



UNIVERSITÀ
DEGLI STUDI
DI TORINO

Computer Science Department

An agent-based decision support for a vaccination campaign

Emilio Sulis, Pietro Terna

A2HC@AAMAS 2021

An agent-based decision support for a vaccination campaign

topics covered in this presentation

Motivation

Agent-based business processes simulation

AI techniques for decision making

ABM case study: Piedmont Region

First results

Future work

An agent-based decision support for a vaccination campaign

Motivation

Agent-based business processes simulation

AI techniques for decision making

ABM case study: Piedmont Region

First results

Future work

MOTIVATION

- Practical application in the context of 2020 pandemic emergency
- Agent-based business process simulation (organization, BPM, and complex systems)
- Exploit Agent-Based Modeling (ABM) for decision-making
- AI techniques applied to ABM

An agent-based decision support for a vaccination campaign

Motivation

Agent-based business processes simulation

AI techniques for decision making

ABM case study: Piedmont Region

First results

Future work

Agent-Based Business Process Simulation

- **Business Process Management** to support organizations
- Healthcare Process **Simulation**
- **AI techniques** applied to an ABM

Agent-based modeling and healthcare processes

> Why agent-based perspective?

1. Improve the **understandability**/immediateness for not specialists (e.g., visualization of actors movements)
2. Attention to agents **interactions/robustness** to changes
3. Exploring interactions between **micro-macro** level

Agent-based modeling and healthcare processes

Interactions between agents behaviour and environment

- > Complexity

- > Non-linear interactions

- > Emergent behaviour

- >>> Agent-Based Modeling [*NetLogo*]

Why NetLogo ?

- The **capability** of managing collection of (instances of) 'agents'
- BehaviourSearch tool to perform **Genetic Algorithm**
- The **graphical representation** of the agents' world
- Its **openness**, also in a web-based version, it's easy to connect to R or Python, extend with GIS or SNA libraries, or to build new extensions written in Java or Scala.

NetLogo: FOSS and community support

Models Library

- Sample Models
 - Art
 - Biology
 - Chemistry & Physics
 - Computer Science
 - Earth Science
 - Games
 - Mathematics
 - Networks
 - Diffusion on a Directed Network
 - Giant Component
 - Preferential Attachment
 - Small Worlds
 - Team Assembly
 - Virus on a Network
 - Philosophy
 - Psychology
 - Social Science
 - System Dynamics
- Curricular Models
 - BEAGLE Evolution
 - Connected Chemistry
 - EACH
 - epiDEM
 - GasLab
 - GenEvo
 - Lattice Land
 - MaterialSim
 - Mind the Gap
 - ModelSim
 - NIELS
 - Problab
 - Urban Suite
- Code Examples
 - HubNet Activities
 - IABM Textbook
 - Alternative Visualizations

About the Models Library

Sample Models are the most carefully checked models we have. They are examples of good coding and documentation practice.

Unverified models are also complete and functional, but are still in the process of being reviewed for content, accuracy, and quality of code.

Code Examples are not complete models, but short illustrations of particular features and coding techniques. They are a supplement to the NetLogo User Manual.

Curricular Models are associated with curricula developed at the CCL. The models also appear, sometimes in different form, in Sample Models. For information on the curricula, see the CCL home page at <http://ccl.northwestern.edu>.

HubNet Activities are for use with our HubNet participatory simulation architecture.

IABM Textbook models are from: Wilensky, U & Rand, W. (2015). Introduction to Agent-Based Modeling: Modeling Natural, Social and Engineered Complex Systems with NetLogo. Cambridge, MA: MIT Press. The models, as well as any updates to them, can also be found on the textbook website: <http://intro-to-abm.com>.

Alternative Visualizations models demonstrate the application of guidelines presented in: Kornhauser, D., Wilensky, U., & Rand, W. (2009). [Design guidelines for agent based model visualization](#). Journal of Artificial Societies and Social Simulation, JASSS, 12(2), 1.

User Community Models are models contributed from the user community to be shared with other NetLogo users. They are not included with NetLogo but are available on the web by pressing the

NetLogo Modeling Commons

Register to share and participate | Forgot Password

Email Address Password Login

Start TogetherJS

Home List models Help Blog Search Models

Welcome to the Modeling Commons!

The Modeling Commons is for sharing and discussing agent-based models written in NetLogo. With more than 1,000 models, contributed by modelers from around the world, you're bound to learn something new.

Have you created a new NetLogo model? We would love to see it; please [register](#), and share it with us!

Explore The Modeling Commons

- Search Models Search
- Suggestion: Search for 'flock'
- List all 1,000+ models
- List recently changed models
- Jump to a random model
- View projects (model collections)
- Help!

