sprint structure.

Some of the advantages of using the scrum framework are:

- Scrum can help teams complete project deliverables quickly and efficiently
- Developments are coded and tested during the sprint review
- Works well for fast-moving development projects
- Scrum, being agile, adopts feedback from customers and stakeholders, in our case the supervisor and GLAs.
- Short sprints enable changes based on feedback a lot more easily
- The individual effort of each team member is visible during daily scrum meetings

Some of the disadvantages of the scrum framework are:

- Scrum often leads to scope creep, due to the lack of a definite end-date
- The chances of project failure are high if individuals aren't very committed or cooperative
- The framework can be successful only with experienced team members
- If any team member leaves in the middle of a project, it can have a huge negative impact on the project
- Quality is hard to implement until the team goes through an aggressive testing process

After evaluating these two structures and researching more about the scrum framework and the way it's used we opted for the use of the scrum framework over the use of the waterfall and traditional agile structures. The scrum framework brings a lot of flexibility in the development process and allows for changes that can come from feedback and new ideas, the absence of the rigidness that is present in this framework can make the team work more fluidly and gives more freedom when in the development process.

5.2 Tools for project management and planning

When it comes to planning our project we had to find our planning platforms. We decided to use Trello and Jira as they are connected and you use both together. If we look at both of these Trello is a free project planning platform which allows you to create boards that you can follow. As shown in figure 7, this also follows our methodology of the scrum technique.

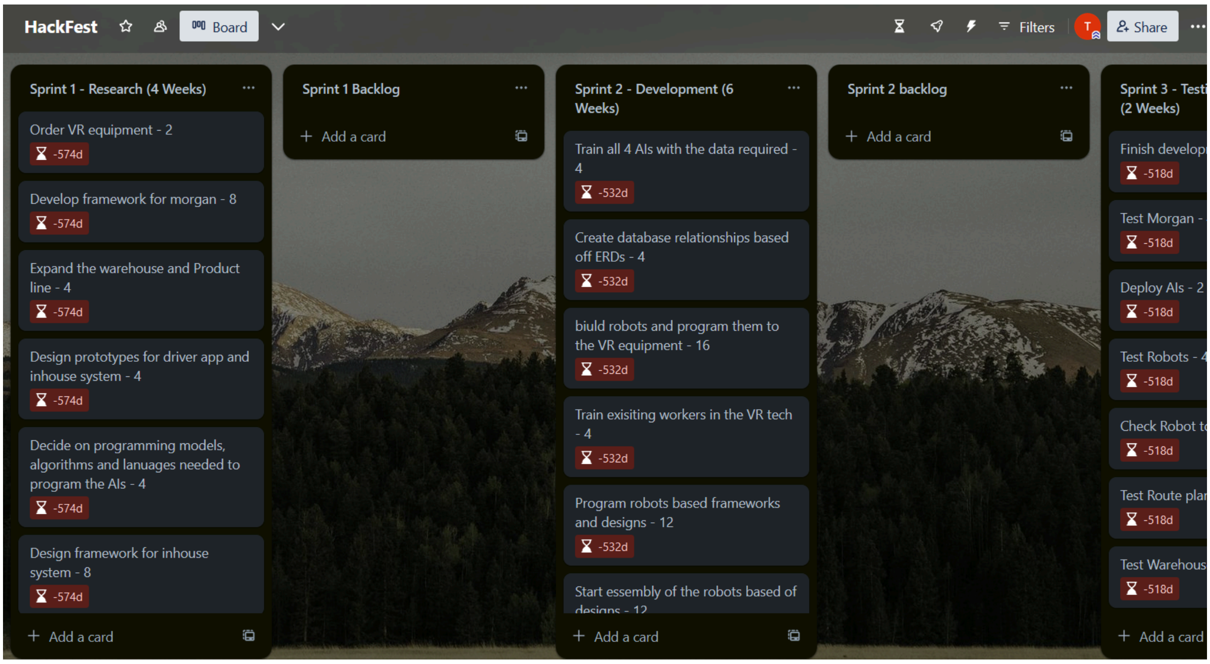


Figure 7. Trello screenshot

Next is Jira. We will use Jira alongside Trello as it allows for more functionality such as connecting to Gitlab. We will use this to track the time scale of the project so we know when our deadlines are. We will also be able to use this to follow any bugs or errors that a team member might find. They can easily put this into the board for all to see. We can also assign team members to certain tasks so we know who is working on what at any given moment.

