An Agent-Based Model of the Covid-19 epidemic, using Genetic Algorithms to optimize vaccinations: a very short presentation

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Tool and links

- We use NetLogo, at `https://ccl.northwestern.edu/netlogo/`.
- S.I.s.a.R. is at `https://terna.to.it/simul/SIsaR.html` with information on model construction, the draft of a preliminary paper also reporting results, and an online executable version of the simulation program, built using NetLogo.
- A short paper is published at `https://rofasss.org/2020/10/20/sisar/`

G. Pescarmona, P. Terna, A. Acquadro, P. Pescarmona, G. Russo, and S. Terna. How Can ABM Models Become Part of the Policy-Making Process in Times of Emergencies—The SISAR Epidemic Model. *RofASSS*, 2020.

The scale and the items (in Piedmont, a North-West Italian region with 4,350,000 residents)

- 1 : 1000.

- Houses.
- Schools.
- Hospitals.
- Nursing homes,
- Factories.

The world 3D

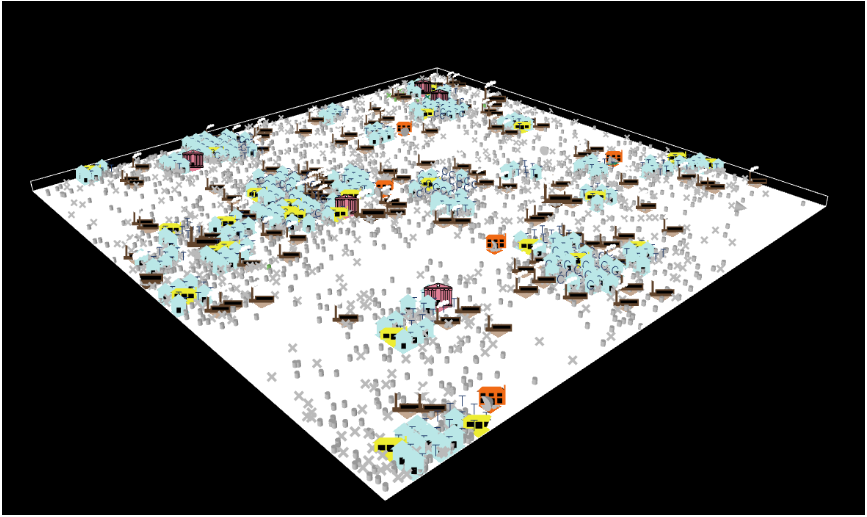

Figure 1: The world 3D

Simulation batches

- We explore systematically the introduction of factual, counterfactual, and prospective interventions to control the spread of the contagions.
- Each simulation run—whose length corresponds to the disappearance of symptomatic or asymptomatic contagion cases—is a datum in a wide scenario of variability in time and effects.
- We need to represent compactly the results emerging from batches of simulation repetitions, to compare the consequences of the basic assumptions adopted for each specific batch.
- Besides summarizing the results with the usual statistical indicators, we adopt the technique of the heat-maps.
- Each heat-map reports the duration of each simulated epidemic in the x axis and the number of the symptomatic, asymptomatic, and deceased agents in the y axis. The z axis is represented by the colors, as in the logarithmic scale on the right of each picture.
- In our batches we have 10,000 runs.

10,000 epidemics without control in Piedmont

	symptomatic	totalInfected&Deceased	duration
count	10000.00	10000.00	10000.00
mean	969.46	2500.45	303.10
std	308.80	802.88	93.50

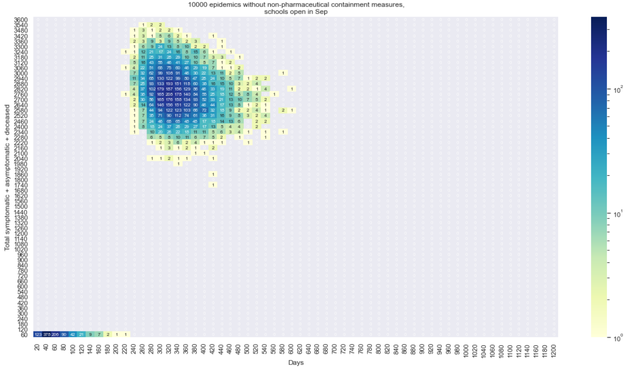

Figure 2: Without non-pharmaceutical containment measures

10,000 epidemic with basic control in Piedmont, first wave

	symptomatic	totalInfected&Deceased	duration
count	10000.00	10000.00	10000.00
mean	344.22	851.64	277.93
std	368.49	916.41	213.48

