How can ABM models become part of the policy-making process in times of emergencies - The S.I.s.a.R. Epidemic Model

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Outline

Objectives of the model

- We propose an agent-based model to simulate the Covid-19 epidemic diffusion, with Susceptible, Infected, symptomatic, asymptomatic, and Recovered people: hence the name S.I.s.a.R. The scheme comes from S.I.R. models, with (i) infected agents categorized as symptomatic and asymptomatic and (ii) the places of contagion specified in a detailed way, thanks to agent-based modeling capabilities.
- The infection transmission is related to three factors: the infected person's characteristics and the susceptible one, plus those of the space in which contact occurs.
- The model includes the structural data of Piedmont, an Italian region, but it can be readily calibrated for other areas. The model reproduces a realistic calendar (e.g., national or local government decisions), via its script interpreter.

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

The scale and the items

- 1 : 1000.
- Contagions are related to; (i) the characteristics of infected persons, (ii) the fragility of susceptible ones, (iii) the peculiarity of the different places, (iv) the distances, (v) probabilities.
- Houses.
- Schools.
- Hospitals.
- Nursing homes,
- Factories.

The interface and the information sheet

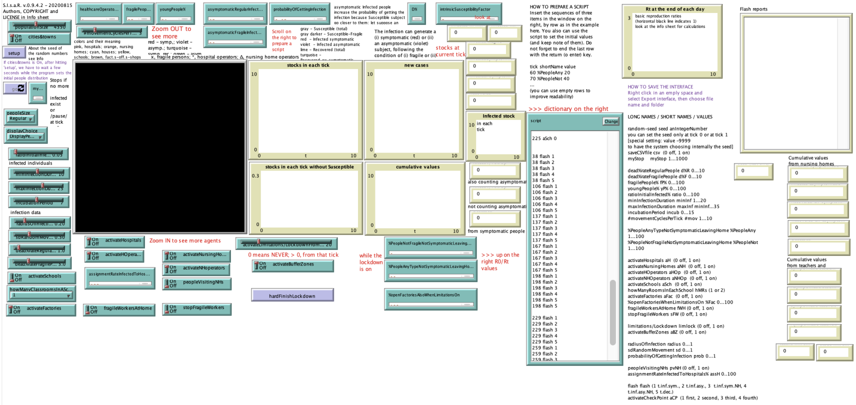
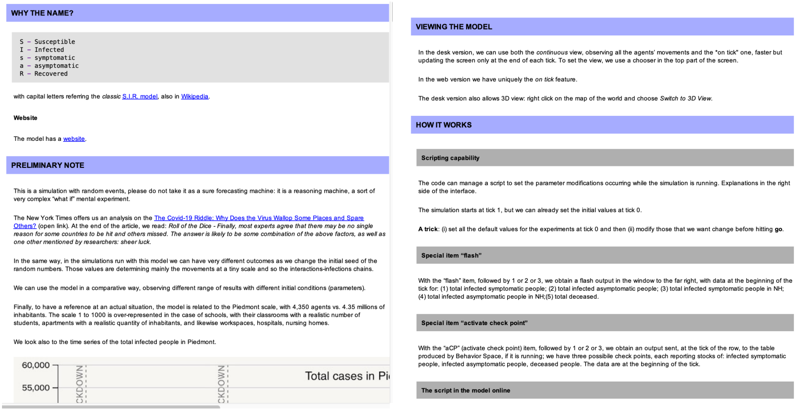


Figure 1: The interface

The interface and the information sheet



WHY THE NAME?

```
S – Susceptible
I – Infected
s – symptomatic
a – asymptomatic
R – Recovered
```

with capital letters referring the *classic* S.I.R. model, also in Wikipedia.

Website

The model has a website.

PRELIMINARY NOTE

This is a simulation with random events, please do not take it as a sure forecasting machine: it is a reasoning machine, a sort of very complex "what if" mental experiment.

The New York Times offers us an analysis on the The Covid-19 Riddle: Why Does the Virus Wallop Some Places and Spare Others? (open link). At the end of the article, we read: *Roll of the Dice - Finally, most experts agree that there may be no single reason for some countries to be hit and others missed. The answer is likely to be some combination of the above factors, as well as one other mentioned by researchers: sheer luck.*

In the same way, in the simulations run with this model we can have very different outcomes as we change the initial seed of the random numbers. Those values are determining mainly the movements at a tiny scale and so the interactions-infections chains.