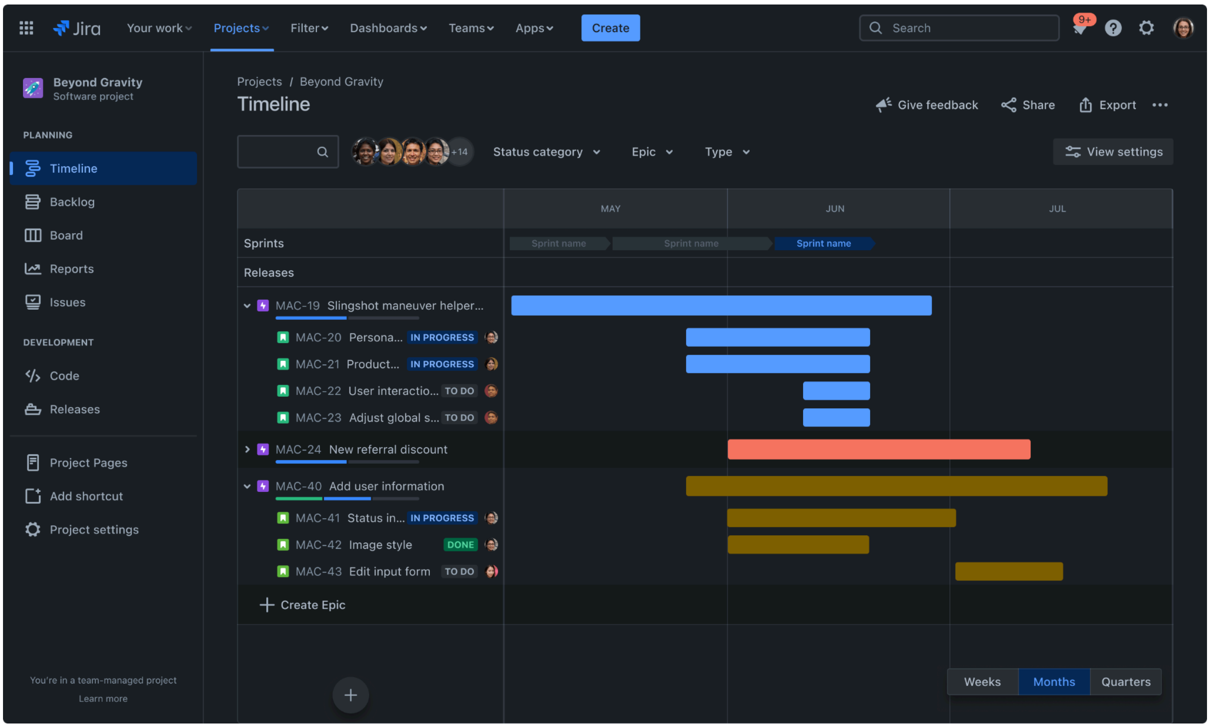
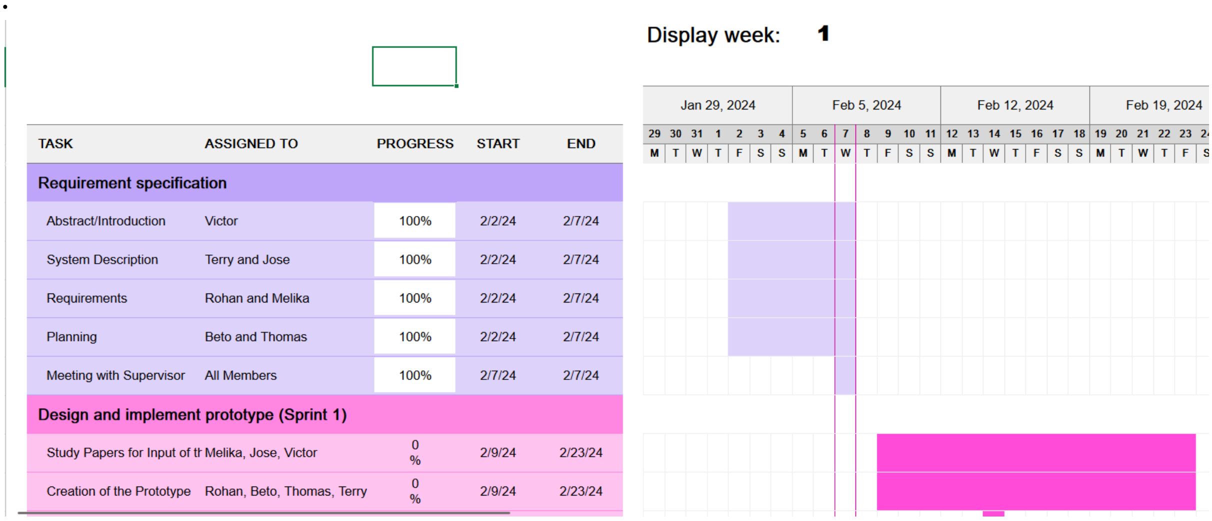