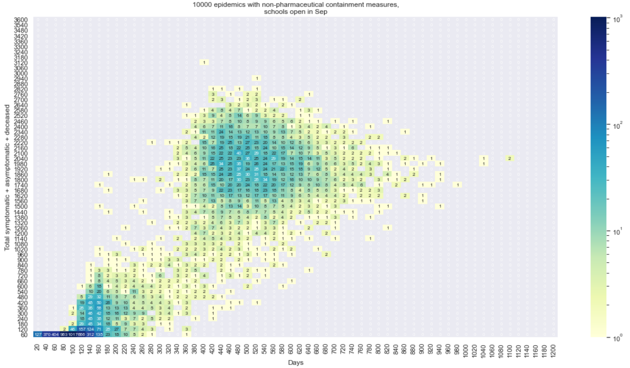

Figure 3: First wave with non-pharmaceutical containment measures

Second w., new infections from outside, with new specific measures

1407 epidemics stable in Summer 2020 out of 10,000, rule: at Jun 1, 20 select if sym. (10, 70], actual v. 33.3 & at Sep 20, 20 select if sym. (20, 90], actual value 37.5; **874** at Dec 15, 20, rule: sym.+asym.>Sep 20, 20, actual value: 200.0.

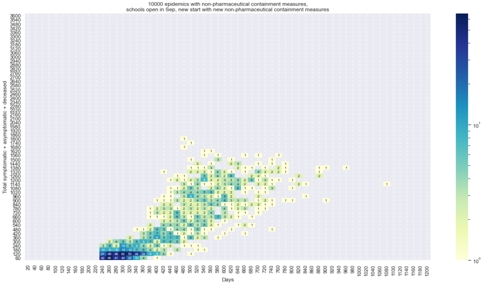

Figure 4: First wave with non-ph.containment measures, forcing the second wave, **with new specific non-ph. containment measures**

(1000) cum. v.	Jun 1, 20 sym.	all	Sep 9, 20 sympt.	totalInf.	Dec 15, 20 sympt.	totalInf.	Feb 1, 21 sympt.	totalInf.	May 1, 21 sympt.	totalInf.	Dec 15, 20 to end sympt.	totalInf.	days
count	1407.0	1407.0	1407.0	1407.0	874.0	874.0	719.0	719.0	523.0	523.0	874.0	874.0	874.0
mean	35.6	72.7	40.0	84.1	**130.0**	**340**.6	**194.4**	**512.8**	**295.7**	**791.2**	252.7	666.4	494.1
std	14.1	42.6	16.7	52.8	83.9	232.6	104.1	276.9	119.1	300.6	156.8	416.4	122.7

Fragile persons and future considerations

- A quite impressive analysis in Nature, Feb. 16, 2021, *The coronavirus is here to stay—here's what that means*

  `https://www.nature.com/articles/d41586-021-00396-2`

  A Nature survey shows many scientists expect the virus that causes COVID-19 to become endemic, but it could pose less danger over time.

- If Nature is right, a possible long-term strategy is to stop all fragile people for a given period when R_t starts increasing (also with fragile workers in sick leave, if unable to work remotely).

  With social benefits, e.g., schooling, and economic benefits, if activities do not stop

- Besides, mainly for the fragile people, adopt prevention and vaccinations.

- A note: the same strategy would also have been surprisingly efficient now, for the second wave.

Sec. w., new infect. from outs., stop fragile people. 60 days from Oct. 5[1]

1407 epidemics stable in Summer 2020 out of 10,000, rule: at Jun 1, 20 select if sym. (10, 70], actual v. 33.3 & at Sep 20, 20 select if sym. (20, 90], actual value 37.5; **886** at Dec 15, 20, rule: sym.+asym.>Sep 20, 20, actual value: 200.0.

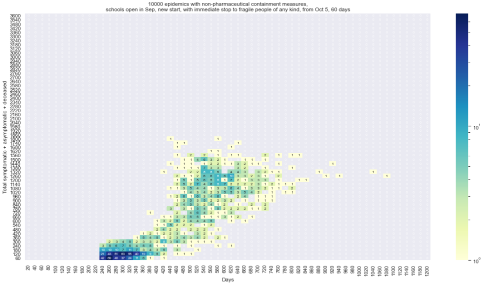

Figure 5: First wave with non-ph, cont, meas., forcing the sec. w.; **in sec. w., uniquely stop fragile people, including fragile workers**

(1000)	Jun 1, 20		Sep 9, 20		Dec 15, 20		Feb 1, 21		May 1, 21		Dec 15, 20 to end		
	sym.	all	sympt.	totalInf.	sympt.	totalInf.	sympt.	totalInf.	sympt.	totalInf.	sympt.	totalInf.	days
count	1407.0	1407.0	1407.0	1407.0	886.0	886.0	761.0	761.0	637.0	637.0	886.0	886.0	886.0
mean	35.6	72.7	40.0	84.1	128.1	326.3	**211.0**	**555.1**	**323.3**	**862.1**	301.1	792.3	515.5
std	14.1	42.6	16.7	52.8	89.6	234.2	118.1	306.7	126.4	315.9	170.7	450.2	116.9

[1] Schools are always working 100% in this case.

