Visualisation of Pandemics Simulation

Final Year Project Report

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October 2024 - May 2025

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Chapter 1

Abstract

With the recent pandemic of COVID-19, the world has become more aware of the need for data visualisation. The ability to see the spread of a virus and how it affects different countries is important for understanding the virus and how to contain it.

This project aims to create a tool which can visualise epidemic and pandemic data in a way that is easy to understand. The tool will be able to show the number of cases and deaths per week for each country. The tool will also be able to show a timeline of the pandemic and give the user the ability to compare how different countries are affected.

The application discussed in this report is a web application which uses D3.js to render the data. The data is in a JSON format and is sourced from the European Centre for Disease Prevention and Control (ECDC). However, the data encoded into a more general format to allow for the application to be used for any data.

The application is able to be used analyse the data and compare how different countries are affected over a time period.

Chapter 2

Introduction

The specific problem I am addressing in this project is in aide of communication of data. Data visualisation is a powerful, if not necessary, tool to understand large datasets such as the ones that concern worldwide pandemics.

Of course, data visualisation is just one step of the solution to eradicating pandemics. It relies on countries having accurate data and being willing to share it. However, this is not always the case. For example, in the early days of the COVID-19 pandemic, China was not forthcoming with their data [5]. This made it difficult for other countries to prepare for the virus.

2.1 Aims and Objectives

The aim of this project is to create a tool which can visualise epidemic data in a way that is easy to understand. The tool will be able to show the number of cases and deaths per week for each country. The tool will also be able to show a timeline of the epidemic and give an worldwide overview of the spread of the virus.

To achieve this aim, I will be using a node.js backend to serve the data to the front end. The front end will be a web application which will use D3.js to render the data. The data will be in a JSON format and will be sourced from the European Centre for Disease Prevention and Control (ECDC) [2]. The data will be in a similar format to the COVID-19 data, but will be more generic so it can be used for any epidemic data.

For my design methodology, I will be using the Waterfall model to structure my project. This will ensure that my code and report are developed in a structured and ordered fashion. Doing the project section by section will allow me to focus on each part of the project individually and ensure that I am on the right path.
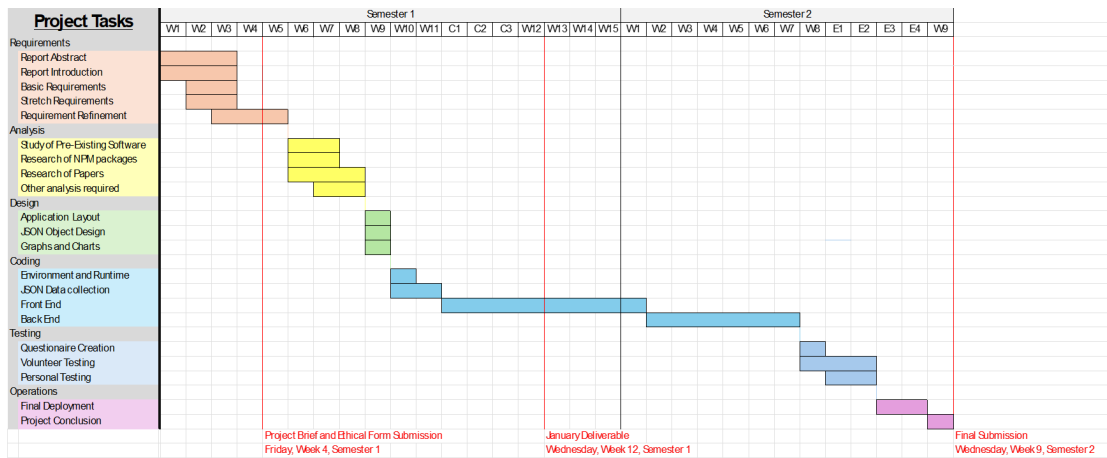
Figure 2.1: Gantt Chart

Along with using the Waterfall model, I created a Gantt chart to roughly plan my time for the project. This will help me stay on track and ensure that I am not spending too much time on one section of the project. I will go into further detail about the Gantt chart in the Methodology section of this report.

Chapter 3

Problem Domain

For this project, I will use the MoSCoW structure to define the requirements of the project. This specifies the requirements into layers of priority and sets the scope of my project into perspective.

- **Must Have (Minimum Viable Product)**
  - The dashboard must show a map of the Earth.
  - The dashboard must visualise the COVID-19 data and show the number of global cases and deaths per week.
  - The map will render polygon and country data from a GeoJSON file.
  - The individual countries must be clickable.
    * Clicking a country will update a panel on the right.
    * The panel will have a time-series graph showing the number of cases and deaths in that country over the time period.
    * The panel will have another time-series for use in comparison. The user will be able to choose a factor to compare against, such as population, GDP or another country's statistics.
    * Highlight the secondary country if applicable.
  - The dashboard must have a timeline slider of the epidemic.
    * The user must be able to scrub through the timeline.
    * There will be a "playback" feature which will automatically scrub through the timeline.
    * The timeline will show the current week in ISO 8601 format.
  - Search Bar
    * The user must be able to search for a country by name.
    * The search bar will have a dropdown list of countries.
    * The dropdown list will be filtered by the user's input.
    * If an unknown country is entered, the user will be prompted to enter a valid country name.
    * If a valid country is entered, it will be the same as clicking on the country and the text field will be wiped.
  - Reactive and responsive design.
    * Use of smooth transitions and animations to make the dashboard more visually appealing.
    * All graphs and functionalities should be connected to the timeline slider and country selected.

- **Should Have**
  - Zooming in on the map.
    * Adding a button to toggle a "zoom" feature on the map.
    * When clicked, the map will zoom into the selected country.
    * When clicked again, the map will zoom back out to the world view.
  - Hotspots on the map.
    * This would require analysis of the data to find out where the rate of infection is highest.

- **Could Have**
  - Analysis of data with other data sources to search for correlations.
    * I am currently unsure what data sources I would use for this, but it would be interesting to see if there are any correlations between the spread of the virus and other factors.
    * Comparing the number of cases or deaths to different countries.
    * Normalising the data to a GDP per capita basis.
  - Extensibility to other datasets.
    * The code should be generic enough to be used for any epidemic data.
    * Want to use a generic data format and a script which is able to cast the data into the correct format.
  - Frame updating to resizing the window.
  - Removal of spurious and erroneous data at runtime.

- **Would Have**
  - Predictctive modelling and forecasting.
    * This is my most ambitious stretch goal. I would like to be able to predict the spread of the virus using the data I have. This would require a lot of work and research into the field of predictive modelling. This would likely be a separate project in itself.

Chapter 4

Methodology

For this project I will incorperate a Waterfall model into my project since it will ensure my code and report as a whole is developed in a structured and ordered fashion.
The steps of Waterfall I will be following are:

1. **Requirements**

    - This section requires producing and refining a set of requirements. I plan on having 2 groups of requirements: Minimum Viable Product requirements and Stretch requirements.
    - I plan on refining all the requirements in this stage so I can stay on this path plan.

2. **Analysis**

    - In this section, I will be doing research into the problems which are discovered by my requirement refinement. I will investigate papers and other relevant published sources.
    - I also want to investigate node packages to represent my data graphically. (This would continue into the design section)
    - This section will likely take up a large section of my report, and I may return to this section midway through the project.

