A cellular automaton model of infectious disease epidemiology

Morgan ∼ Bryant.

1/2: emails transcribed (and lightly edited), Sept. 11, 2020.

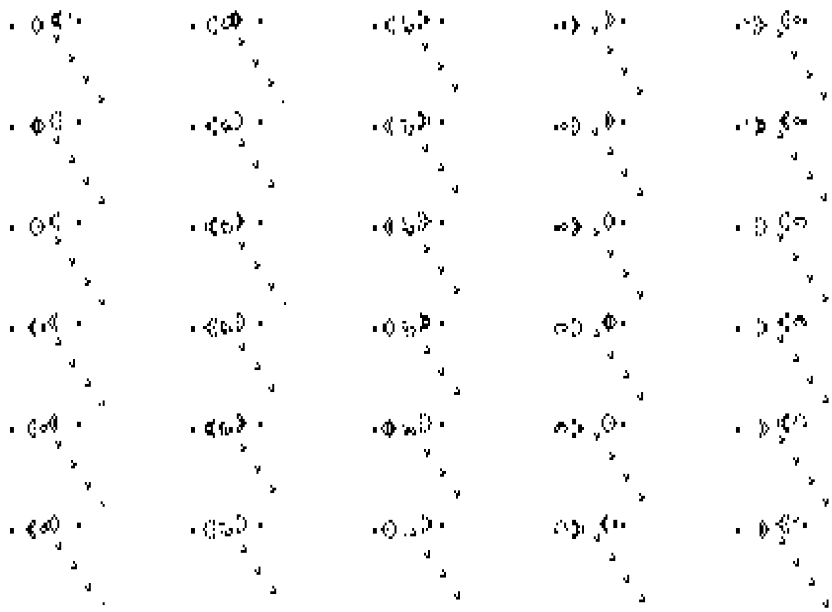
RE: I am wondering if the Covid containment/political problem results from public misunderstanding of the math underlying pandemics. Do you follow behavioral economics (and related fields in psychology, epistemology, etc)?

Yep, partially. If it's not contained at all, eventually a 'herd immunity' will settle after everyone is exposed and things return to normal (as in impoverished nations). If it's totally contained, then it is 'suppressed' (as in N. Korea). Turns out either of those things happen eventually anyways if everyone is consistent about their actions (it just takes longer). However, it can remain perpetually infectious precisely when individuals or communities are inconsistent if it evolves even slightly (which is inevitable). If, say, one year CA shuts down totally but IL doesn't, then it'll become prevalent in IL and suppressed in CA. The next year CA opens up (because it had been suppressed) but IL does the opposite (because it had become prevalent). However, since it survived in large quantity in IL, it will be very infectious towards CA and CA will need to suppress the next year. So it theoretically goes back and forth eternally. Same with individuals and communities: if one community/household hides effectively but everyone else doesn't, then it becomes hard for that one community/neighborhood to avoid them, and then will spread like wildfire in that community. Of course, if possible, it's much better to suppress than let herd immunity settle in, but both of those are better than non-extinction at all.

Basically – numbers aside, the US's non-homogeneous approach is alarming and inauspicious.

I'm actually building a novel computational model that will demonstrate this principle. All I need is data on social transmittance patterns and the correspondences between impact and responses.

a little visualization: see `https://en.wikipedia.org/wiki/Cellular_automaton#/media/File:Gospers_glider_gun.gif` or `https://upload.wikimedia.org/wikipedia/commons/e/e5/Gospers_glider_gun.gif` for the animations; or, the grid of images transformations below.



At the top are 'infectious clusters' that perpetually travel back and forth, left-to-right. At each timestep, a square gets infected if but only ifsome of its neighbors are infected; it doesn't get infected if none of its neighbors are infected (it's suppressed in that region) nor if all are infected (there's herd immunity there). And where there's any perpetual infected area (like the top half), there's a chance of regular unavoidable outbursts (the 'gliders' flying south-east).

2/2: brief writeup about an effective model

[wip!!]
The automaton would best be modeled as a manifold that can be nearly projected to something flat. The need for a specific manifold, not a simple geographic grid-graph, is because humans have a neighborhood that is not 'von Neumann' or 'Moore' in style, but more overlapping, partially birds-eye, and somewhat more randomly connected. (Plus, it's hard to defensibly model buildings with multiple floors or even the presence of walls and roads with a flat grid.) But of course a first PofC model ought to use a flat Conway grid. You'd likely want to make the manifold graph have clusters at all scales.

Your infectivity life/death rule could be rather similar to Conway's: if $N\% < x < M\%$ of your neighbors are infected, you'd get infected. (The stochasticity could be approximated by having a large enough population, making the infectivity deterministic instead of stochastic, and instead lightly inject noise into the probability of connections. I'd guess this is linear or close-enough but might be subject to a relationship resembling Jensen's Inequality.) Weighted edges could be useful but not even necessary, provided you sufficiently artificially seed an initial infected population that doesn't die out immediately. Also, would need to calibrate connections and infectivity rules subject to (1) bio-sociological empirical models of how humans interact and (2) the dynamics of the network. For Covid in particular, a time-delay system might be helpful: a person is infected for more than one timestep.