We can use the model in a comparative way, observing different range of results with different initial conditions (parameters).

Finally, to have a reference at an actual situation, the model is related to the Piedmont scale, with 4,350 agents vs. 4.35 millions of inhabitants. The scale 1 to 1000 is over-represented in the case of schools, with their classrooms with a realistic number of students, apartments with a realistic quantity of inhabitants, and likewise workspaces, hospitals, nursing homes.

We look also to the time series of the total infected people in Piedmont.

VIEWING THE MODEL

In the desk version, we can use both the *continuous* view, observing all the agents' movements and the "on tick" one, faster but updating the screen only at the end of each tick. To set the view, we use a chooser in the top part of the screen.

In the web version we have uniquely the *on tick* feature.

The desk version also allows 3D view: right click on the map of the world and choose *Switch to 3D View*.

HOW IT WORKS

Scripting capability

The code can manage a script to set the parameter modifications occurring while the simulation is running. Explanations in the right side of the interface.

The simulation starts at tick 1, but we can already set the initial values at tick 0.

A trick: (i) set all the default values for the experiments at tick 0 and then (ii) modify those that we want change before hitting **go**.

Special item "flash"

With the "flash" item, followed by 1 or 2 or 3, we obtain a flash output in the window to the far right, with data at the beginning of the tick for: (1) total infected symptomatic people; (2) total infected asymptomatic people; (3) total infected symptomatic people in NH; (4) total infected asymptomatic people in NH;(5) total deceased.

Special item "activate check point"

With the "aCP" (activate check point) item, followed by 1 or 2 or 3, we obtain an output sent, at the tick of the row, to the table produced by Behavior Space, if it is running; we have three possibile check points, each reporting stocks of: infected symptomatic people, infected asymptomatic people, deceased people. The data are at the beginning of the tick.

The script in the model online

Figure 2: The information sheet, about 20 pages

The interface

A live look to the running model, also in a 3D view.

Contagion representation

- The model allows analyzing the sequences of contagions in simulated epidemics, taking in account the places where they occur.
- We represent each infecting agent as a horizontal segment with a vertical connection to another agent receiving the infection. We represent the second agent via a further segment at an upper layer.
- With colors, line thickness, and styles, we display multiple data.
- This enables understanding at a glance how an epidemic episode is developing. In this way, it is easier to reason about countermeasures and, thus, to develop intervention policies.

An example

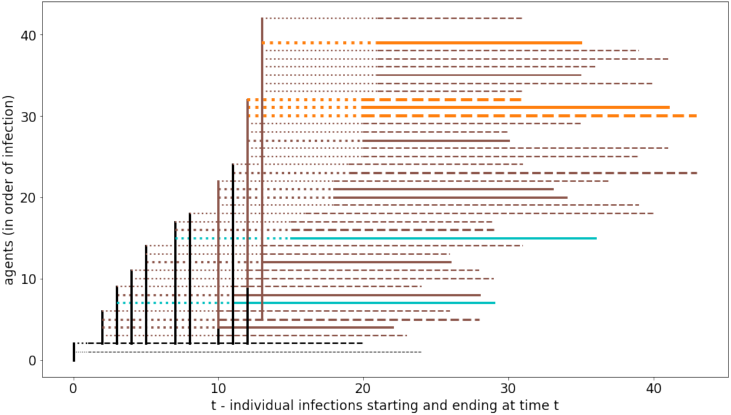


Figure 3: A case with containment measures, first 40 infections: workplaces (brown) and nursing homes (orange) strictly interweaving

Same example, more cases

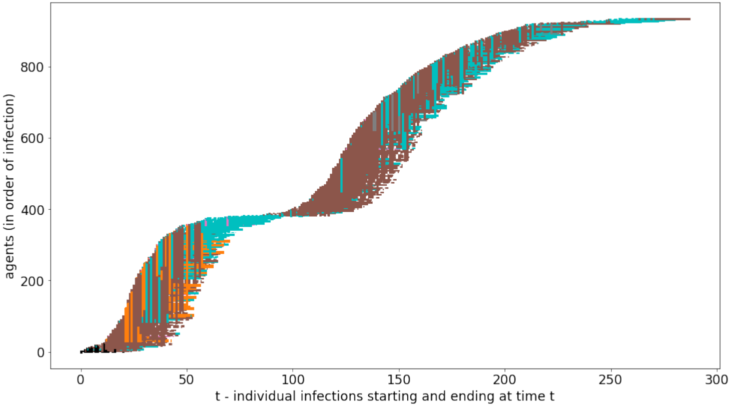


Figure 4: A Case with containment measures, the whole epidemics: workplaces (brown) and nursing homes (orange) and then houses (cyan), with a bridge connecting two waves