3. **Design**

    - I would be designing the layout and colour scheme of my application as it would appear in a browser window. It is worth noting that different size screens would render it differently, so I need to take that into account when planning.
    - I am not using a database for this project, but I will be using JSON and creating a standard design for objects in JSON will be beneficial.
    - I need to decide what values I use for graphs and what kind of graphs to use.

4. **Coding**

    - I will be making a web application with node.js. This will require me to create a valid work environment and get the node runtime working on my local machine. I will likely use Docker for this since it is a very easy to work with tool perfect for this application.
    - I will mostly be using JavaScript for this project because of previous experience and native compatibility with web development. There will also be HTML and CSS for loading the d3 canvas and aligning elements.
    - Node.js also comes with node package manager which will also be useful for loading the custom packages I plan on using in this project.

5. **Testing**

   - For testing, I will be using a variety of normal, boundary and erroneous tests to check my software for crashes, unexpected results, and vulnerabilities.

   - I also plan on having 3rd-party applicants to test my application. They would have a list of things to do in the application so I can analyse the ease of use.

   - I would also ask them to fill in a questionnaire.

6. **Operations**

   - I want to deploy my application to a server hosted by the university.

   - Node.js applications are commonly deployed onto servers and having a production repository would be a good standard for myself. Pushing to a server from a local git repository is a highly transferable skill which is widely used.

4.1 Gantt Chart
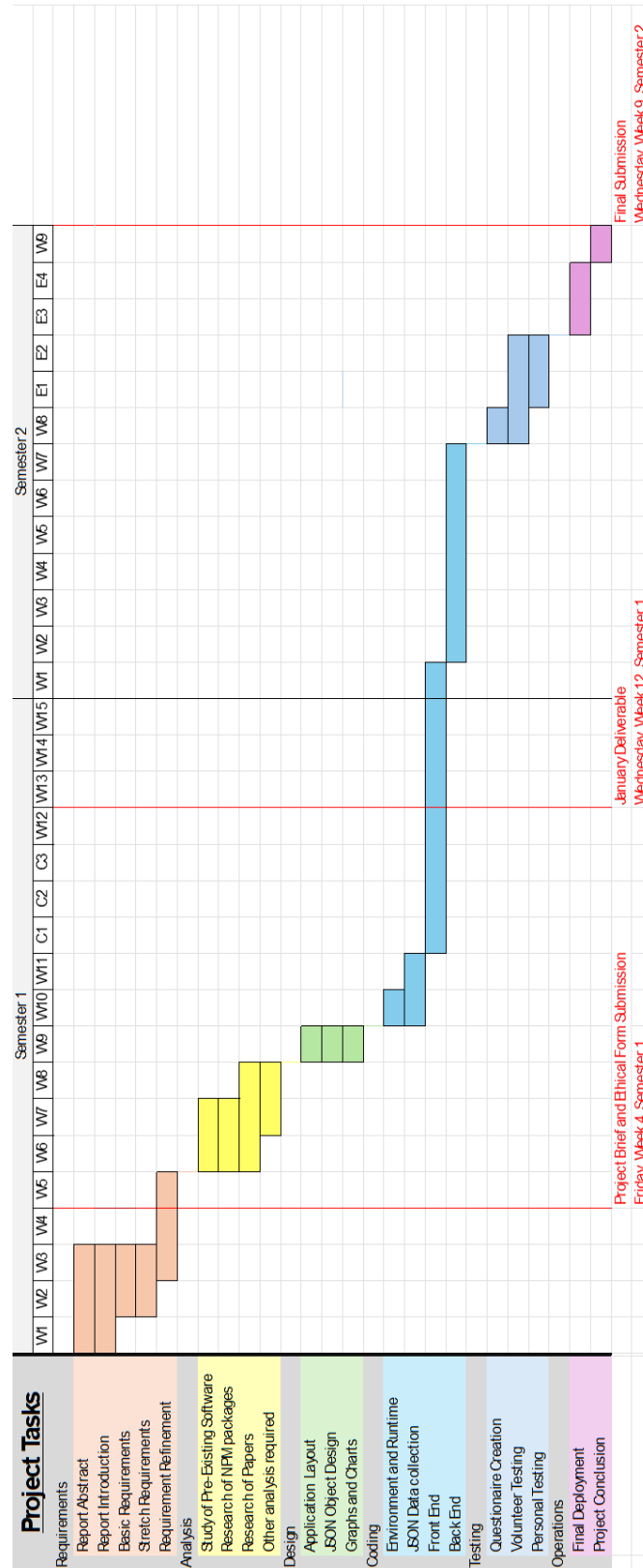
Chapter 5

Literature Review

5.1 Existing Solutions

5.1.1 COVID-19 Dashboard

A common tool for data visualisation is a software called PowerBI, a Microsoft product which allows for the creation of dashboards. The dashboard in the figure shows a real-time representation of the COVID-19 pandemic.

Figure 5.1: COVID-19 Dashboard Example

This dashboard has a lot of information on it even at first glance. The map uses bubbles to denote hotspots of activity for the virus. The bubbles are sized by the number of cases in that country. The bubbles can also be clicked for more detailed information on that country.
The user is also able to alter the time frame of the data, and the data is updated in real time.
There is a lot here which I would like to incorperate into my own project. The map is a good way to visualise the data and the bubbles are a good way to show the number of cases in each country. I also like the big bold text which summarises the data which is easy to read.

5.1.2 Plague Inc.

Plague Inc. is a game published in 2012 by Ndemic Creations. It gives the user the ability to create and spread a virus across the world. The game was initially released on mobile devices and has since been released on PC and console.

Mobiles games require accessible and easy to use interfaces, which is why Plague Inc. is a good example of a visual epidemic simulation. The game is simple to use and has a lot of information on the screen at once.

Figure 5.2: Plague Inc. Dashboard Example

Despite many systems being dramatised for the sake of gameplay, the game offers many features which could be useful for a real-world epidemic simulation.

The game uses a world map which gradually changes colour as the virus spreads, this is from many red dots appearing on the map. The user also has access to individual breakdowns of each country and can see the number of cases and deaths in each country.

The game also has a transmission system which changes from coutnry to country.

There is certain information provided in these examples that I will not be able to provide in my project. For example, the COVID-19 dashboard has real-time data, which I will not be able to provide. The Plague Inc. game has a transmission system which changes from country to country, which I will not be able to provide.

5.2 Visualisation

5.2.1 Covid-19 Data Sources

The data for this project will be sourced from the European Centre for Disease Prevention and Control (ECDC) [2]. The data is historic and only has data from the 1st week of 2020 to the 23rd week of 2022. The data is in a JSON format and includes the number of cases and deaths per week for each country. The format of the data is as follows:

```json
{
    "country": "Afghanistan",
    "country_code": "AFG",
    "continent": "Asia",
    "population": 38928341,
    "indicator": "cases",
    "weekly_count": 1368,
    "year_week": "2020-47",
    "rate_14_day": 6.5043,
    "cumulative_count": 44771,
    "source": "Epidemic
    intelligence national data"
}
```

Listing 5.1: Cases JSON Example

```json
{
    "country": "Afghanistan",
    "country_code": "AFG",
    "continent": "Asia",
    "population": 38928341,
    "indicator": "deaths",
    "weekly_count": 69,
    "year_week": "2020-47",
    "rate_14_day": 3.3395,
    "cumulative_count": 1695,
    "source": "Epidemic
    intelligence national data"
}
```

Listing 5.2: Deaths JSON Example

This is the format that the ECDC provide, but I will be ammending it slightly to make it easier to work with. I will be combining the cases and deaths into one object and adding a date field. This will make it easier to work with the data in the front end.

