COVID-19 INDIVIDUAL BASED MODEL WITH INSTANTANEOUS CONTRACT TRACING

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1. Overview

The individual based model (IBM) is for simulating the spread of COVID-19 in a city and to analyse the effect of both passive and active intervention strategies. The model includes demographic data, which control both the dynamics of the interactions of individuals as well as the the outcome of the disease. The disease is spread via interaction between individuals which are remembered to facilitate contact tracing. Intervention strategies such as self-quarantining, testing and contact-tracing can then be analysed.

2. Demographics

The demographics of the model are based upon UK-wide data for 2018 from the Office of National Statistics (ONS). Individuals are put in one of 3 categories: child (0-17 years), adult (18-64 years) and elderly (65+). Every individual is part of household which forms an important part of each persons daily interactions. We use household size data from the ONS.

Demographic Parameters		
Name	Description	Value
uk_pop_0_17	UK population 0-17 years old (millions)	14.05
uk_pop_18_64	UK population 18-64 years old (millions)	40.22
uk_pop_65	UK population 65+ years old (millions)	10.04
uk_house_1	UK households with 1 person (thousands)	8,198
uk_house_2	UK households with 2 person (thousands)	9,609
uk_house_3	UK households with 3 person (thousands)	4,287
uk_house_4	UK households with 4 person (thousands)	3,881
uk_house_5	UK households with 5 person (thousands)	1,254
uk_house_6	UK households with 6 person (thousands)	596

3. Interaction Network

Interactions between individuals are modelled via membership of numerous networks which represent peoples daily interactions. The membership of different networks leads to age-group assortativity in the interactions. Previous studies of social contacts for infectious

Mean daily interactions	
Age-Group	Value
children (0-17 years)	15
adults (18-64 years)	13
elderly (65 years+)	7

disease modelling has estimated the mean number of interactions that individuals have by age group (Mossong, 2008). We estimate mean interactions by age-group by aggregating this data

Our model contains 3 types of networks. One to represent households, one work-place (for children this would be school) and one random daily interactions.

3.1. **Household Network.** Each individual is assigned to live in a household, with the proportion of people in each household taken from the UK household data (see demographics section). Each day, each person has an interaction with everybody within their household. Elderly people are assumed to live in either 1 or 2 person household with other elderly people, with the ratio of elderly 1 and 2 person households being the same as the general population. Children are assumed to live in household with two adults (so they can only live in 3/4/5/6 person households). The proportion of 3/4/5/6 person with children is the same as the those with adults only.

3.2. **Work-place Network.** Each individual is part of a single work-place network. The work-place networks are Watts-Strogatz small-world networks. There is one network for each age group, with the child and elderly network containing a small proportion of adults (i.e. teachers and carers). When constructing the work-place networks we randomly sort the individuals, so there is no link between the household interactions and the local interactions on the small-world network. Every day each person interacts with a random subset of their connections on their work-place network.

Work-place Network Parameters		
Name	Description	Value
mean_work_interaction_child	mean number of connections for children	10
mean_work_interaction_adult	mean number of connections for adults	7
mean_work_interaction_elderly	mean number of connections for elderly	3
child_network_adults	fraction of adults in child network	0.2
elderly_network_adults	fraction of adults in elderly network	0.2
daily_fraction_work	fraction of daily work connections made	0.5
prob_network_rewire (*)	probability of rewiring a connection in the Watts-Stogatz small-world network	0.1

The difference in the number of interactions for each age group is due to the overall number of daily interactions that each group have

3.3. **Random Network.** In addition to the recurring structured networks of households and work-places, we include a number of random interactions as well. These interactions are drawn each day and are independent of the previous days connections. The number of random connections an individual makes is the same each day (without interventions) and is drawn at the start of the simulation from a negative-binomial distribution. This variation in the number of interactions introduces "super-spreaders" in to the network who make much larger numbers of interactions than the average.

Random Network Parameters		
Name	Description	Value
mean_random_interaction_child	mean number of connections for children	2
mean_random_interaction_adult	mean number of connections for adults	4
mean_random_interaction_elderly	mean number of connections for elderly	3
sd_random_interaction_child (*)	s.d. number of connections for children	2
sd_random_interaction_adult (*)	s.d. number of connections for adults	4
sd_random_interaction_elderly (*)	s.d. number of connections for elderly	3

The mean numbers of connections were chosen so that the total number of daily interactions matched that from the social interaction studies. The split between work and random interactions was chosen to be lower in children. Each day a list is made which contains all individuals who make random interactions and each person is repeated by the number of interactions they make. This list is then randomly shuffled and interactions are made between adjacent pairs on the shuffled list.

4. Disease Dynamics

5. Passive Interventions

6. Active Interventions

7. References