Other examples (i) on the left, an epidemic without containment measures; (ii) on the right, an epidemic with basic non-pharmaceutical containment measures

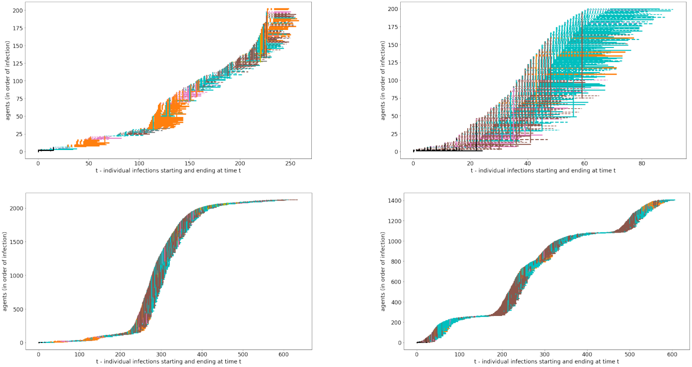


Figure 5: Two cases with initial and full periods

A contagion sequence suggesting policies: in Fig. 6 we can look both at the places where contagions occur and at the dynamics emerging with different levels of intervention.

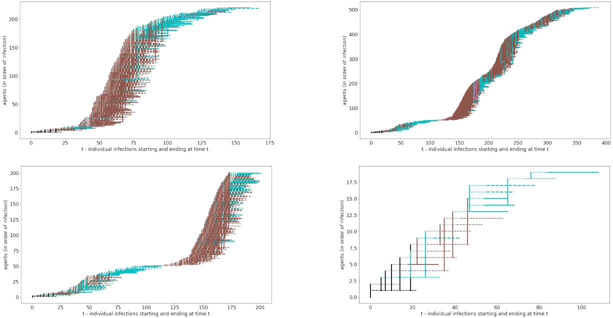


Figure 6: (*top left*) an epidemic with regular containment measures, showing a highly significant effect of workplaces (brown); (*top right*) the effects of stopping fragile workers at day 20, with a positive result, but home contagions (cyan) keep alive the pandemic, exploding again in workplaces (brown); (*bottom left*) the same analyzing the first 200 infections with evidence of the event around day 110 with the new phase due to a unique asymptomatic worker, and (*bottom right*) stopping fragile workers and any case of fragility at day 15, also isolating nursing homes

Batches

- We explore systematically the introduction of factual, counterfactual, and prospective interventions to control the spread of the contagions.
- Each simulation run—whose length coincides with the disappearance of symptomatic or asymptomatic contagion cases—is a datum in a wide scenario of variability in time and effects.
- Consequently, we need to represent compactly the results emerging from batches of repetitions, to compare the consequences of the basic assumptions adopted for each specific batch.
- We used blocs of one thousand repetitions. Besides summarizing the results with the usual statistical indicators, we adopted the technique of the heat-maps.

Two quite different heat-maps for the Piedmont region

In Fig. 7 we have two heat-maps reporting the duration of each simulated epidemic in the x axis and the number of the symptomatic, asymptomatic, and deceased agents in the y axis. 1,000 runs in both cases.

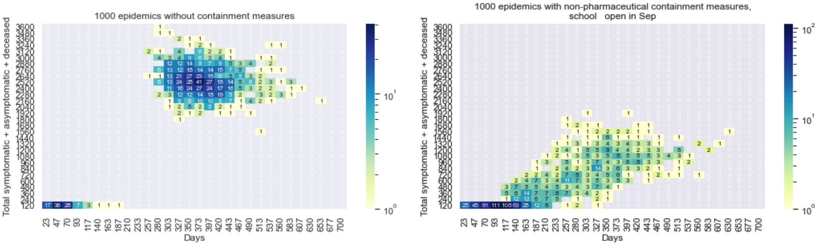


Figure 7: (*on the left*) Epidemics without containment measures; (*on the right*) Epidemics with basic non-pharmaceutical containment measures, schools open in September 2020