It also needs to correspond with the GeoJSON data I will be using to render the map.

It is worth noting that I don't want this code to be limited to just COVID-19 data. I want to be able to use this code for any epidemic data. This is why I am making the data more generic and easier to work with.

5.3 Compartmental Models

5.3.1 SIR Model

Compartmental models are a type of mathematical model used to represent the different populations in a system. The most common compartmental system in epidemiology is the SIR model [1]. The SIR model is a simple model which divides the population into three compartments: Susceptible, Infected and Recovered. The model is represented by the following differential equations:

$$\frac{dS}{dt} = -\alpha SI \tag{5.1}$$

$$\frac{dI}{dt} = \alpha SI - \beta I \tag{5.2}$$

$$\frac{dR}{dt} = \beta I \tag{5.3}$$

Where:

- S is the number of susceptible individuals.

- I is the number of infected individuals.

- R is the number of recovered individuals.

- α is the rate of infection.

- β is the rate of recovery.

To explain this model, it's important to understand proportional reasoning. In the first equation, 5.1, the rate of change of the susceptible population is proportional to the complement of the product of the susceptible and infected populations.
A way to think of why that is true is because the more infected people there are, the more likely it is for a susceptible person to become infected.
This model is a good starting point for undestanding the spread of a virus, but it has some limitations. In this model, once you have recovered, you are no longer able to be infected. Another issue is that the model assumes the disease is non-fatal.

5.3.2 Solution to the SIR Model

The SIR model can be solved using numerical methods. The most common method is the Euler method. The Euler method is a simple method for solving ordinary differential equations. It is not the most accurate method, but it is easy to implement. The Euler method is represented by the following equations:

$$S_{n+1} = S_n - \alpha S_n I_n \Delta t \tag{5.4}$$
$$I_{n+1} = I_n + \alpha S_n I_n \Delta t - \beta I_n \Delta t \tag{5.5}$$
$$R_{n+1} = R_n + \beta I_n \Delta t \tag{5.6}$$

Where:

- S_n is the number of susceptible individuals at time n.

- I_n is the number of infected individuals at time n.

- R_n is the number of recovered individuals at time n.

- Δt is the time step.

If we look at the phase space of the SIR model, we can see that the model has a fixed point at the origin. This means that the model will always return to the origin. This is not the case in real life, as the disease will eventually die out. This is because the model does not take into account the finite population size.

5.3.3   Improvements to the SIR Model

The SIR model can be improved by adding more compartments to the model. However, this makes the model more complex and harder to solve.

SEIR Model

This model adds an exposed compartment to the SIR model. For individuals who have been infected but are not yet infectious. The model is represented by the following differential equations:

$$\frac{dS}{dt} = \mu N - \mu S - \frac{\beta IS}{N} \tag{5.7}$$

$$\frac{dE}{dt} = \frac{\beta IS}{N} - (\mu + a)E \tag{5.8}$$

$$\frac{dI}{dt} = aE - (\mu + \gamma)I \tag{5.9}$$

$$\frac{dR}{dt} = \gamma I - \mu R \tag{5.10}$$

The SEIR model is better for simulations than the SIR model since it takes into account the incubation period of the disease. This is important as it is possible for a person to be infected but not yet infectious.
It is beyond the scope of this project to go into detail about the SEIR model, but it is worth noting that the model is more complex and requires more data to solve. The model is also more accurate than the SIR model.

5.4   Statistical Analysis

Statistical analysis is a key part of this project. I will be using statistical analysis to find correlations between the data and other factors. I will be comparing the cumulative cases and deaths of two countries to see if there are any correlations between the two.

I also want to make a statistic comparing the number of cases to the gdp per capita of the country to see if there is an inverse correlation between the two. This would be interesting to see richer countries were able to contain the virus better than poorer countries.

$$\text{Infections} \propto \frac{1}{\text{GDP Per Capita}} \tag{5.11}$$

If this is the case, I would like to calculate the constant of proportionality. This would be a good indicator of how much money a country needs to spend to contain the virus.

I would also like to compare number of cases to other statistics I have available to me in my GeoJSON file. This includes:

- Population

- Sovereign status

- Type of economy

- etc

Chapter 6

Design Review

6.1 Wireframing

I need to work within the constraints of node.js and D3.js for my designs. Below is a wireframe of the dashboard I plan on creating.
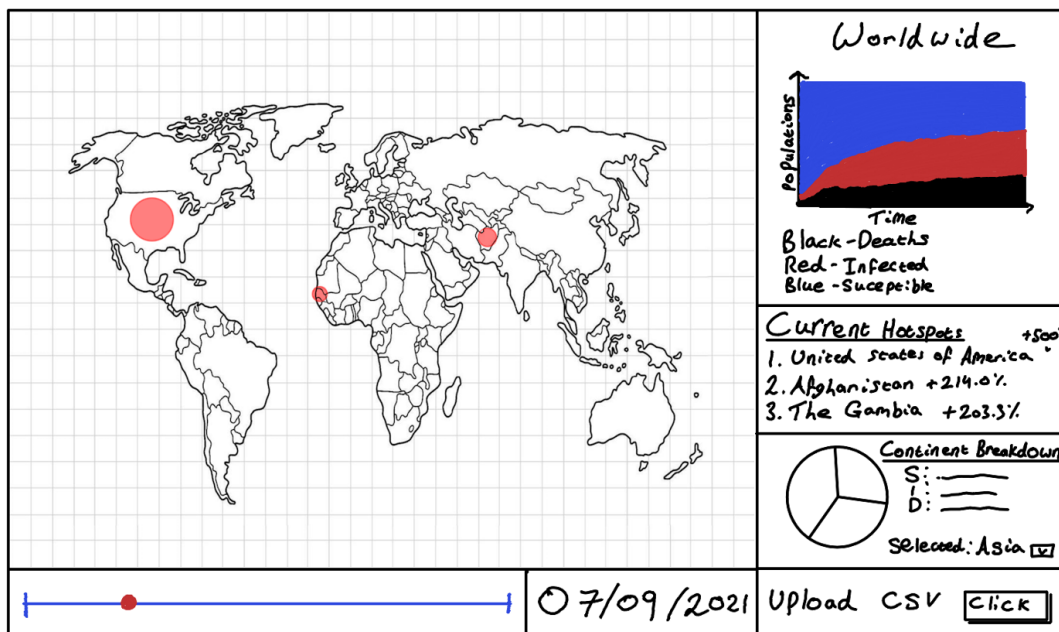

Figure 6.1: Wireframe of Dashboard

Specific features of the dashboard include:

- A map of the Earth.

- An interactive timeline of the epidemic.

- A area chart showing the number of cases, deaths and population susceptible.

- Listed hotspots and the percentage change within the countries.

- Hotspots on the map.

- A pie chart for susceptible, infected and dead populations within continents.