Most Viewed Models (in the past 2 weeks)

- Michael Novak
new villi food model
Viewed 197 times in the past 2 weeks
- Amel Kouidrat
Food-web in Arabic
Viewed 161 times in the past 2 weeks
- Amel Kouidrat
Food-web Algerian desert
Viewed 157 times in the past 2 weeks
- Alvaro Gil



Computational Model Library

An agent-based decision support for a vaccination campaign

Motivation

Agent-based business processes simulation

AI techniques for decision-making

ABM case study: Piedmont Region

First results

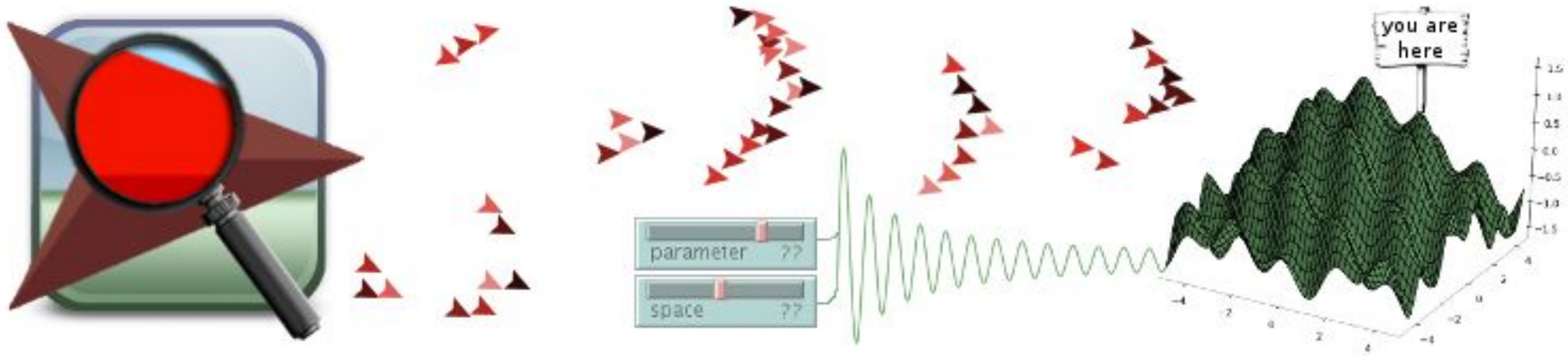
Future work

Genetic Algorithm

- GA is a search heuristic to solve an optimization algorithm reflecting the process of **natural selection**
- “survival of fittest”: the **fittest individuals** are selected for reproduction of a new population
- crossover (recombination): to combine the genetic information of two parents to generate **new offspring**
- **iterative** use of genetic operators on individuals in the population

BEHAVIOR SEARCH

A software tool to help with automating the exploration of ABMs
Genetic algorithms (and other heuristic techniques) to search the
parameter-space.



