IDSIM v 5.04

User's Guide

Revision 0.0

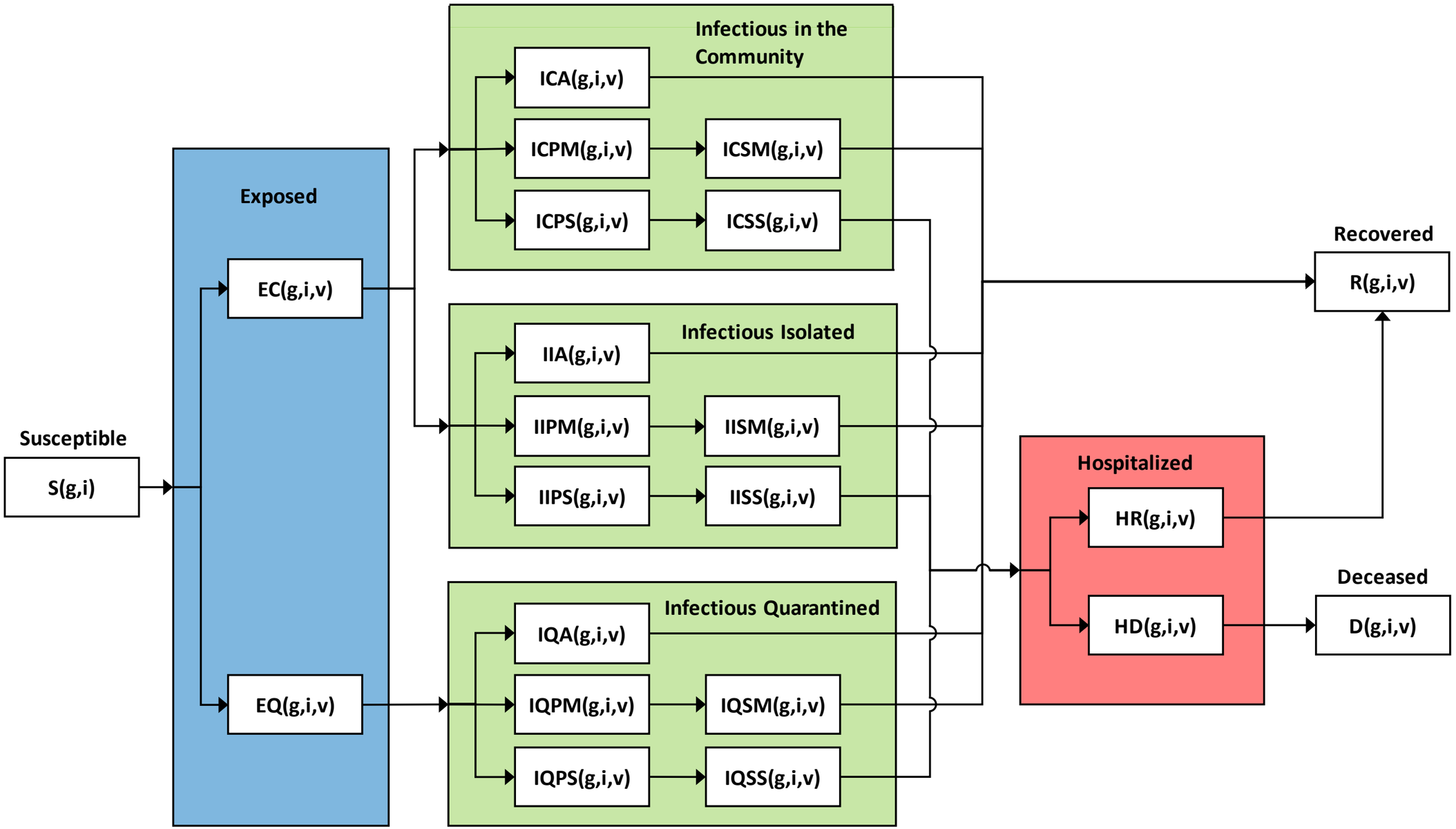
Contents

Introduction

IDSIM is a computer code for the deterministic simulation of epidemics using an enhanced compartment model. IDSIM has several useful modelling features:

- Modelling of multiple user-defined stratifications.
- Modelling of multiple strains (variants) of the pathogen
- Modelling of pre-symptomatic and asymptomatic infectious individuals
- Modelling of multiple rounds of vaccinations and for immunity following vaccination to develop over time and subsequently decrease
- Modelling of quarantine and isolation

Compartment diagram



Compartments

1. S = susceptible

   Exposed

2. EC = exposed community (not quarantined)
3. EQ = exposed quarantined

   Infectious

   Infectious in the **C**ommunity (not isolated and not quarantined)

4. ICA = **I**nfectious, in the **C**ommunity, **A**symptomatic
5. ICPM = **I**nfectious, in the **C**ommunity, **P**re-symptomatic, will progress to **M**ild symptoms
6. ICPS = **I**nfectious, in the **C**ommunity, **P**re-symptomatic, will progress to **S**evere symptoms
7. ICSM = **I**nfectious, in the **C**ommunity, **S**ymptomatic, **M**ild symptoms
8. ICSS = **I**nfectious, in the **C**ommunity, **S**ymptomatic, **S**evere symptoms

   Infectious **I**solated
9. IIA = **I**nfectious **I**solated **A**symptomatic
10. IIPM = **I**nfectious **I**solated **P**re-symptomatic, will progress to **M**ild symptoms
11. IIPS = **I**nfectious **I**solated **P**re-symptomatic, will progress to **S**evere symptoms
12. IISM = **I**nfectious **I**solated **S**ymptomatic **M**ild
13. IISS = **I**nfectious **I**solated **S**ymptomatic **S**evere

   Infectious **Q**uarantined
14. IQA = **I**nfectious **Q**uarantined **A**symptomatic
15. IQPM = **I**nfectious **Q**uarantined **P**re-symptomatic, will progress to **M**ild symptoms
16. IQPS = **I**nfectious **Q**uarantined **P**re-symptomatic, will progress to **S**evere symptoms
17. IQSM = **I**nfectious **Q**uarantined **S**ymptomatic **M**ild
18. IQSS = **I**nfectious **Q**uarantined **S**ymptomatic **S**evere

   Hospitalized
19. HR = **H**ospitalized **R**ecovering
20. HD = **H**ospitalized **D**ying
21. R = **R**ecovered
22. D = **D**eceased

Additional calculated quantities that are not compartments

DNEC = **D**aily **N**ew **E**xposures in the **C**ommunity (daily number of newly-exposed individuals in the community)
DNEQ = **D**aily **N**ew **E**xposures **Q**uarantined (daily number of newly-exposed individuals successfully quarantined)

Indices

g = combined stratum index

i = immunization (vaccination) status index

v = variant index

Installing and running the app

To install the app double-click the installation file and follow the prompts. The installation password is “durham”. It is strongly recommended to select the option to create a desktop icon for the app.

To start the app double-click its icon or use the Windows (START) button.

To exit the app choose **Quit** from the **File** menu.

To run an app command, select it from the **Commands** menu.

Overview of IDSIM concepts and terminology

To run an epidemiological simulation, the user needs to first specify all the simulation parameters, such as number of variants, the latency period for each variant, the population distribution by compartments and strata, etc. All this data constitutes the simulation *setup data*. The *setup data* (even an incomplete set) can be saved at any time for later *loading* and use. The file containing the *setup data* is called *setup_data5.bnr*.

In addition to the setup data, any simulation requires *initial conditions* , in other words the *detailed initial populations* (for each compartment, combined stratum, vaccination level and variant) at the start of the simulation (*day zero*). The detailed initial populations are calculated by IDSIM based on the total population and the fractions of the population belonging to each compartment, combined stratum, vaccination level, and variant, specified in the setup. The combination of setup data and detailed initial populations is called the *initial state*. Once the simulation is run, the detailed populations in each compartment and stratum are calculated for each day, from day zero to the last day of the simulation. The combination of setup data and detailed populations at the end of the simulation interval is called the *final state* of the simulation. Both the *initial state* and the *final state* can be saved for later *loading* and use. The file containing a full simulation state (either initial or final) is called *state_data5.bnr*. To save both states, the user needs to first save one of them, then rename the *state_data5.bnr* file and, finally, save the other state; otherwise the second saved state data will overwrite the first saved stated data.