- A button to load different data files.

- The current date in the data.

When clicking on a country, the canvas will zoom onto the country, giving more specific information on how the pandemic is affecting that country. A button will also be available to return to the world map.
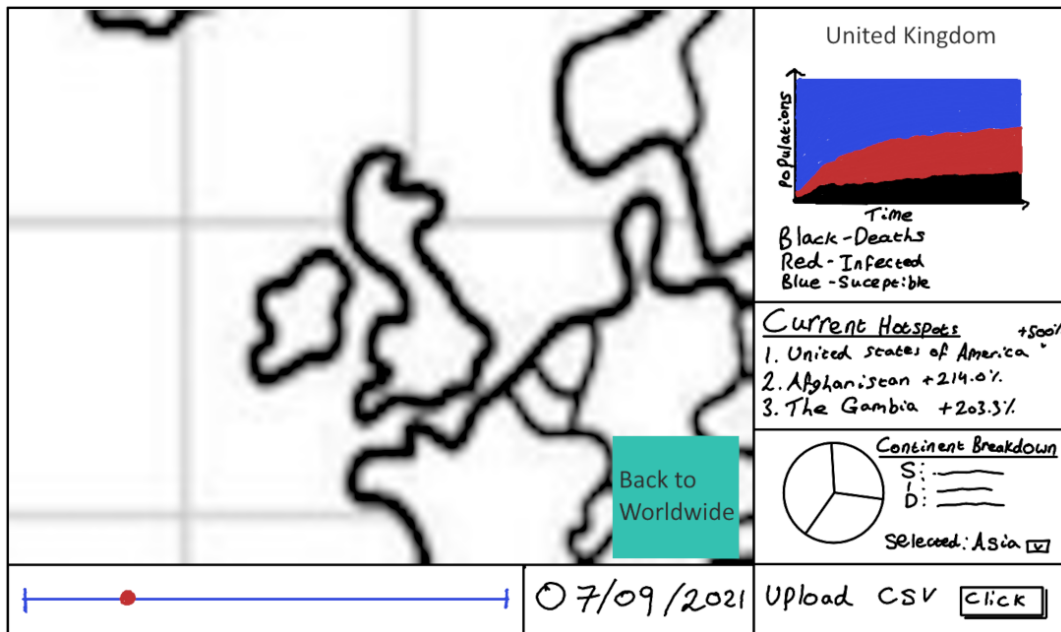

Figure 6.2: Wireframe of Country Page

A perk of using SVG to render the map is that when zooming, no resolution is lost. This is because SVG is a vector format, meaning that the image is made up of lines and shapes rather than pixels. This means that the image can be scaled up and down without losing quality.

6.2 D3.js

D3.js is a JavaScript library for producing dynamic, interactive data visualisations in web browsers. It makes use of the widely supported SVG format to render graphics. D3.js is a powerful tool for creating visualisations and is widely used in industry.

D3.js is a good choice for this project as it natively supports GeoJSON data which is the format I will be using for the map. The polygon data is open source. [4]

This is exclusively used on a web browser, so I will be using node.js to serve the data to the front end.

D3.js also has many built-in functions for creating different types of graphs and charts and interacting with them. As an example, D3.js has a built-in function for calculating the bounding box of a country polygon. I will be using this function to calculate where to zoom in on the map. Here's a JavaScript snippet of how I will be using this function:

```
1   // Creates a 2d array of the bounding box of the country
2   const bounds = path.bounds(d);
3   const dx = bounds[1][0] - bounds[0][0];
4   const dy = bounds[1][1] - bounds[0][1];
5   const x = (bounds[0][0] + bounds[1][0]) / 2;
6   const y = (bounds[0][1] + bounds[1][1]) / 2;
7
8   // Calculate the scale of the zoom
9   const scale = Math.max(1, Math.min(8, 0.9 / Math.max(dx / width, dy / height)));
10  const translate = [width / 2 - scale * x, height / 2 - scale * y];
11
12  // Smoothly transition to the new zoom level
13  svg.transition()
14      .duration(750)
15      .call(
16          zoom.transform,
17          d3.zoomIdentity.translate(translate[0], translate[1]).scale(scale)
18      );
```

The GeoJSON data has much more information than the COVID-19 data. It includes geometry of the country, information regarding the countries economy, sovereign status, GDP, all in multiple languages. I will be cleaning the data to only include relevant information for this project: country name in English, country code (to link the data with the Covid-19 JSON file) and geometry information.

6.3   Chloropleth Maps

For this project, I referred to a book on data visualisation by Andy Kirk [3]. The book is a good introduction to maps with data visulalisation as well as the use of colour in maps making it a good resource.
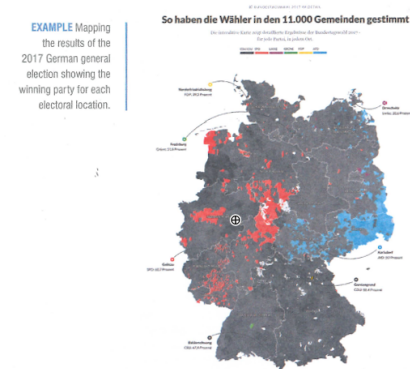

Figure 6.44   How Voters in the 11,000 Municipalities Voted, [Translated] by Berliner Morgenpost

Figure 6.3: Example Chloropleth Map from Andy Kirk's Book [3]

used scale for pandemic data.

Choropleth maps are a type of map which uses colour to represent data. The map is divided into regions and each region is coloured based on the data. This is a good way to visualise data as it allows for easy comparison between regions.

The figure on the left is colouring the regions based on different voter populations in Germany. This differs to how I will be using chloropleth. My legend will be a logarithmic scale from white to red to signify the number of cases in that region. The darker the red, the more cases there are in that region.

The reason I am choosing a logarithmic scale is due to the disparity of the numbers, especially in the early days of the pandemic. The logarithmic scale allows for a better visualisation of the data as it allows for a wider range of values to be represented. It is commonly the

Chapter 7

Technical Solution

7.1   Node.js

Before I start working on any code, I need to set up my development environment. As I discussed in my design section, I will be using node.js to serve data in front end and D3.js to render the data.

This is my first time using node.js and web development in general, so I spent a lot of time researching how to set up a node.js server. The first step I took was to install node.js on my local machine. I intend on deploying the application to a server hosted by the university using a Docker container, but I will be developing the application on my local machine.