Figure 8. Jira example

When combined Trello and Jira can become a very powerful way to track our project allowing us to use the features both offer to greatly benefit us. We can use Trello to add more in depth details about the issues or tasks we are working on. We also have the ability to customise the boards to suit our project methodology so we will have our sprints and backlogs when necessary.

5.3 Project plan

We have created a gantt chart within excel with our project timeline in it. This is our base outline of what we are expecting to have completed and when by. This chart will give us a good indication as a team, to see if we are falling behind or if we are ahead. This chart is currently only a preliminary outline of our project and could be subject to change as issues appear.



TASK	ASSIGNED TO	PROGRESS	START	END
Requirement specification				
Abstract/Introduction	Victor	100%	2/2/24	2/7/24
System Description	Terry and Jose	100%	2/2/24	2/7/24
Requirements	Rohan and Melika	100%	2/2/24	2/7/24
Planning	Beto and Thomas	100%	2/2/24	2/7/24
Meeting with Supervisor	All Members	100%	2/7/24	2/7/24
Design and implement prototype (Sprint 1)				
Study Papers for Input of tl	Melika, Jose, Victor	0 %	2/9/24	2/23/24
Creation of the Prototype	Rohan, Beto, Thomas, Terry	0 %	2/9/24	2/23/24

Figure 9. Our Gantt Chart

Design and implement prototype (Sprint 1)				
Study Papers for Input of the A	Melika, Jose, Victor	0 %	2/9/24	2/23/24
Creation of the Prototype	Rohan, Beto, Thomas, Terry	0 %	2/9/24	2/23/24
Meeting with Supervisor	All Members	0 %	2/14/24	2/14/24
TBD based of feedback		0 %	2/9/24	2/23/24
TBD based of feedback		0 %	2/9/24	2/23/24
Implementing and Visualization of graph states (Sprint 2)				
Testing single round of Moran Process		50%	3/2/24	3/16/24
Finding real Networks		60%	3/2/24	3/16/24
Testing on Real networks		50%	3/2/24	3/16/24
Results and conculsions		25%	3/2/24	3/16/24
Meeting with Supervisor		25%	3/2/24	3/16/24
Documentation (Sprint 3)				

Figure 10. Our Gantt Chart continued

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