FINAL YEAR PROJECT DIARY – SIMULATING AN INFECTIOUS DISEASE USING AN INDIVIDUAL BASED MODEL

MEETING 1 – 02/10/2023

Elizabeth has provided a PDF document after our first-ever meeting which should serve as an introduction to the final-year project that I will be working on this academic year. The project is entitled “Simulating an infectious disease using an Individual-Based Model (IBM). I was asked to read the Introduction paragraph which described the history and significance of these mathematical models. I found out that there are a few types of epidemiological models with one being the SIR model (1st ever model ever; invented in 1927). It consists of 3 compartments which are “Susceptible”, “Infected” and “Recovered”, meaning that all individuals in their respective compartments are all the same and that individuals move on to another compartment after a certain time. However, this is not the case with the Individual Based Model where all individuals move around in the same – meaning no compartments. The idea is to see how they all act and interact within the same environment. The plan is to simulate such a model to see how the population within the environment evolves over a certain period. So, this was my first understanding from reading the Introduction and Subsection 2.2 (Compartment models).

In the meeting on the 2nd of October 2023, we went through the idea of compartment models again where I managed to gain a better understanding of how a SIR model works (compartment model). Furthermore, the differential equation for the SIR model has been explained thoroughly so, I have now a better understanding of what each equation stands for.

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Susceptible

Infected

Recovered

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α = death rate

µ = birth rate

γ = recovery rate

β = transmission rate

Susceptible equation:

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Average number of susceptible over a certain period of time = Number of susceptible introduced into compartment (number of births) – number of deaths within susceptible compartment – transmission rate after multiplying Individuals who are susceptible with the ones who have become infected with the disease.

Infected equation:

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The average number of infected over a certain period of time + Transmission rate after multiplying individuals who are susceptible with the ones who have become with the disease (It's positive since the compartment is gaining new individuals from the susceptible compartment) - the number who have recovered – number of individuals who have died from being infected

Recovered equation:

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The average number of recovered individuals over a certain period of time = + Number of recovered individuals from the Infected compartment – the number of individuals who have recovered from disease but still died from natural causes.

After the session, Elizabeth told me to go through the concept of compartment models and their differential equations so that I fully understand the concept of them. In addition, I was also told to read subsection 2.1 about the Individual-Based Model and have a first look at the Pseudo Code in the Appendix to get familiar with it. Also, I should have a little try with ODE which is a simulation tool.

Representation of the SIR model:

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MEETING 2 – 09/10/2023

During my last meeting, we went into detail on the meaning and application of an Individual-Based Diagram (IBM). Firstly, the Individual-Based Model's main target is to make it easier to understand how all individuals interact with one another in a shared environment, especially when there are groups of different individuals that go by the name of Susceptible, Infected, and Recovered. We also had a brief discussion about compartment models during the session, highlighting the main differences between the two models.

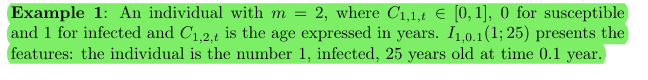
At the end of the meeting, Elizabeth told me to read Chapter 3 of the PDF that she provided in the first-ever meeting. Chapter 3 mainly focuses on the implementation of a basic IBM. It should give me a basic idea of how to construct an IBM and what the things are that I should consider. Elizabeth has asked me to choose a suitable programming language to construct the IBM. I have decided to go for Python as I have previous experience in using Python. For the next meeting, I aim to read and understand the whole of Chapter 3 and come back to Elizabeth with any questions and doubts that I may encounter when reading Chapter 3.

In addition, I was told to continue the implementation of the IBM using the pseudo-code that can be found at the bottom of the PDF. The goal of this academic year is to create an IBM simulation which will be executed a good number of times to observe how agents' interactions are at each run. It is expected to see different results at each simulation. The result of each run will eventually be plotted on a graph and compared with the results obtained from those students who are working on constructing an SIR model. All this work needs to be completed by next Monday when the next meeting is.

MEETING 3 – 23/10/2023

In this meeting, we delved into Section 3 titled “Creating an IBM for Infectious Diseases” to gain a better understanding of the functionality of an Individual-Based Model. Elizabeth asked me in the last meeting to have a first read of that section and come back with questions about anything that I hadn’t understood when reading the section. I had several questions because I found some aspects of this section a little bit confusing, so Elizabeth kindly addressed my concerns and provided a better understanding of the symbols and notations used when defining the characteristics of an individual in the Individual-Based Model.