I used the express.js framework to create a simple server with a router to serve the data. I have a diagram of the structure of my router schema below.
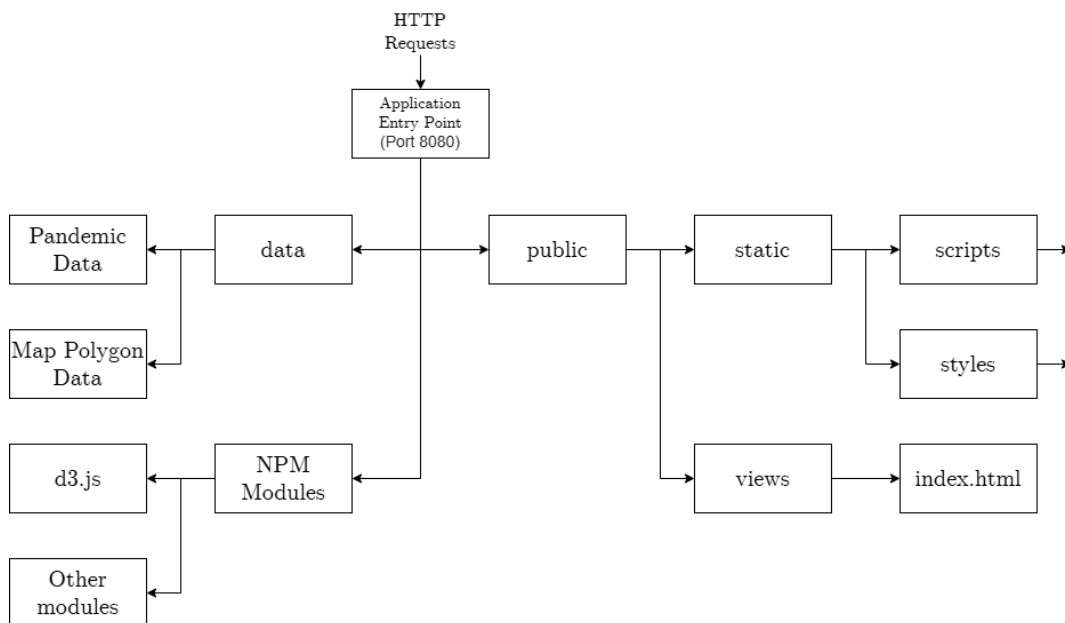

Figure 7.1: Data Routing Structure

7.2 Asynchronous Data Fetching

When dealing with data in JavaScript, and web programming as a whole, you must deal with asynchronous data fetching. This is because the data is not available immediately and the program must wait for the data to be fetched before it can be used. In my project, I used the fetch API to fetch the data. The word "server" in this context is a bit misleading, as the data is not being served from a server, but rather a local file. In node.js, the lines between server and client are blurred, as the server is also the client.

The fetch API is a promise-based API which returns a promise object. This means that the data is not available immediately and the program must wait for the data to be fetched. If the promise is resolved, it will contain the okay response of "200", and the data requested. If the promise is rejected, for example if the file is not found, it will contain the error message with an error code.

Because of the chance of the promise being rejected, I used error validation and a catch statement to handle the error. This is a good practice when dealing with asynchronous data fetching, as it allows for better error handling and debugging. Here is an example of how I used the fetch API to fetch the data:

```
1    fetch('https://api.example.com/data')
2    .then(response => {
3        if (!response.ok) throw new
4            Error('Network response was not ok'); // #404
5        return response.json();
6    })
7    .then(data => {
8        console.log('Data received:', data); // #200
9        // Process the data here
10   })
11   .catch(error => {
12       console.error('Fetch error:', error);
13   });
```

On the next page is a sequence diagram of the data fetching process. The diagram shows the flow of data from the server to the client and how the data is fetched asynchronously.
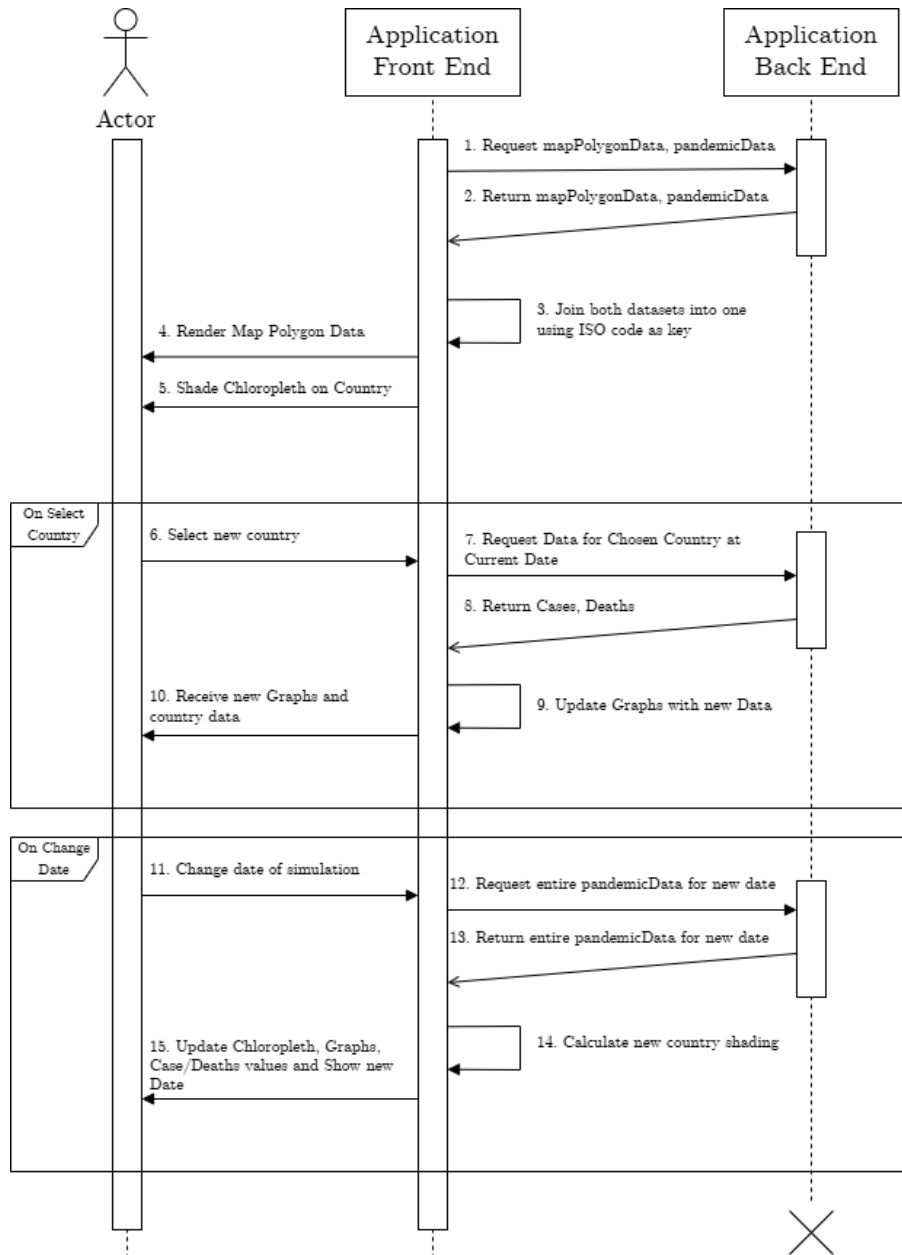
Figure 7.2: UML Sequence Diagram for Asynchronous Data Fetching