Once a simulation has been performed, NDSIM can display a summary plot of the simulation, consisting of two epidemiological curves: the susceptible-compartment (S) population and the number of daily new exposures (DNE). Because the susceptible population is generally much larger than the daily number of new exposures, its plot is scaled down by a factor of 50 (S/50 is plotted). Whenever such a summary plot is generated, a file called *plot_summary.png* is also created. The full simulation results can be saved as an Excel-readable (csv) file called *results.csv*. The file includes the detailed compartment populations broken down by combined stratum, vaccination level and variant for each day of the simulation.

Any saved state can be subsequently *loaded* as an *initial state*. This can be used to extend the simulation time by saving the final state of a simulation, re-loading it as the initial state and continuing the simulation from that point on. Simulation parameters can also be modified after loading the initial state.

All files are saved to and loaded from a *working folder* which is user selectable.

Useful tips

Any file name (including folder path) cannot exceed 1000 characters.

Neither file names nor folder names can include blanks. Underscores are ok. Avoiding special characters is also a good idea.

Character input variables (e.g., variant names) cannot exceed 10 characters and cannot include blanks. Underscores are ok. Avoiding special characters is also a good idea.

Some input parameters depend on others. Dependent parameters can only be set up after setting up the parameters they depend on. Usually, IDSIM alerts the user if they try to set up dependent parameters before setting up the independent ones. For example, the strata cannot be set up before setting up the stratifications.

After setting up or modifying certain parameters, their respective dependent parameters will have to be re-input. For example, if the number of stratifications is changed, the strata will have to be setup again.

Input parameters are deemed to have been input/changed only if the user presses “OK” (as opposed to “cancel”) in the input window.

When setting up a specific parameter for the first time, IDSIM provides some default values in the respective fields. However, those values will not be recorded unless the user presses “ok” (as opposed to “cancel”) in the input window.

Setting up and running a simulation

A simulation proceeds in a sequence of steps, as follows (each step corresponds to a command):

Set up simulation parameters

1. Set up general simulation parameters
    a. Number of stratifications
    Stratifications are the categories used to classify the population. Example of stratifications are age, occupation, size of household, etc. If a simulation uses only age and occupation as stratifications, then the number of stratifications is two. There needs to be at least one stratification. The number of strata (groups) in each stratification are defined later.
    b. Number of vaccination levels (statuses)
    A vaccination level/status is the status of an individual with respect to being vaccinated. The progression is, usually, as follows:
        i. Unvaccinated
        ii. First (priming) dose (immunity not yet developed)
        iii. Immunity developed after first dose
        iv. Second (booster) dose (immunity not yet developed)
        v. Immunity developed after second dose
        vi. …. Additional (booster) doses
    c. Number of strains/variants. The "ancestral" strain is considered variant one, so there needs to be at least one variant.
    d. Number of contacts per day for each individual.
    This is an average number, taken over all stratifications.
2. Set up vaccination levels/states
    For each vaccination level, input:
    a. Level name (e.g., "unvacc", "one_dose", etc.)
    b. Type of "removal" Choose one of the following options
        i. Persons/day (if people progress to the next level by vaccination)
        ii. Days before advancing (if people progress to the next level simply by the passage of time, such is the case when people develop immunity a certain number of days after receiving the vaccine)
    c. Numerical value of removal parameter
3. Set up stratifications
    For each stratification, input:
    a. Stratification name
    b. Number of strata/groups in the stratification

    For example, for one stratification, the stratification name can be "age" and the number of strata can be, say, 4, meaning that there will be 4 age groups, to be defined in more detail later. For another stratification, the name can be "household_size".