Different Intervention: policies and results

Scenarios	total sym.	total sym., asympt., deceased	days
1. no control	851.12 (288.52)	2253.48 (767.58)	340.10 (110.21)
2. basic controls, no school in Sep 2020	158.55 (174.10)	416.98 (462.94)	196.97 (131.18)
3. basic controls, *schools open* in Sep 2020	153.71 (168.55)	409.73 (454.12)	199.35 (129.00)
4. basic controls, **stop fragile workers**, no schools in Sep 2020	120.17 (149.10)	334.68 (413.90)	181.10 (125.46)
5. basic controls, **stop f. workers & f. people & n. h. isol.**, no sch, Sep.	**105.63** (134.80)	**302.62** (382.14)	174.39 (121.82)
6. b. controls, stop f. workers & f. people & nur. h. isol., & **factories op.**, no sch. Sep.	124.10 (132.42)	397.05 (399.64)	200.31 (121.46)
7. b. controls, stop f. workers & f. people & nur. h. isol., & **factories op., sch. open** Sep.	116.55 (130.91)	374.68 (394.66)	195.28 (119.33)

Table 1: Report of the key results, with mean and (std)

Where we were

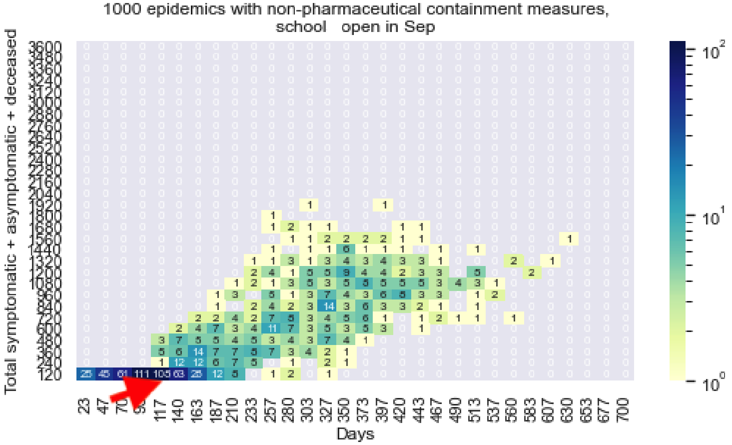


Figure 8: → the cell of epidemics concluded in May (less than 120k symptomatic + asymptomatic)

Where we are

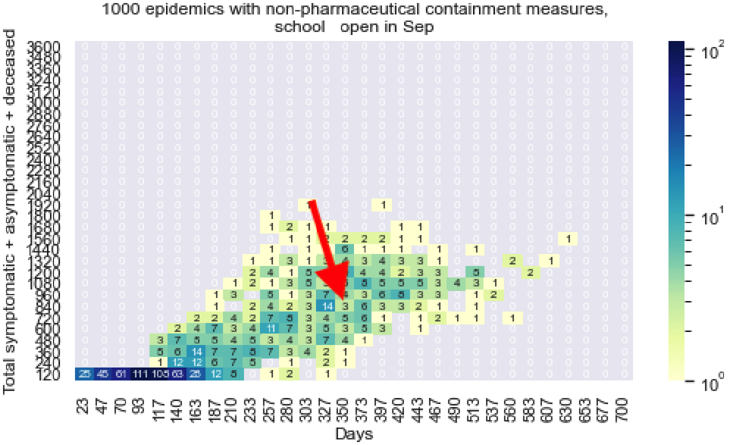


Figure 9: → where (and when) the second wave will end?

Raw data

Sources: `https://terna.to.it/datiProtezioneCivile.html` based on `http://www.protezionecivile.gov.it` data, daily updated.