To simplify things for me, she went through this example here:



This example specifies that Individual 1 has 2 characteristics denoted as (m = 2). The first characteristic indicates the individual’s status, whether the individual is susceptible (0), infected (1), or has recovered (2). In this specific case, Individual 1 was infected. The 2nd characteristic represents the individual’s age, which, in this example, was 25 years old.

We would express the individual’s characteristics as outlined below:

A hand holding a piece of paper with writing on it

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2nd characteristic - age

Therefore, it was established that at time t = 0.1, individual 1 was both infected and 25 years old.

After that example, we went through some of the probability density functions which are mainly used to calculate how likely it is for someone to get infected and recover in a particular environment. The higher the number, the lower the recovery rate.



Subsequently, Elizabeth went through another question of mine which was the example shown below:

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The example has stated that the average life expectancy for all individuals in this specific environment is 70 years old. So, people in this environment tend to live around that age. When a new individual is introduced into this environment, it receives characteristics that determine when it will die. A random number between 0 and 1 will be given to each new individual which will help to find out the age that individual is going to die.

In this case, the random number we have chosen is x = 0.8147

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We use this formula and substitute the values into it.

Cn,m,t = -

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We calculate the natural logarithm of x

Cn,m,t = -70 x ln(0.8147)

Cn,m,t = -70 x (-0.2049)

Cn,m,t = 14

This individual will live roughly 14 years

Th

We are looking at one individual hence

The average life-expectancy in the population

This session has significantly improved my understanding of the formulas and calculations presented in Section 3. However, to ensure my complete understanding, Elizabeth has suggested that I revisit Section 3 in preparation for implementing my own infectious disease model using the pseudo-code provided in the PDF file.

MEETING 4 – 30/10/2023

During this meeting, we delved into the contents of Section 3, primarily to ensure that I have a better understanding of the fundamental concepts related to how an individual behaves within an individual-based model (IBM).

Furthermore, we have spent a good amount of time discussing the structure of the final year report. Elizabeth has kindly provided me with a structured template to follow for the report. The image underneath shows exactly how the report should be structured. The final year report is expected to have 5 major sections.

**STRUCTURE OF FINAL YEAR REPORT:**

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1. **Introduction** – In this section, the report begins with an introduction that lays the foundation for the entire research project. It will provide a clear overview of infectious diseases, why it is important to model these diseases, what models have been introduced in the decades, and the goals and objectives of this project.
2. **Literature Review** – Literature Review, the second section will delve into existing research that exists in the field of modeling infectious diseases. Numerous past papers will be explored and used to showcase the existing knowledge experts already have on this topic.
3. **Individual-Based Model** – Following the literature review, I will dedicate a section to detail the IBM that I intend to implement. This is the main goal of this project, and it will cover all the methodologies and any interesting things related to the model. Before talking about IBM, I will also make some references to the SIR model, a compartment model which the IBM model shares similarities with.
4. **Results** - Subsequently, I will present the results I gained from simulating my Individual-Based Model. This section will showcase all my findings which can be graphs, tables, screenshots, etc. I will eventually, analyze and describe all the findings that I have provided in this section. It is here where I evaluate the model’s performance.
5. **Conclusion** – The final section of the report will be dedicated to a conclusion. In this part, I will summarize my key findings, mention the significance of this project, and perhaps provide recommendations for people who may be interested in constructing their own IBM based on infectious diseases.
6. **After Conclusion** – Following the conclusion, I’ll include helpful visuals like graphs and screenshots related to the project in the report. I’ll also add important documents like the Project Definition Form and Ethical Form. Furthermore, I’ll also provide all the summaries of all mines weekly meetings that I have had with Elizabeth, showing how the project evolved. These summaries are like a diary of my progress. After all items I will place references and appendixes, giving readers a clear idea of where I have obtained some of the information that I have mentioned throughout the report.

After Elizabeth has broken down the structure of the final year report, she has said that it is important to have the 3 first sections of the report (Introduction, Literature Review, IBM) completed by the end of Term 1. These sections are considered stable and therefore are unlikely to be changed later in this academic year.

