1 Patchs

The model is of agents at locations, the world is a grid of patches. There are $2,500$ agents and $5,041$ patches.

2 Infectivity

Every day, every infected agent has a chance to infect everyone else on its patch.

$$\text{patchInfectivity} = \text{virulenceTriangle} * \text{mask} * \text{variantMult} * \text{asymptFactor} * \text{isoFactor}$$

- Agents draw infection duration and peak infectivity.
- Distribution of peak infectivity is main lever for R_0.
- virulenceTriangle is 0 1.5ish days, reaches peak after 4ish days, back to 0 after 18ish days.

The duration and peak of the triangle are scaled down proportionally with vaccination and lingering immunity.

3 Susceptibility

Each susceptible agent has five chances (simulated with a binomial distribution) per infected agent per day to be infected.

$$\text{susceptibility} = \text{mask} * \text{vaccineRisk} * \text{vaccinationVariantMult}$$

4 Cohorts

Every agent is part of a cohort. These set parameters such as age, base susceptibility, vaccination status, vaccination branch, worker/student status, and region.

Agents are part of households, which each have their own home patch that they are likely to spend most of their time around.

5 Vaccination

Configuration determines when agents are vaccinated and with how many doses. The system has become increasingly micromanaged.

- Vaccines have infectivity and risk modification, with infectivity modifying peak infectivity and duration.
- Vaccines take some number of days to come into effect.

- Vaccine efficacy and immunity from infection wanes over time.
- People can be vaccinated while sick.

6 Movement

Movement has the following steps.

1. **Move** - Flip a coin then either teleport home, or turn slightly and take a step of a random small distance.
2. **Visit gather location** - Randomly decide to teleport to a gather location patch within a local radius (about 200 such patches).
3. **Avoid** - If the simulant wants to avoid people, then move to an adjacent empty patch (if there is one).
4. **Super spread** - Randomly decide to teleport to a random gather location.

Isolation compliant agents teleport home then skip steps 2-4. An agent wants to avoid all of the following are satisfied.

- The patch has agents not from their household.
- Their predestined propensity to avoid others is below the global avoidance threshold.
- They pass a random check against the global avoidance chance.
- They are not an essential worker, or they pass a random check for essential workers to do avoidance.
- They are not a student, or schools are closed, or the patch has non-student agents not from their household.

7 Stages

A stage is a set of public health measures designed to impact transmission. Stages contain parameters for:

- Maximum move distance in Step 1 of movement.
- Global avoidance threshold.
- Global avoidance chance.
- Complacency bound - A lower bound on the above two parameters, as they decay as time is spent in a stage.
- The proportion of the workforce considered to be essential.
- Global mash wearing threshold, compared to agents mask wearing propensity.

- Visit radius and frequency for Step 2 of movement.
- Probability of super spreading for Step 4 of movement.
- Whether schools are open.

8 Policies

A policy determines how to move between stages. Policies are informed by case numbers averaged over the last week or two. Many more things are possible than make sense. Poorly formed policies lead to models that fluctuate between stages too rapidly.

9 Case reporting and tracking

All infected agents flow through case reporting in the following order. Not all agents reach the end.

Infected Unknown to the case reporting system or themselves.

Contact Makes a random check each day to become tracked. Only makes three attempts. The check is harder for asymptomatic agents.

Tracked An agent that becomes tracked upgrades the agent that infected it and the agents that it has infected to Contact. Agents that are already at level Contact have their track attempt counter reset. Tracked agents make random checks to isolate each day and upgrade to Reported the day after they become tracked.

Reported Agents add to the global case tally when they become Reported. They otherwise behave the same as Tracked agents.

If an agent becomes tracked then the Contact check is run on new contacts, to allow powerful tracing to go down multiple levels in one day. The primary factor in the Contact to Tracked random check is trace efficacy, which scales down drastically as reported cases increases. The trace efficacy equation is currently parameterised as two points and an asymptote that sets the maximum number of cases tracked per day (in expectation)

Steps can be skipped.

- Infected agents in the same household as a Tracked agent become Tracked.
- Symptomatic agents have a random check to become Tracked on days seven, eight and nine of their infection.

10 Incursions

Incursions work by overwriting the vaccination and infection status of an existing non-infected agent. The parameters of the agent revert after the infection is over.