4. Set up detailed strata for each stratification
    For each stratum/group in each stratification input:
    a. Stratum/group name
    b. Fraction of population belonging to that stratum
    c. Susceptibility modulator (a factor that multiplies the probability of transmission with contact for "receiving" individuals belonging to the stratum).
    d. Severity modulator (a factor that multiplies the fraction of symptomatic individuals that go on to develop severe symptoms, for individuals belonging to the stratum. For example, in the 80+ age population group, a value greater than 1 would be appropriate to represent the higher probability of severe outcomes for that age group.)
5. Set up strains/variants
    For each variant, input the following:
    a. Variant name
    b. Latency time (since exposure)
    c. Incubation time (since exposure)
    d. Time to hospitalization for severe cases (since exposure)
    e. Time to recovery for non-severe cases (since exposure)
    f. Time to recovery after hospitalization (for severe cases that recover)
    g. Time to death after hospitalization (for severe cases that do not recover)
    h. Probability of transmission with contact
    i. Fraction of infectious that are symptomatic
    j. Fraction of infectious symptomatic that have severe symptoms
    k. Fraction of hospitalized that recover
    l. For each vaccination level/status, input:
        i. Transmissibility factor (a, usually less or equal to 1, factor that multiplies the probability of transmission with contact for infectious individuals with a specific vaccination level. For infectious individuals belonging to the "unvaccinated" or "recently-vaccinated" level, this factor would be 1. For infectious individuals who have already developed some immunity, the factor would, normally, be less than 1, to represent the fact that those individuals are less contagious.)
        ii. Susceptibility factor (a, usually less or equal to 1, factor that multiplies the probability of transmission with contact for susceptible individuals that are in a specific vaccination level. For susceptible individuals belonging to the "unvaccinated" or "recently-vaccinated" level, this factor would be 1. For susceptible individuals who have already developed some immunity, the factor would, normally, be less than 1, to represent the fact that those individuals are less likely to become infected. This factor is, essentially, equal to one minus the vaccine efficacy.)
        iii. Severity factor (a, usually less than 1, factor that multiplies the fraction of symptomatic individuals that have severe symptoms. For infectious-symptomatic individuals belonging to the "unvaccinated" or "recently-vaccinated" level, this

factor would be 1. For infectious-symptomatic individuals who have already developed some immunity, the factor would, normally, be less than 1, to represent the fact that those individuals are less likely to develop severe symptoms.)

6. Set up public-health measures
    a. Fraction of exposed individuals that are successfully quarantined
    b. Fraction of infectious individuals that are tested and successfully isolated
    c. Coefficient for additional, unspecified, public-health measures. (This is a catch-all, smaller tan 1, coefficient that is meant to help account for measures such as mask-wearing, or physical distancing. In a single-strain scenario, this would be the ratio of the actual Rt to the Rt predicted in the absence of the additional public-health measures. Equivalently, it would be the ratio of actual R_0 to the predicted R_0 in the absence of the additional public-health measures.)

Set up initial conditions at the start of the simulation

7. Set up fraction of population in each compartment at the beginning of the simulation(at least one exposed or infectious compartment has to have a non-zero fraction, or there will be no transmission of disease)
8. Set up fraction of population in each vaccination level at the beginning of the simulation (Only fractions for levels 2, 3, … are input. The remainder of the population is assumed to belong to level 1)
9. Set up fraction of "infected" (exposed or infectious) individuals affected by each variant at the beginning of the simulation.
10. Calculate detailed initial populations in each compartment by stratum, variant and vaccination level. (This a command takes the total population as input.)
11. OPTIONAL: Rebalance initial populations. This command checks whether the input initial-population fractions are consistent with the virus having circulated before the start of the simulation and, if necessary, adjusts (rebalances) the populations in each compartment. For example, if the virus has been in circulation for a few months but the input shows only exposed individuals but no infectious ones, this command will rectify that situation.

Run Simulation

12. Run simulation (command requires the number of days as input)

At this point the simulation is complete.

There are a few additional commands that can be used for various purposes, as described below:

Select working folder (This allows the user to select the working folder where files produced by the simulation will be saved and where files that may be required by the simulation will be read from).

Plot summary (Plots and displays the curves for the total number of susceptible individuals and for the total number of daily new exposures.)

Save results as Excel-readable file (Saves detailed populations for each compartment by stratum, vaccination status and variant at each time step, in an excel-readable file)

Save setup data [Saves the simulation parameters but not the initial conditions (detailed populations).]

Load setup data [Loads the simulation parameters but not the initial conditions (detailed populations).]

Save initial state [Saves the simulation parameters and the initial conditions (detailed populations).]

Save final state [Saves the simulation parameters and the conditions (detailed populations) at the end of the simulation]

Load saved state (Loads a saved state as an initial state. By saving a final state and subsequently loading it as an initial state, the simulation can be continued beyond the time interval originally used.)

IDSIM detailed model and theory

A paper giving a detailed description of the model can be downloaded from here: https://arxiv.org/abs/2112.15252 .