In addition to writing the report, Elizabeth encouraged me to start the implementation of a basic Individual-Based Model using our preferred programming language. She expects me to have a basic individual-based model ready by the end of the term. If I encounter any questions or run into issues during the implementation, I should bring them up in the next meeting.

*MEETING 5 – 13/11/2023*

In the meeting, I expressed concern to Elizabeth about certain lines of code in the pseudo-code in the PDF. Elizabeth took the time to walk through the entire pseudo code, ensuring that I gained a clearer understanding of its content.

1. Parameters – these will serve as inputs for the simulation.

* N(t) – Total population at a specific “t”
* △t – Time step/ stamp (e.g., Day 1, Day,2…. Day 365)
* y – Recovery rate – how quickly someone recovers
* µ - Birth rate – the rate at which new individuals are born into the population
* βI – Transmission/Infection rate – rate represents the probability the probability of transmission of the infectious disease from an infected individual to a susceptible individual per unit of time. It quantifies how easily the disease is spread from infected individuals to those who are still susceptible to the infection.

1. Initialization

* P0 – Initial population (which can be 100; must be constant)
* Pt – Population at time

1. Calculating the values for everyone in the population using formulas.
2. Implement for-loops to check conditions and perform an action accordingly (e.g., adding new births when an individual dies).
3. Repeating this process daily until the specified end time is reached.

Following the meeting, I can confidently say that I have improved my understanding of how to implement the code and conduct the simulation. The goal for our upcoming meeting next week is to have initialized the required parameters and potentially start coding the 1st For-Loop outlined in the pseudo-code.

Additionally, Elizabeth also reminded the importance of making progress on the first few sections of our final year project, I plan to begin the introduction this week to ensure I meet her deadline for the first few parts of the report by the end of the term.

**Sheet Elizabeth has used to explain the entire pseudocode to me:**

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Example of how one of the graphs looks like

Matrix of 100 individuals

MEETING 6 – 20/11/2023

During our meeting, we went through the Abstract I had written for my Final Year Project Report. Elizabeth emphasized that, at this early stage in the academic year with the project deadline in April, the Abstract isn't a section that I should focus on now. She suggested prioritizing more detailed sections like the Introduction, Literature Review, and Methodology, as there hasn't been significant progress on the project yet. Elizabeth highlighted that these sections require more attention and development at this point. I plan to make a start on the introduction and the literature review this week, aiming to reach the mid-point of the literature review for our next meeting on Monday.

In terms of implementing the individual-based model, I have not yet started the process, as I found it necessary to gather additional information from the resources that were provided to me. Now, having gained a better understanding, I plan to initiate the implementation this week. The goal is to present any progress I make this week to Elizabeth during our upcoming meeting.

MEETING 7 – 27/11/2023

During our meeting, we reviewed the introduction that I have drafted so far for my Final Year Project Report. Elizabeth insisted that it was a good approach but highlighted the need for additional references. She emphasized the importance of including more references whenever I make strong statements. Furthermore, Elizabeth suggested including a brief passage where I will be talking about the compartment model, which is the pioneering model used for simulating infectious diseases and has significantly influenced IBM's approach.

Moreover, Elizabeth went through the layout of the final year project. She has said that the section following the introduction is the background research, where I am expected to review eight related works conducted by individuals in the past. Each study that I chose should be summarized in short paragraphs. After the Literature Review section, I will have a section where I talk about the compartment models (SIR model) and the IBM model in more detail. All these sections are expected to be completed by the end of the term, within the next three weeks.

Regarding the coding for this project, I began coding last week and wanted Elizabeth to have a brief look at what I have produced so far. Additionally, I asked questions to her about a line in the pseudo-code that I didn’t understand fully. Elizabeth provided a clear explanation of that code during the meeting, enabling me to understand that line of code now. Now, after the meeting, I can confidently say that I understand what that specific line of code does. I will now continue to write appropriate code that aligns with that line in the pseudo-code. Elizabeth has assured me that what I have produced so far is acceptable, and I should continue working on it, considering that the deadline to have the entire simulation functional is in January, after we return from the Christmas break.

The goal for this week is to make the necessary amendments to my introduction in response to the feedback provided by Elizabeth during the meeting. Additionally, I plan to make a start on the background research section and aim to complete it before our next meeting. In terms of coding, I will be going to make progress on that aspect as well before the next meeting.