11 Scale

Conceptually the model is a window into the part of the region with all the infection. This is represented by the same set of $2,500$ agents. As infections increase we scale the agents so that each agent represents more than 1 person. The model tries to keep the number of infected agents around 100, unless the maximum scale is reached, at which point each agent is one $2,500^{\text{th}}$ of the population.

For some n, each infected agent in the model represent either 2^n or 2^{n+1} people. Attributing a number of people to the non-infected agents is not required and just makes things harder. When an agent infects someone, the number of people represented by the new infected agent matches that of its infector.

If there are too many infected agents in the model, it *scales up* by selecting two infected agents, A and B, that each represent 2^n people, from the same cohort if possible. It then copies the contract tracing information from B to A, makes A represent 2^{n+1} people, and removes the infection from B.

Similarly, if there are too few infected agents, it *scales down* by selecting an infected agent, A, that represents 2^{n+1} people, and a susceptible agent, B, of the same cohort. It then makes A represent 2^n people, and copies all the infection parameters of A to B.

12 Recover proportion matching

Scaling up then down increases the number of recovered agents in the population. This results in an unrealistically high number of recovered agents mixing with the infected agents, which unrealistically slows the pandemic.

The recover proportion matching system gradually shifts the proportion of recovered agents to the fraction of recovered people in the overall population. It does so by flipping whether an agent is recovered or susceptible at some rate that produces a decay curve.

13 setup.setup

Setup the simulation.

14 main.go

The main simulation loop.

14.1 scale.CheckScale_cont

Scale up or down individual simulants to accommodate the current caseload.

14.2 stages.setupstages

Set policy parameters (such as mask wearing, person-avoidance) based on current stage.

14.3 policy.update_vacRestrictionEasing

Update whether vaccinated simulants have eased restrictions.

14.4 policy.CovidPolicyTriggers

Set current stage based on fixed model parameters, or recent reported cases.

14.5 incursion.incursion_update

Randomly add incursions. These are simulants that override an existing susceptible with an infection and vaccination status. The simulant reverts at the end of the infection.

14.6 simul.simul_updateIsolationResponse

Update whether or not the simulant stays at home this day.

14.7 simul.simul_move

Randomly either teleport home or move to a nearby location.

14.8 simul.simul_visitDestination

Possibly teleport to a random gather location within visiting radius.

14.9 simul.simul_update_patch_utilisation

Record when a patch last had a simulant on it.

14.10 simul.simul_avoid

Simulants potentially move to a nearby empty patch if they are in the same position as someone they are trying to avoid.

14.11 simul.simul_superSpread

Possibly teleport to a random gather location.

14.12 simul.simul_updatepersonalvirulence

Update the infectivity of the simulant.

14.13 simul.simul_checkMask

Update infectivity and transmission resistance based on mask wearing.

14.14 simul.simul_record_patch_infectiveness

Record my infectiousness on the diseased simulants on the patch.

14.15 simul.simul_infect

Susceptible simulants get infected from the recorded infectiousness of their patch.

14.16 simul.simul_updateHouseTrackedCase

Update last time each household had a tracked case.

14.17 simul.simul_isolateAndTrackFromHouseHold

Potentially set isolation state based on household tracking.

14.18 scale_shared.ShiftRecoveredTowardsTotalProportion

Recovered people slowly become susceptible, moving the proportion of recovered people in the simulation towards the proportion of recovered people in the population. This treats the agents as a 'window' into the entire population, and the shift assumes that people in the population filter in and out of this window. All infection happens in the window, so it is unrealistic to, indefinitely, have a higher proportion of recovered people in proximity to the infected people.

This gets around the fact that scaling does not affect recovered people.

14.19 trace.trace_doTrace

Recursive contract tracing system for simulants.

14.20 simul.simul_settime

Update case reporting and recovery immunity waning.

14.21 simul.simul_end_infection

End infections and collect resulting stats.

14.22 vaccine.vaccine_update

Vaccinate people as appropriate for stages.

14.23 simul.simul_updateVaccineAndRecover

Update immunity and vaccine waning.

14.24 policy.updateComplacency

Reduce avoidance behaviour due to complacency.

14.25 Various end of step cleanups and calculation

14.26 trace.traceadjust

Modify track chance based on tracked cases.