Planning a vaccination campaign

- Exploring vaccination sequences, using *genetic algorithms*. A detailed note, frequently updated, is at `https://terna.to.it/simul/GAresultPresentation.pdf`.
- We compare the effect of choosing vaccination quotas via GAs with two predetermined strategies.
- Key dates:
  - in the internal calendar of the model, day 373 is Feb. 12th, 2021, which is effectively the starting point of the vaccinations in the region;
  - the day of the effectiveness of the initial vaccinations, 40 days later, is day 413 (Mar. 22nd, 2021).

Vaccination groups

We take into consideration seven groups in order of decreasing fragility but also considering the exposure to contagion:

g1 extra fragile people with three components;
- due to intrinsic characteristics: people in nursing homes;
- due to risk exposure:
  - nursing homes operators;
  - healthcare operators;

g2 teachers;

g3 workers with medical fragility;

g4 regular workers;

g5 fragile people without special characteristics;

g6 regular people, not young, not worker, and not teacher;

g7 young people excluding special activity cases (a limited number in *g1*).

Vaccination sequence, *wise* strategy

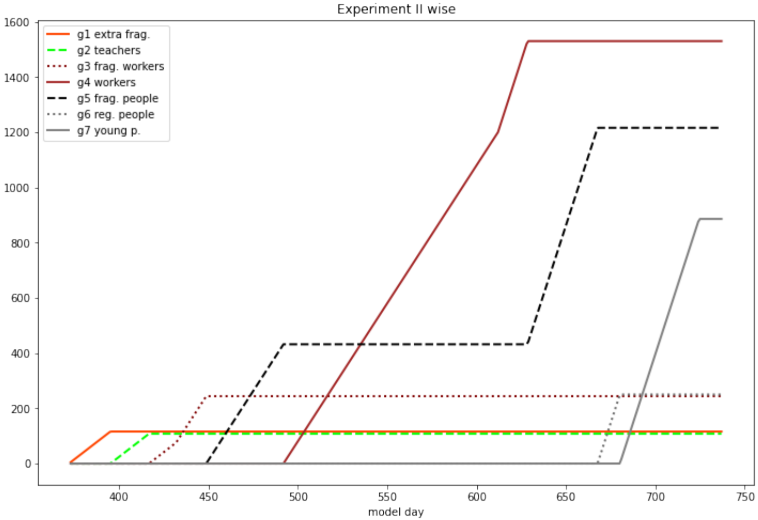

Figure 6: A “wise” vaccination sequence

GAs vaccination sequence, with vaccinated people still spreading the infection

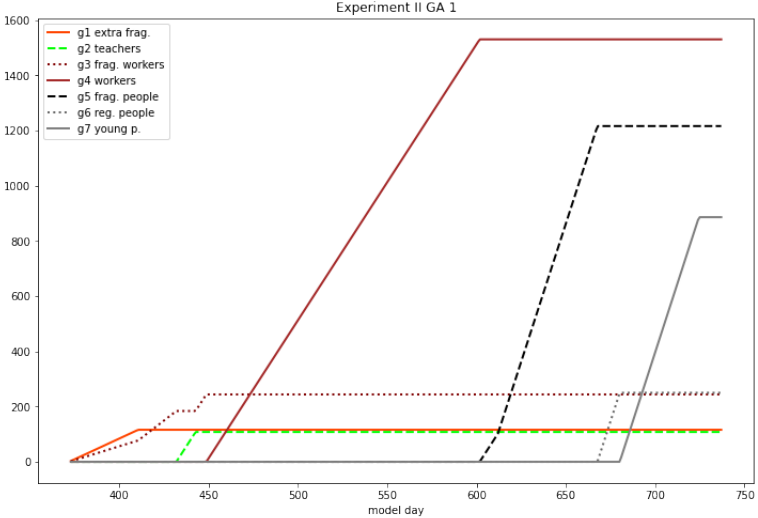

Figure 7: GAs vaccination sequence

Synopsys

Three hypotheses about contagion transmission from vaccinated people, if infected: 100%, never, 50%.

Case (1000)	At day 413	Final no vaccin.	Final plain vaccin. infect. 100%	Final wise vaccin. infect. 100%	Final GAs vaccin. infect. 100%	Final plain vaccin. infect. 0%	Final wise vaccin. infect. 0%	Final GAs vaccin. infect. 0%	Final plain vaccin. infect. 50%	Final wise vaccin. infect. 50%	Final GAs vaccin. infect. 50%
I	197 -	325 128	236 39	263 66	**200** **3**	203 6	211 14	199 2	204 7	229 32	203 6
II	233 -	375 142	355 122	344 111	**305** **72**	340 107	334 101	**297** **64**	356 123	344 111	**288** **55**

Table 1: Results of the campaigns in the two cases, only symptomatic people (second row in each case: minus day 413)

https://terna.to.it