

## SEIR Agent-based Model

This paragraph describes the assumption needed to set up four different agent-based models that can be used to generate the fundamental deterministic SEIR compartmental model which illustrates the changes of each individual within four states in the following direction: from state S (Susceptible) to state E (Exposed), followed by state I (Infectious), and finally, ended at state R (Recovered).

By mapping the states in ascending order according to the given direction of flow,

- State S is mapped to State 1.
- State E is mapped to State 2.
- State I is mapped to State 3 .
- State R is mapped to State 4.

From the previous description of the changes in the states, it follows that whenever two individuals from different states interact with one another within a distance of  $d$  (feet), only an individual whose state corresponds to a smaller integer can shift to a new state which corresponds to a larger integer, but not vice versa.

Consider a fixed distance of close contact of  $d = 6$  feet, a population of  $N = 500$  people, and the observation period of 14 days.

Let  $t$  denotes the  $t^{th}$  day of observation. It follows that  $1 \leq t \leq 14$  (days).

For each day,  $S(t) + E(t) + I(t) + R(t) = N = 500$  (people).

The agent-based SEIR Model is described as below:

Each of the four states is associated with two parameters,  $\mu_i$  and  $\delta_i$  (for  $1 \leq i \leq 4$ ), and a 4-tuple  $\alpha_{ij}$  of four parameters  $\beta_{ij}, \epsilon_{ij}, \theta_{ij}, \sigma_{ij}$  (for  $1 \leq i < j \leq 4$ ), followed by these rules:

- At the beginning of day 0, each agent is randomly assigned to a state, from State 1 to State 4, and  $\mu_i$  denotes the probability of the populating starting at state  $i$  at  $t = 0$  (day), in other words, on day 0.
- During the observation period, there exists a baseline death rate  $\delta_i$  per day in each state, which represents the number of agents randomly getting removed each day.
- When two agents in different states come into contact with one another within a specified distance of  $d$  feet, depending on the state of each agent, there exist different transmission coefficients from one state to another,  $\beta_{ij}$ , which also follow the ascending order of possible transition of states of each agent.
- The time it takes (in days) for an individual to be able to move from one state to another is recorded in parameter  $\epsilon_{ij}$ .
- The probability of whether any other different individual's health issues, age, and external factors which can affect the transition between the states is recorded in parameter  $\theta_{ij}$ .

- Due to either a symptomatic or an asymptomatic case of an individual in each state, the probability of true negative is recorded in parameter  $\sigma_{ij}$ .
- A 4-tuple  $\alpha_{ij}$  represents the information of the transmission coefficients from one state to another,  $b_{ij}$ , the time it takes for each agent to move from one state to another,  $\epsilon_{ij}$ , the probability of reception and transmission risk,  $\theta_{ij}$ , and the probability of true negative,  $\sigma_{ij}$ .

The figure below summarizes the previously described agent-based SEIR Model.

## SEIR Model

### State Variables:

S: Susceptible (fraction) is mapped to  
 E: Exposed is mapped to  
 I: Infected is mapped to  
 R: Recovered is mapped to

### Enumerate the states:

State 1  
 State 2  
 State 3  
 State 4

### Parameters:

For  $1 \leq i \leq 3$ :  $\mu_i$ : Probability of the population starting on day at state  $i$  at  $t = 0$  (day)

For  $1 \leq i \leq 4$ :  $\delta_i$ : Death rate of state  $i$  per day (baseline)

For  $(i, j) \in \{(1, 2), (1, 3), (2, 1), (2, 3), (3, 4)\}$ :  $\alpha_{ij} = (\beta_{ij}, \epsilon_{ij}, \theta_{ij}, \sigma_{ij})$

$\alpha_{ij}$ : A 4-tuple contains 4 parameters from State  $i$  to State  $j$

$\beta_{12}$ : Transmission coefficient (product of either the rate susceptible and infectious individuals, or the rate susceptible and exposed come into contact, and probability of transmission from State 1 to State 2)

$\beta_{13}$ : Transmission coefficient (product of the rate susceptible and infectious individuals come into contact, and probability of transmission from State 1 to State 3)

$\beta_{21}$ : Transmission coefficient (product of the rate exposed and removed individuals come into contact, and probability of self-recovery (and/or self-isolated) from State 2 to State 4)

$\beta_{23}$ : Rate of progression through infectious stage

$\beta_{34}$ : Rate of progression to infectiousness (following infection)

$\epsilon_{ij}$ : Time (in days) it takes for an individual to be able to move from State  $i$  to State  $j$

$\theta_{ij}$ : Probability of reception and transmission risk (due to different individual's health issues, age, and other external factors) from State  $i$  to State  $j$

$\sigma_{ij}$ : Probability of true negative (due to symptomatic or asymptomatic cases) from State  $i$  to State  $j$

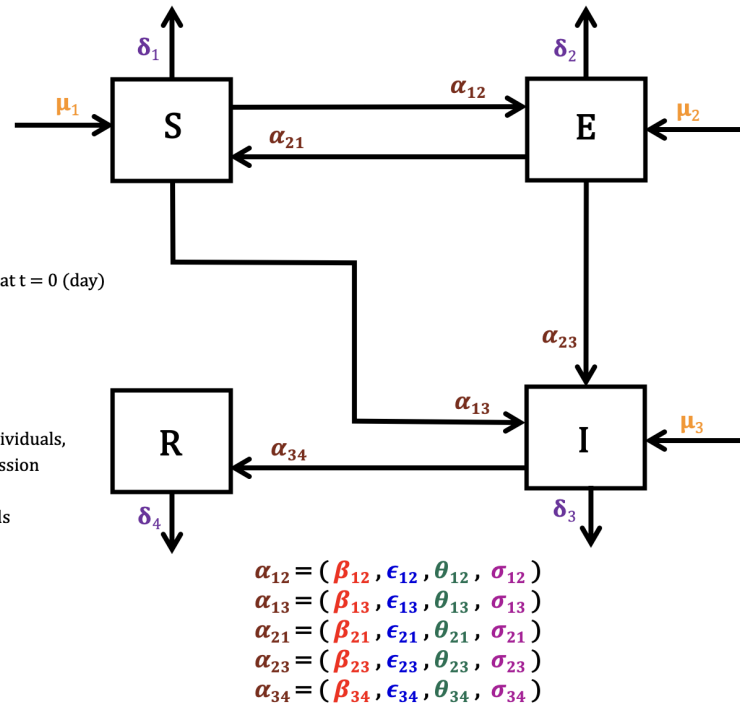


Figure 1 Agent-based SEIR Model.