**MIBTP2020 Modelling Assignment**

Due: by 23:59GMT on 31st of January 2021

**Task**

In a distant, dystopian future, a pandemic is ravaging the world… Until now, England has remained virus-free, however, today a case has been reported in the city of Coventry. The Prime Minister of England, John Borisson, has asked for your help.

This is what we know about the virus so far:

* It is a novel virus, with no pre-existing immunity in the population.
* It replicates in the body incredibly fast. As a result, once infected, individuals become immediately infectious to others.
* Given the way the virus is transmitted, transmission is frequency-dependent.
* No one survives if infected.
* In England, the first infection was detected in Coventry, with an estimated population of 316,960 (from the 2011 census data). We assume there are no other cases as of yet.
* Due to the discovery of the disease, Coventry was immediately shut off from the rest of the country – no one is allowed in or out.
* We have data for a similar outbreak involving the same virus, that occurred in an Italian city a few months ago. The number of infectious people in this city was recorded every 3 days for the first 60 days and is provided in the Italy\_outbreak\_data.csv file. The Italian city has twice the population of Coventry.
* Given the speed at which the disease spreads, you may assume throughout that the effect of births and natural (non-disease-related) deaths is negligible.
* There is an experimental treatment which appears to increase the survival rate from 0% to 75%, but does not change the length of the infectious period. Also, since no one has ever survived this disease before, it is unclear whether once someone recovers they have immunity or not.

Jo-Bo would like you to provide a report containing the following information:

1. A description of the disease and its likely parameters, based on the available data. (Hint: use ABC to find 500 acceptable parameter sets for your chosen compartmental model. Use sum of squares on the daily number of infections as the summary statistic with an acceptance threshold of your choice – it will be in the billions. Justify your choice of threshold by comparing simulations using your accepted parameters to the data. You do not need to run the ABC algorithm for more than a few minutes at most. Use the same prior distributions for the transmission and removal rates as in Workshop 4 Q2)
2. A description of how the virus might spread throughout Coventry. You may assume that the population in Coventry is large enough such that a deterministic ODE model provides a good approximation. This should be done for a number of different parameter values in order to portray the uncertainty from our fitted parameters (Hint: use the accepted parameters from your ABC procedure to run a deterministic compartmental model, using a different parameter set each time, and ‘summarise’ the results)
3. Using your best guess of disease parameters, give a range of how many lives could be saved by using the experimental treatment on anyone who is infected. Point out any possible negative outcomes that we should be aware of if we do this. (Hint: you will need to compare two models, one with immunity and one without)
4. There are many small villages on the outskirts of Coventry, just outside the radius of the lockdown. If a single infection was to make its way to one of these villages, what is the probability that the outbreak would take off and infect a significant proportion of the villagers? Use your best guess of disease parameters and assume the villages are approximately 1000 people in size. Also comment on how long a village should be locked down for, if the outbreak does take off in a village, to ensure a high chance of the outbreak being finished once it is reopened. (Hint: use the Gillespie Algorithm to generate a large number of simulations)
5. Using your best guess of disease parameters, describe what would happen if we allowed travel between Coventry, Birmingham and Leicester (you may ignore the existence of other cities). Comment on the cost (in lives lost) of implementing this policy. Would reducing the amount of interaction between cities have a significant effect on this cost? You may assume that Birmingham has a population of 1,073,045 and Leicester 329,839. Describe the interaction between cities using a coupling parameter, the strength of which is symmetric and given by the reciprocal of the distance between cities in km (i.e. 1/distance). The distance between cities can be taken as Birmingham - Coventry 31.4km, Birmingham - Leicester 68.7km, and Coventry - Leicester 43.3km. (Hint: use a deterministic, coupling metapopulation model with 3 patches)

**Report structure**

Your report should be written in the style of a scientific paper, in a single R markdown file and knitted to a PDF. The major differences between this and a real paper will be the lack of a literature review and references and the inclusion of code in the report. I recommend the following sections:

Introduction

A brief summary of the situation, what you did and your main results. You are not required to do any sort of literature review or provide any references.

Methods

This section should contain all the theory (NOT CODE) you have applied and assumptions you have made, similar to what was contained in the lecture slides. This is at least: a description of the models used (including equations – these can be written in Latex style format directly in R markdown using $$ …. $$), and the fitting procedure implemented. You can split this into subsections as you see fit.

Results

This is where you should put the code that you have used and figures you have generated. This should also contain the bulk of your explanation regarding your results, relating to the information you have been asked to provide. You can split this into multiple subsections as you see fit. Statements in the results section should be concise and factual, based on what you can see from your figures. It is entirely your choice what figures you use to help your explanation, however you should not make statements without some form of evidence. Figures should be captioned and referred to where appropriate; do not include figures that you do not refer to in the text. Include all code that you have used. Code should be commented.

Discussion

This should start with a summary of the results and their implications, followed by a discussion on the limitations and justifications of the methods you have used, the effect of changing assumptions and any possible improvements that could be made in future work. Statements in the discussion can be more speculative than those in the results section. You are not required to provide any references.

**Marking criteria**

Your mark will be made up of:

* Construction and explanation of models (20%)
* Correct coding of models (20%)
* Presentation of results (30%)
* Interpretation of results (30%)

**Other notes**

* There is no minimum / maximum word limit. However, treat this as you would a scientific paper: your explanation of the results should be enough to answer the questions, but be concise and factual. Similarly, the discussion points should show that you understand the assumptions and limitations of the work, but should be explained concisely. I recommend keeping sentences as short as possible. A clear, easy-to-follow discussion that covers the main points is more beneficial than a literary masterpiece with flowery language (in a scientific context!).
* I have purposefully left the brief very vague in places (as it would likely be in real life!). For example “ensure a high chance of the outbreak being finished”… You must decide what a high chance is, or you could also give a range of values etc. The point of this is that these sorts of analyses often involve many arbitrary decisions such as this. You should be confident in making such decisions!
* You should set the seed once at the very start of your .Rmd file, to ensure that the results will be the same each time you knit the whole document (as in Workshops 3 and 4). Use your student ID number to set the seed.
* ALL WORK MUST BE YOUR OWN. Code may be copied from the workshop materials, however you should write your own comments in the code. Do not copy code off each other. This obviously also applies to the writing of the report.
* We will organise 1 or 2 help sessions in January (timing tbc), however do not hesitate to contact demonstrators before then to ask for help if you need it. The earlier you ask for help, the more help we can give you…
* You are to submit as a PDF, not .Rmd or html. This means you will need to change the “output: html\_document” at the start of your .Rmd file to “output: pdf\_document”. Note that the PDF output will not automatically split long lines of code into multiple lines, so you will need to do this manually if necessary (this is also good coding practice).

**Submission**

Submit as a single PDF file, with the filename: LASTNAME\_FIRSTNAME\_MIBTP2020.pdf

Submissions made through the following link:<http://www2.warwick.ac.uk/fac/cross_fac/mibtp/intranet/training/taught_modules/modelling/modellingassignment>