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MEETING 8 – 04/12/2023

The meeting lasted only a couple of minutes. During the meeting, we discussed the progress I made last week on the final year report, which is due between the 15th and 17th of December. Last week, I also emailed Elizabeth regarding the literature review section that I have started. I asked her to provide feedback on the paragraph I have written so far. She provided some appropriate feedback, which I will use to structure the rest of the literature review section.

Regarding coding the IBM, I have also made some progress in that aspect respectively. Elizabeth once again emphasized that she wants the IBM to be fully functional by the time we resume in January. She also reminded me that each chunk of code should be tested properly before moving on to the next block of code.

**Feedback that she has provided:**

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SESSION 9 – 11/12/2023

This was the final meeting that we had before the Christmas break. In the meeting, we briefly went through the final year report that I have written so far. Elizabeth was happy with the progress I have made so far on the report. She now expects to have the report handed in by Friday. In addition, I had a question about the last line of the pseudo-code. It wasn’t understandable to me, so Elizabeth did explain the line of code to me. The code basically tells the number of how many Susceptible, Infectious, and Recovered individuals at each simulation run. The number of those 3 disease states will also differ in each simulation. However, it is always expected that all individuals from the 3 compartments add up to 100 since it is a constant environment. I have now a better understanding of the line and know now how to convert that pseudo code to Python code for the simulation. During the Christmas break, I will actively work on the code and aim to complete the entire simulation in January before our next meeting.

**The line of code that she explained perfectly:**



SESSION 10 – 25/01/2024

This was the first after the Christmas break. In the session, we went through the report that I had handed in before we broke up for Christmas. Elizabeth made comments on the quality of my writing. She said that the overall quality of the report is good, but she also mentioned that some amendments needed to be made to the report. Firstly, she insisted that the word choice throughout the report is relatively complex. She said that I should use simpler words but still make sure to keep the tone of the report formal. Another thing that she mentioned is to get rid of the sentences where I conclude what each paragraph is about. They are not needed because they are repetitions of what I have already said before. Lastly, she asked me to write the equations manually instead of using screenshots of them. This will make the report look more neater and could potentially help in gaining more marks when it comes to the structure/layout of the report. So, these are the 3 main key areas of the report that I will focus my attention on before the next meeting before I proceed to work on the rest of the report.

Regarding the code, I also worked actively on the IBM model during my Christmas break. I have to some extent managed to complete a version of the model that runs perfectly. However, some more features need to be added before the next meeting. I should use the experiments in the documents that were provided to me at the beginning of the academic year as a reference. The experiments will give examples of how the final version of my code is expected to look. For the next meeting, I will check out the experiments and make some amendments to my code as well, so it meets the expectations of what is required.

SESSION 11 – 01/02/2024

In this meeting, I showed Elizabeth the amendments that I have made to the final year report as she requested. She has said that I am on the right track and that I should now proceed to complete the IBM model section before she can have a proper read of what I have written so far in the report.

Regarding the code, I have managed to complete the basic IBM model. Elizabeth was satisfied with the functions and results that my current IBM model produces. She expects me to include a vaccinated compartment in a few weeks to add a level of complexity to the scenario. The aim is to observe how the introduction of a vaccinated compartment influences the dynamics of transmission within a population. But, before I can proceed with incorporating a vaccinated compartment into my model, I need to carry out 2 simulation experiments found in the PDF. These experiments should help me understand what impacts changes to the parameters can have on the disease spread within a population.

For our next meeting, I will aim to have the section about the IBM model entirely completed and I will also perform those 2 simulations mentioned in the PDF document.

SESSION 12 – 08/02/2024

In this meeting, I showed Elizabeth the progress I have made on the IBM model section of my final year project. I have more and less completed the section, but there are still some amendments that need to be made. While Elizabeth had a look at what I have produced during the last week, she pinpointed that the way I write mathematical equations in the report is not acceptable. She explained that equations need to be numbered, and when used in sentences, they should be followed by a period. This is something that I need to do for the remaining equations mentioned in the report  
  
Regarding the actual IBM simulation, I have made a start on the experiments that are on the PDF document. The plan is to have both simulation experiments that Elizabeth asked me to do completed by next week.