7.3 User Interface and Experience

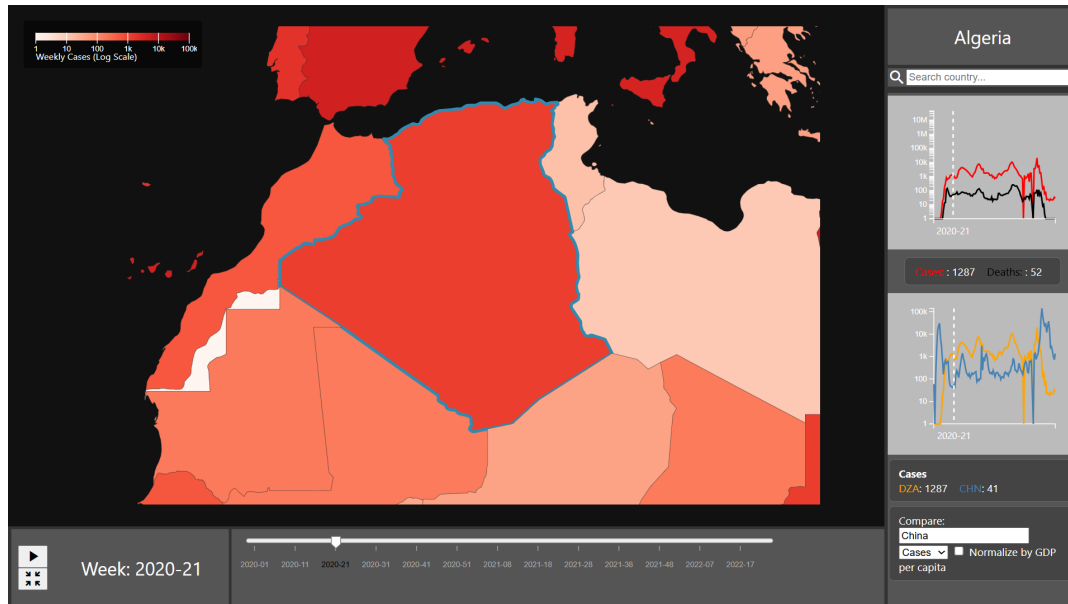Below is my dashboard created using d3.js and HTML.

Figure 7.3: Dashboard

7.4 Cleaning the Data

Before I start working on the front end, I need to clean the data. The data from the ECDC is in a JSON format, but it is not in a format that is easy to work with. I need to combine the cases and deaths into one object and add a date field. This will make it easier to work with the data in the front end.

I will be using Python to clean the data, since doing this is a one-time task and Python is a good language for data manipulation. I will be using the Pandas library to read the JSON file and manipulate the data. I will then write the cleaned data to a new JSON file.

I restrucutred the data to look like this:

```
 1   {
 2       "Afghanistan": {
 3           "properties": {
 4               "country": "Afghanistan",
 5               "country_code": "AFG",
 6               "continent": "Asia",
 7               "population": 38928341,
 8               "source": "Epidemic intelligence national data"
 9           },
10           "data": {
11               "2020-01": {
12                   "cases": 0,
13                   "deaths": 0,
14                   "cumulative_cases": 0,
15                   "cumulative_deaths": 0
16               },
17               [...]
18           }
19       },
20       [...]
21   }
```

The python code I used can be found in the appendix.

7.5 Country Selection

For this project, I need to decide on what list of countries to use. The GeoJSON file I will be using has a selection of countries, but a definitive list of countries doesn't exist.

There are multiple countries that are in dispute due to political or territorial reasons. For example, Taiwan is not recognised as a country by the United Nations due to China needing to agree, but it is a country in its own right. I will be including Taiwan in my list of countries.

Another consideration are countries which aren't included in the **ISO 3166 − 1 Alpha − 3** country code set which is what both the ECDC and GeoJSON file use. An example is Somaliland which is a self-declared state but is not recognised by the United Nations or the ISO-3166-1 country code, but the dataset does contain data so we will extend the country code set to include this.

There are multiple more examples like this, here is a list of countries I will be including in my dataset:

Country or Area Name	ISO Code	Country or Area Name	ISO Code
Afghanistan	AFG	Chile	CHL
Africa (total)	N/A	China	CHN
Albania	ALB	Colombia	COL
Algeria	DZA	Comoros	COM
America (total)	N/A	Congo	COG
American Samoa	ASM	Cook Islands	COK
Andorra	AND	Costa Rica	CRI
Angola	AGO	Cote Divoire	CIV
Anguilla	AIA	Croatia	HRV
Antigua And Barbuda	ATG	Cuba	CUB
Argentina	ARG	Curaçao	CUW
Armenia	ARM	Czechia	CZE
Aruba	ABW	Democratic Republic Of The Congo	COD
Asia (total)	N/A		
Australia	AUS	Denmark	DNK
Austria	AUT	Djibouti	DJI
Azerbaijan	AZE	Dominica	DMA
Bahamas	BHS	Dominican Republic	DOM
Bahrain	BHR	Ecuador	ECU
Bangladesh	BGD	Egypt	EGY
Barbados	BRB	El Salvador	SLV
Belarus	BLR	Equatorial Guinea	GNQ
Belgium	BEL	Eritrea	ERI
Belize	BLZ	Estonia	EST
Benin	BEN	Eswatini	SWZ
Bermuda	BMU	Ethiopia	ETH
Bhutan	BTN	EU/EEA (total)	N/A
Bolivia	BOL	Europe (total)	N/A
Bonaire, Saint Eustatius And Saba	BES	Falkland Islands (Malvinas)	FLK
Bosnia And Herzegovina	BIH	Faroe Islands	FRO
		Fiji	FJI
Botswana	BWA	Finland	FIN
Brazil	BRA	France	FRA
British Virgin Islands	VGB	French Polynesia	PYF
Brunei Darussalam	BRN	Gabon	GAB
Bulgaria	BGR	Gambia	GMB
Burkina Faso	BFA	Georgia	GEO
Burundi	BDI	Germany	DEU
Cambodia	KHM	Ghana	GHA
Cameroon	CMR	Gibraltar	GIB
Canada	CAN	Greece	GRC
Cape Verde	CPV	Greenland	GRL
Cayman Islands	CYM	Grenada	GRD
Central African Republic	CAF	Guam	GUM
		Guatemala	GTM
Chad	TCD	Guernsey	GGY

Country or Area Name	ISO Code	Country or Area Name	ISO Code
Guinea	GIN	Moldova	MDA
Guinea Bissau	GNB	Monaco	MCO
Guyana	GUY	Mongolia	MNG
Haiti	HTI	Montenegro	MNE
Holy See	VAT	Montserrat	MSR
Honduras	HND	Morocco	MAR
Hungary	HUN	Mozambique	MOZ
Iceland	ISL	Myanmar	MMR
India	IND	Namibia	NAM
Indonesia	IDN	Nauru	NRU
Iran	IRN	Nepal	NPL
Iraq	IRQ	Netherlands	NLD
Ireland	IRL	New Caledonia	NCL
Isle Of Man	IMN	New Zealand	NZL
Israel	ISR	Nicaragua	NIC
Italy	ITA	Niger	NER
Jamaica	JAM	Nigeria	NGA
Japan	JPN	North Macedonia	MKD
Jersey	JEY	Northern Mariana Is-	MNP
Jordan	JOR	lands	
Kazakhstan	KAZ	Norway	NOR
Kenya	KEN	Oceania (total)	N/A
Kiribati	KIR	Oman	OMN
Kosovo	XKX	Pakistan	PAK
Kuwait	KWT	Palau	PLW
Kyrgyzstan	KGZ	Palestine	PSE
Laos	LAO	Panama	PAN
Latvia	LVA	Papua New Guinea	PNG
Lebanon	LBN	Paraguay	PRY
Lesotho	LSO	Peru	PER
Liberia	LBR	Philippines	PHL
Libya	LBY	Poland	POL
Liechtenstein	LIE	Portugal	PRT
Lithuania	LTU	Puerto Rico	PRI
Luxembourg	LUX	Qatar	QAT
Madagascar	MDG	Romania	ROU
Malawi	MWI	Republic of Türkiye	TUR
Malaysia	MYS	Russia	RUS
Maldives	MDV	Rwanda	RWA
Mali	MLI	Saint Kitts And Nevis	KNA
Malta	MLT	Saint Lucia	LCA
Marshall Islands	MHL	Saint Vincent And The	VCT
Mauritania	MRT	Grenadines	
Mauritius	MUS	Samoa	WSM
Mexico	MEX	San Marino	SMR
Micronesia (Federated	FSM	Sao Tome And Principe	STP
States Of)		Saudi Arabia	SAU