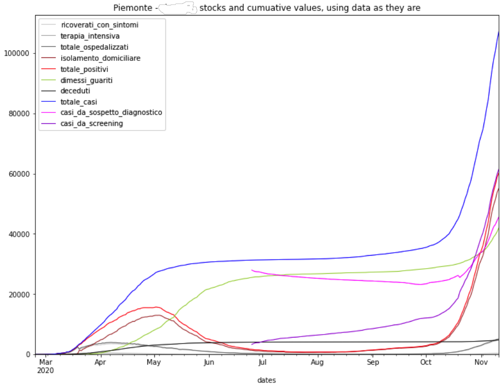


Figure 10: Raw data introduces the cases of screening analysis, making tests

Comparable current data

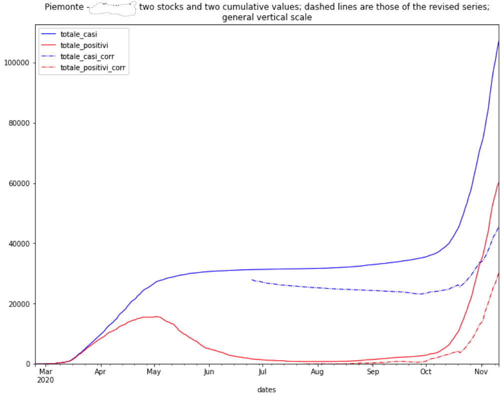


Figure 11: Dashed lines (cumulative values and daily stocks) are corrected deducing the number of screening cases (as cumulative values or 14 days differences

A new model: the map

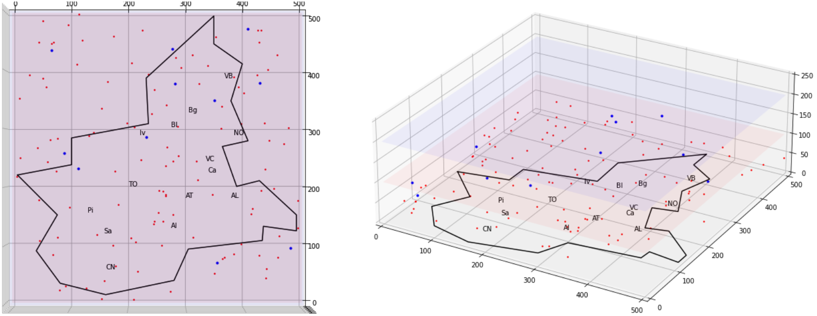


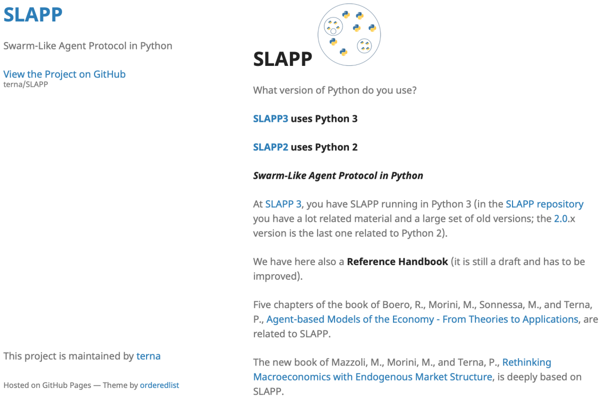
Figure 12: 3D Piedmont

A new model: the scale and the items

- 1 : 100.
- *Infection engine*.
- Houses.
- Schools.
- Hospitals.
- Nursing homes,
- Factories.
- Transportations.
- Aggregation places: happy hours, night life, sport stadiums, discotheques, ...

The tool: S.L.A.P.P.

Scientific advertising: `https://terna.github.io/SLAPP/`



SLAPP

Swarm-Like Agent Protocol in Python

View the Project on GitHub
terna/SLAPP

This project is maintained by terna

Hosted on GitHub Pages — Theme by orderedlist

SLAPP

What version of Python do you use?

SLAPP3 uses Python 3

SLAPP2 uses Python 2

Swarm-Like Agent Protocol in Python

At SLAPP 3, you have SLAPP running in Python 3 (in the SLAPP repository you have a lot related material and a large set of old versions; the 2.0.x version is the last one related to Python 2).

We have here also a **Reference Handbook** (it is still a draft and has to be improved).

Five chapters of the book of Boero, R., Morini, M., Sonnessa, M., and Terna, P., Agent-based Models of the Economy - From Theories to Applications, are related to SLAPP.

The new book of Mazzoli, M., Morini, M., and Terna, P., Rethinking Macroeconomics with Endogenous Market Structure, is deeply based on SLAPP.

Figure 13: Swarm-Like Agent Protocol in Python

A few considerations

- The model is a tool for comparative analyses, not forecasting (the enormous standard deviation values are intrinsic to the problem).
- *How can your work be adapted to (or is relevant/useful for) another disease, crisis, context, . . .*
- The model is highly parametric and more it will be.
- New crisis calling for immediate simulation could take a substantial advantage from the parametric structure of the model.

The slides are at `https://terna.to.it/PietroTernaEStSeminar.pdf`.