SESSION 13 – 20/02/2024

In this meeting, I informed Elizabeth that I had completed the section on the IBM model for my final year report. She briefly reviewed the document to ensure its correctness. She suggested that I should add more information about IBM since it is the main focus of the project. For next week, my goal is to enhance the section about IBM.

Regarding the simulations she has asked me to do, I was a little bit confused about something. Elizabeth has in detail explained what I need to do for the simulations. Now, I have a much better understanding of what I am required to do regarding the simulations. I plan to attempt these simulation experiments and aim to have the majority of them completed for the next meeting on Tuesday the 27th of February.

**What I am expected to do for the simulations:**

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SESSION 14 – 07/03/2024

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In this meeting, I went through Simulation Experiment 1 and Simulation Experiment 2 which I have been working on since the last meeting we had. Firstly, I showed Elizabeth Simulation Experiment 1, and she straight away noticed a mistake that I had made in the implementation. The population of the simulation needs to remain constant throughout; however, my simulation does the complete opposite where the number of susceptible, infected, and recovered doesn’t add up to the no\_person that I have assigned. This is an error that I will have to address and fix before the next meeting next week. Another issue she detected was related to the way the graph was looking; Elizabeth wasn’t so pleased with the way the lines of the graph were this is related to the fact that my population isn’t constant. So, I will also be going to have a look at this small issue and try to resolve the problem.

Regarding Simulation Experiment 2, the task was to display comparisons between a SIR model and the IBM model. In this case, as well, Elizabeth managed to find an error in the graph. The IBM model doesn’t match with either the SIR model or the IBM model I developed for Social Experiment 1. The plan is to address and fix this issue by the next meeting.

SESSION 15 – 14/03/2024

In this meeting, I went through the amendments I have made to the IBM model. Elizabeth was overall satisfied with what I have produced. We had a little discussion on what I can do to improve the IBM model and what I should do for the upcoming month as the deadline for submission is approaching. She recommended that I research even more on IBM modelling, as she wants me to give a presentation in the next meeting about what happens when playing around with the parameters in the code. She will also ask me questions to confirm my understanding and reflections. So, for next week's meeting, I will need to conduct thorough research on this t) and design a presentation, work on the IBM model (including adding a vaccination compartment), and continue writing the final year report.

SESSION 16 – 21/03/2024

In this meeting, I delivered a short presentation about the IBM model. I explained to Elizabeth what would happen to the dynamics of transmission if I were to change the transmission rate to a higher value than 0.25. Subsequently, I also explained to Elizabeth what is expected to occur on the graph when adjusting the recovery rate. Elizabeth also asked me questions during the presentation to test my understanding. In general, it was a very good practice and a valuable experience before the real demo. After that, we had a brief discussion on the comparison that I had to do between my IBM model and the SIR model from one of my peers. She has provided some information that I could use to improve the comparison even further. Lastly, we also had a conversation about the “vaccinated” element that I would have to include in my current IBM model. She has also provided me with more information and knowledge regarding that. I would use all the insights that I have gained from that meeting and construct the “Vaccinated” compartment by next week, ready for my next meeting with Elizabeth.

SESSION 17 – 28/03/2024

In this meeting, we went through the IBM with the vaccination compartment that I implemented throughout this week. However, when outputting the graph, I quickly realized that something was wrong. I addressed the issue with Elizabeth, and she pinpointed some of the errors that can be seen in the graph and provided explanations on how to fix them. I will take her feedback on board and make improvements to the model, aiming to have a better version of the IBM ready for our meeting next week.

SESSION 18 – 04/04/2024

In this meeting, we have discussed the improvements that I have made to the “vaccinated” curve in the past week. Elizabeth was satisfied with the way the vaccination curve was functioning; however, I also had an inquiry about how vaccine efficacy would work in this model. She has perfectly explained the entire concept and now I have a better idea of how to make the vaccine efficacy parameter work. In this upcoming work, I will make small amendments to the code to ensure that the vaccine efficacy parameters work fine and that would complete the development of the IBM.

SESSION 19 – 11/04/2024

In this meeting, we had a brief discussion on the changes that I have made to my code and Elizabeth was generally really pleased with it and told me that the code was now fully ready. She has urged me to fully focus on the final year report from now on as the deadline is just around the corner. For the upcoming, I will continue working on the report with the aim of sending a complete draft of my report 24 hours before our next meeting.

SESSION 20 – 18/04/2024