Country or Area Name	ISO Code
Senegal	SEN
Serbia	SRB
Seychelles	SYC
Sierra Leone	SLE
Singapore	SGP
Sint Maarten	SXM
Slovakia	SVK
Slovenia	SVN
Solomon Islands	SLB
Somalia	SOM
South Africa	ZAF
South Korea	KOR
South Sudan	SSD
Spain	ESP
Sri Lanka	LKA
Sudan	SDN
Suriname	SUR
Sweden	SWE
Switzerland	CHE
Syria	SYR
Taiwan	TWN
Tajikistan	TJK
Thailand	THA
Timor Leste	TLS
Togo	TGO
Tonga	TON
Trinidad And Tobago	TTO
Tunisia	TUN
Turks And Caicos Islands	TCA
Tuvalu	TUV
Uganda	UGA
Ukraine	UKR
United Arab Emirates	ARE
United Kingdom	GBR
United Republic Of Tanzania	TZA
United States Of America	USA
United States Virgin Islands	VIR
Uruguay	URY
Uzbekistan	UZB

Country or Area Name	ISO Code
Vanuatu	VUT
Venezuela	VEN
Vietnam	VNM
Wallis And Futuna	WLF
Western Sahara	ESH
Yemen	YEM
Zambia	ZMB
Zimbabwe	ZWE
Cyprus	CYP

Initially, I wanted to use UNIX timestamps to store the date, but I have since changed my mind. This is because of of how the HTML slider tag works. The slider expects consistent step values, and UNIX timestamps are not consistent due to daylight savings time.

To combat this, I am storing data in the string form of "YYYY-ww" where YYYY is the year and ww is the week number. This is a consistent format and will work with the HTML slider tag. I will have a function to convert the string to a date object when I need to use it. It is also ISO 8601 compliant, which is a good standard to use.

7.6 Frontend

7.6.1 World Map

The world map in this project was a success in planning. I used the D3.js library to render the map and it worked well. The map is interactive and allows the user to zoom in on countries.

I was able to take advantage of features in D3.js like transisition and zoom for a smoother feel to the map. The chloropleth map is a good way to represent the data and allows the user to see the hotspots of the virus.

I used the GeoJSON polygon data to render the map. This had many beneficial side effects, like: Choice of projection, the multipolygon feature of GeoJSON, rendering the data in SVG format, and the ability to use D3.js features like transitions and zoom.

7.6.2 Info Panel

Originally, I planned to use a stacked area chart for this project, but I have since changed my mind. The reason is that the stacked area chart is not a good way to represent the data. The populations of the susceptible and the cases/deaths are very disproportionate so a linear scale would not work. Instead, I will be using a logarithmic scale for the y-axis. This will allow me to show the data in a more meaningful way.

The area chart will be a simple line chart with the x-axis being the date and the y-axis being the size of the populations. The chart will have a legend to show what each line represents. The chart will also have a title and axis labels.

7.7 Search Bar

The search bar is a simple input field which is designed to behave the same as just clicking a country.

7.8 Backend

For the data in my application, I am using the file "interface.js" to load the data from the JSON file. This file is an async module which exports a function to load the data. The function can fetch all data or data specfied in the parameters. The function will return a promise which resolves to the data. This is a simple way to load data from a file and is a common pattern in JavaScript.

This is my first time ever dealing with async functions and promises.

Chapter 8

User Analysis

For this section, I conducted user testing on my application. I lead the testers through an activity where they had to use the application and extract information from it. I then asked them what they thought of the application and if they had any suggestions for improvement.

8.1   User Testing

The first set of questions was in regards to the UI and UX of the application and how easy it was to use. These were the questions asked:

Question 1: By clicking the country, select Egypt
Question 2: Using the zoom button, zoom into Egypt.
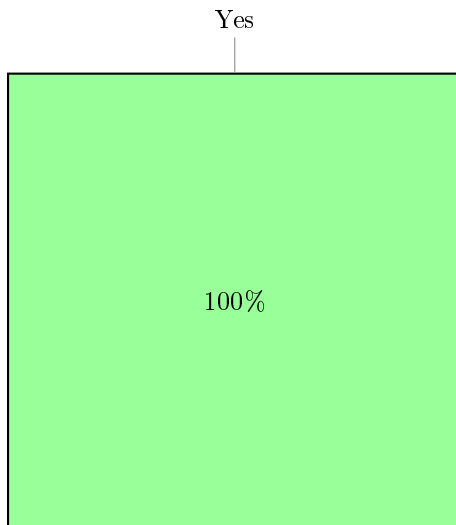
Figure 8.1: Question 1 Results
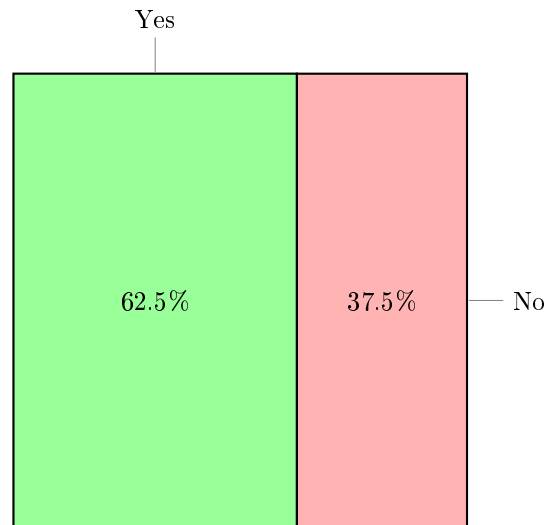
Figure 8.2: Question 2 Results

There was no issue with the first question, all users were able to select a country and see the corresponding data. However, the second question caused some issues. The main issue with the zoom feature was that the button to activate the zoom mode was not clear. The users were confused about how to activate the zoom mode and some of them did not know that they could click on the map to zoom in.

The next set of questions was in regards to getting data from the application. I had 4 questions in this section.

Question 3: How many cases of Covid-19 was recorded in the 20th week of 2020 in Egypt?
Question 4: Using the comparison graph, did Egypt or South Africa have more deaths on the 45th week of 2020?
Question 5: On what week did Sweden have it's peak case count?
Question 6: Compare the cases per GDP between United Kingdom and Germany on the week 2021-48, which country had more cases per GDP?

