Critical thinking:

1. So far, the brief has provided no information whatsoever regarding what the states A and B are and what the individuals are. Thinking about what is happening in this system, provide at least one example of real-world scenario to which this model could apply. Bonus points will be given for any answer that provides two examples, one in which the equilibria are of interest and the other in which the critical regime (when R0 = 1) is of interest. Either way, what is the benefit of being able to model the system? (8 marks)

One real-world scenario in which this model could apply is in the field of epidemiology, more specifically it could be used to model the spread of a disease throughout a population. The individuals in question would be humans and the two states A and B, would be susceptible and infected, retrospectively. Taking the very topical example of the coronavirus pandemic, we can begin to see how this model may be used to predict how the two states would be affected by the parameter R0. R0 is known in the world of epidemiology as the ‘reproduction number’ (Achaiah, Subbarajasetty & Shetty, 2020) and is based on several factors, with the variable factor being amount of contact between individuals.

If R0 is less than 1, this means that one infected person will spread the disease to less than 1 other individual and therefore the disease will perish in the population (Achaiah, Subbarajasetty & Shetty, 2020) which is what we have seen in our integration analysis as the lines fall to 0 over time. On the other hand, if R0 >1, each infected individual will spread the disease to more than 1 other individual and the disease will thrive. Once again, the output form analytical question 5 supports the theory as we can see that high R0 values led to higher B(t) values over time.

This example is focused mostly around our critical regime (R0=1). The main benefit of being able to model this system is to get an idea of how the spread of disease behaves over time and in relation to changes in parameters. Modelling the role of R0 can inform scientists about how changes in social contact (e.g. a national lockdown) will affect how many individuals are in each state. During the course of the coronavirus pandemic, analysis such as these I’m sure have informed policy and aided countries across the globe to keep their healthcare systems from being overwhelmed.

2. [Very tough question]: The model provided implicitly assumes that all individuals are potentially in contact with each other. What would be a more likely scenario? What changes would have to be made to the code of the Gillespie algorithm in order to include such a scenario? If you are able to do this, do it. Then, speculate as to what could affect the results observed in the previous questions. If you feel so inclined, demonstrate it experimentally. NB: Only 10 marks have been given to this question. However, anyone managing it successfully would receive an extra 10 marks for the assignment (with the total mark capped to 100 obviously). (10 marks)

In real-life it is highly unlikely that all individuals are potentially in contact with all other individuals in the population. It would be more likely that people would form groups within which they are more likely to be in contact with each other (for example family, friends or colleagues).

One way to incorporate this into Gillespie could be via some sort of graph algorithm. These types of algorithms are commonly used to track ‘relationships’ on websites such as Facebook (Ching, 2015). In our case, the graph algorithm would need to carry weights on the edges between nodes (the individuals) with these weights being some sort of measure of the likelihood that those two individuals will come into contact with one another. These weights would then need to be taken into account in the Gillespie algorithm.

In the case of the coronavirus pandemic, the UK government used a contact tracing application which individuals were asked to download onto their mobiles. This is one way in which this kind of data could be collected for use in the algorithm.

I have not attempted to implement this in python.

References:

Achaiah, N.C., Subbarajasetty, S.B. and Shetty, R.M., 2020. R0 and Re of COVID-19: Can We Predict When the Pandemic Outbreak will be Contained?. *Indian Journal of Critical Care Medicine: Peer-reviewed, Official Publication of Indian Society of Critical Care Medicine*, *24*(11), p.1125.

Ching, A., Edunov, S., Kabiljo, M., Logothetis, D. and Muthukrishnan, S., 2015. One trillion edges: Graph processing at facebook-scale. *Proceedings of the VLDB Endowment*, *8*(12), pp.1804-1815.