The results of the questions are below:
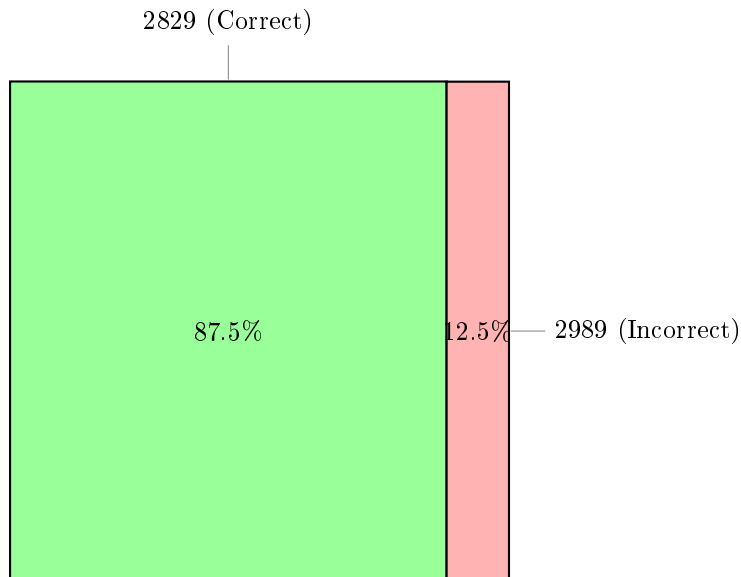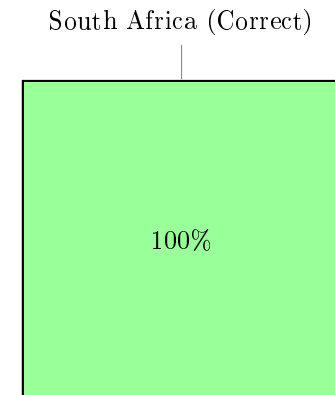

Figure 8.3: Question 3 Results
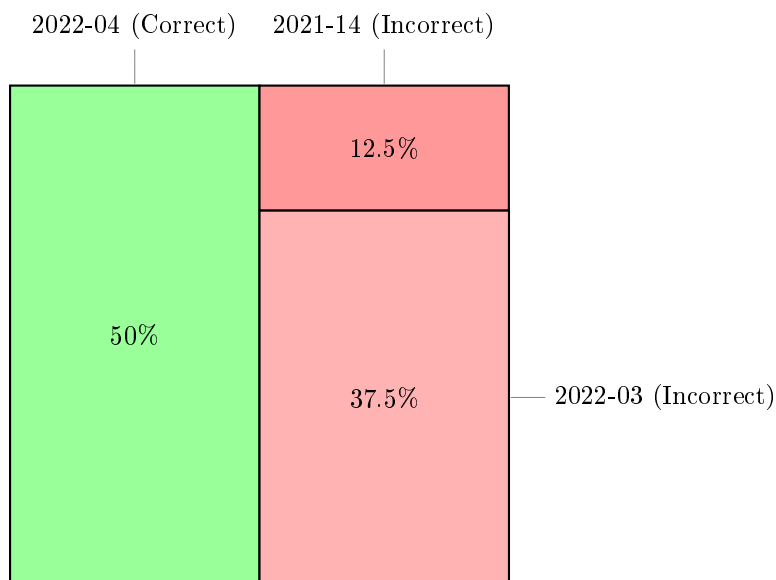

Figure 8.4: Question 4 Results
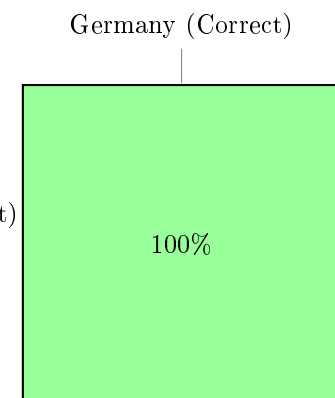

Figure 8.5: Question 5 Results

Figure 8.6: Question 6 Results

Overall, I am happy with the results of the user testing. My worst answered question was question 5, where only 50% of users got the question correct. This was somewhat expected as the question required the uesr to use the program in a way that was not initially intended. The question was asking the user to find the peak case count of a country, which is not a feature of the program. The users were able to find the data, but they were not able to find the peak case count. This is something I will be looking to improve in the future.

8.2   User Feedback

The users were overall happy with the application. They liked the design and the way the data was presented. The users also liked the interactivity of the map and how they could zoom in on countries.

However, I recieved many suggestions for improvement, some of which I will be implementing. The main suggestions were:

- The zoom button was not clear and the users did not know how to activate it.

  - The button was hard to identify and it was not clear what it did. I will be changing the button to a more recognisable icon and adding a tooltip to explain what it does.
  - The current behavior of the button shows a globe icon when the map is not in zoom mode, and a zoom icon when the map is in zoom mode. This is not clear and I be inverting the icons.

- The search bar was not clear and the users did not know how to use it.

  - The behaviour of the search bar and the comparison search bar were slightly different and one required the enter key to be pressed. I will be changing the search bar to behave the same as the comparison search bar.
  - The search icon was not a button like the users expected. I will be changing the search icon to a button and adding a tooltip to explain what it does.

- The users wanted the graphs to be zoomable on a separate window.

- Functionality to right click a country to add country to comparison graph.

- Searching for a country did not highlight the country on the map.

Chapter 9

Conclusion

Chapter 10

Bibliography

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Chapter 11

Appendix

11.1   restructure-json.py

```python
import json
from collections import import defaultdict

# Load JSON data from file
with open("data.json", "r", encoding="utf-8") as infile:
    json_data = json.load(infile)

# Transform data
result = defaultdict(lambda: {"properties": {},
                              "data": defaultdict(lambda:
                                       {"cases": 0,
                                        "deaths": 0,
                                        "cumulative_cases": 0,
                                        "cumulative_deaths": 0})})

for entry in json_data:
    try:
        country = entry["country"]

        # Populate properties
        if not result[country]["properties"]:
            result[country]["properties"] = {
                "country": entry.get("country", "Unknown"),
                "country_code": entry.get("country_code", "N/A"),
                "continent": entry.get("continent", "Unknown"),
                "population": entry.get("population", 0),
                "source": entry.get("source", "Unknown")
            }

        # Organize data by year_week
        year_week = entry.get("year_week", "Unknown")
        weekly_count = entry.get("weekly_count", 0)
        cumulative_count = entry.get("cumulative_count", 0)
        indicator = entry.get("indicator", "").lower()

        if indicator == "cases":
            result[country]["data"][year_week]["cases"]
                    = weekly_count
            result[country]["data"][year_week]["cumulative_cases"]
                    = cumulative_count
        elif indicator == "deaths":
            result[country]["data"][year_week]["deaths"]
                    = weekly_count
            result[country]["data"][year_week]["cumulative_deaths"]
                    = cumulative_count
    except KeyError as e:
```

```
47              print(f"Missing key {e} in entry: {entry}")
48
49  # Convert defaultdict to normal dict
50  final_result = {country: {"properties": data["properties"],
51          "data": dict(data["data"])} for country, data in result.items()}
52
53  # Write output to a new JSON file
54  with open("restructured_data.json", "w", encoding="utf-8") as outfile:
55      json.dump(final_result, outfile, indent=4)
56
57  print("Data successfully transformed and saved to 'new_data.json'")
```