<https://www.behaviorsearch.org/>

An agent-based decision support for a vaccination campaign

Motivation

Agent-based business processes simulation

AI techniques for decision making

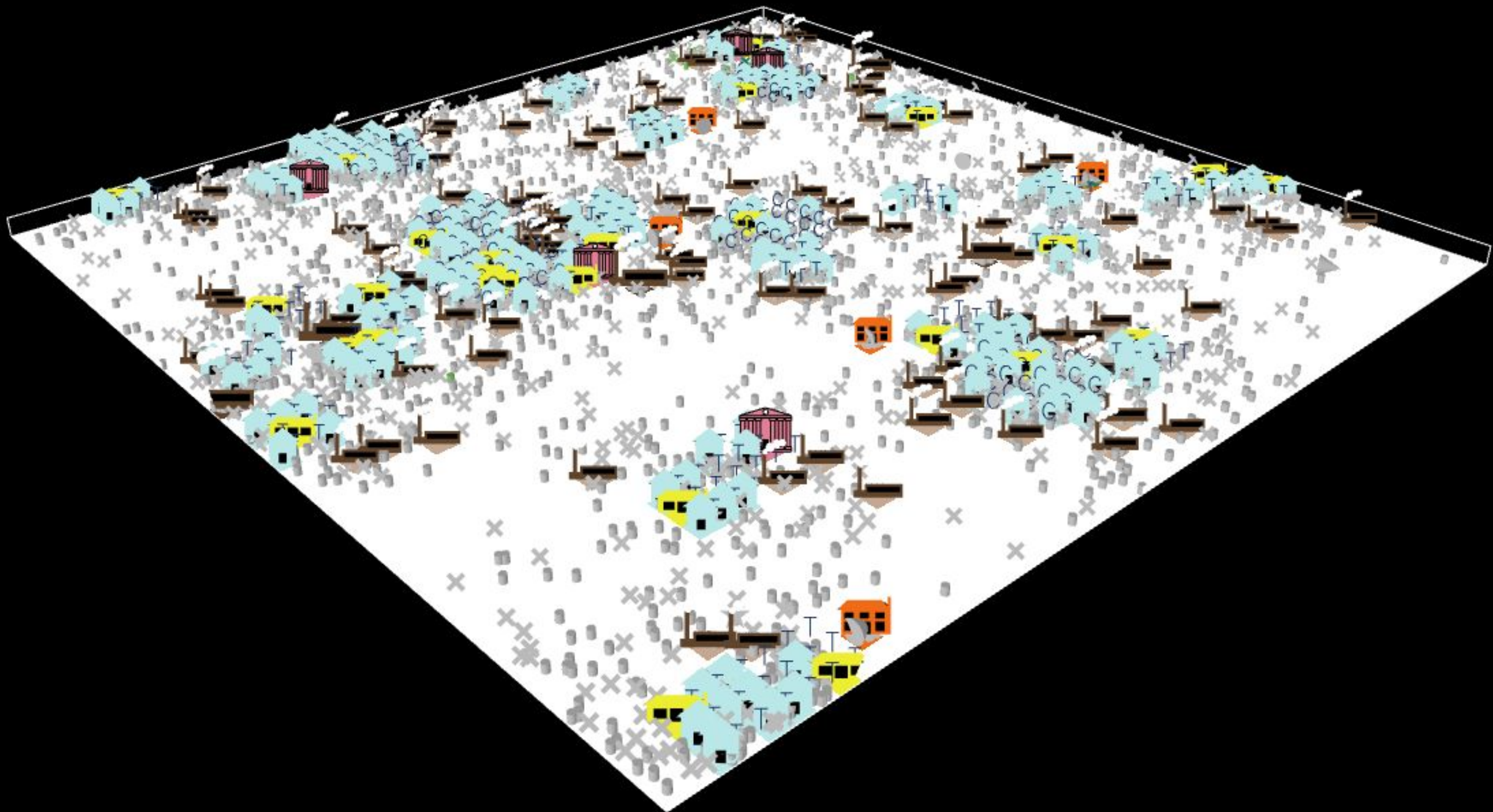
ABM case study: Piedmont Region

First results

Future work

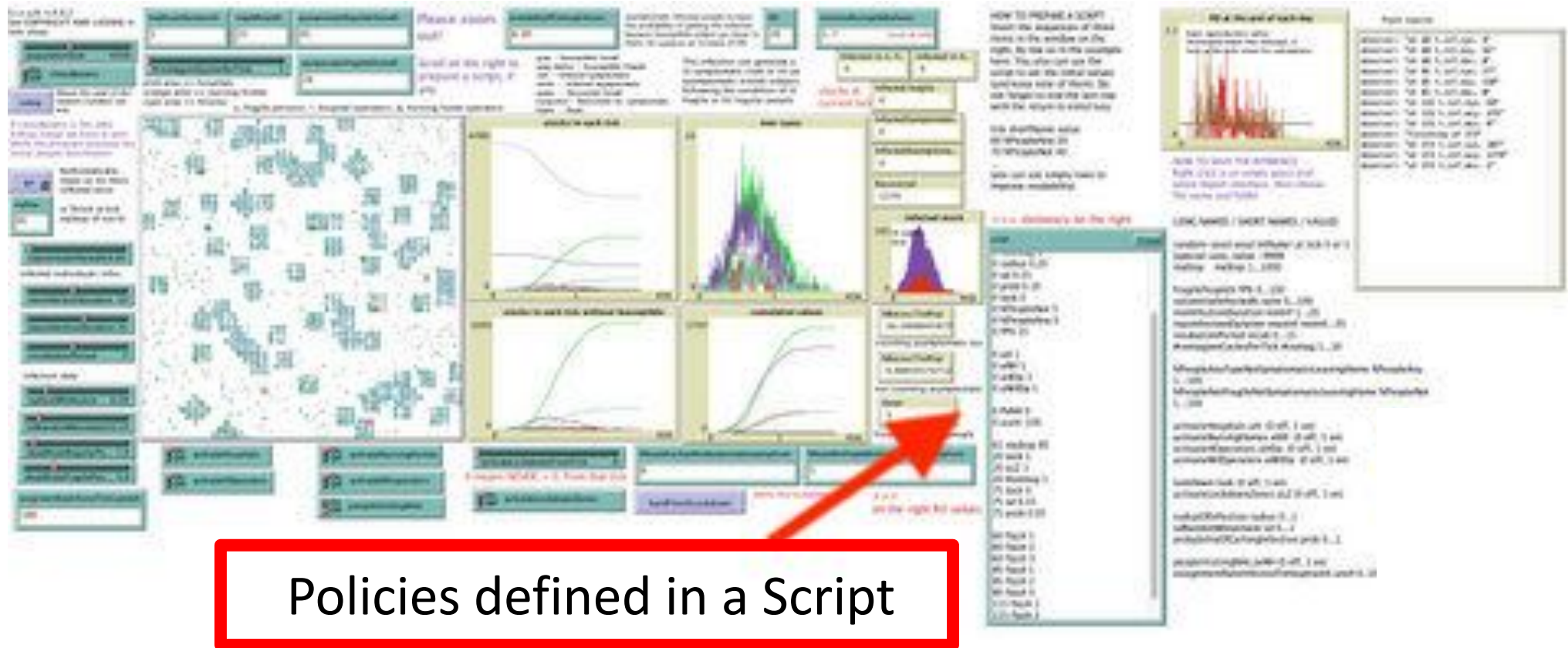
S.I.s.a.R. model

- Piedmont population - scale 1 : 1000 (4,350 agents)
- Four types of agents:
Susceptible, Infected symptomatic, Infected asymptomatic, Recovered
- Agents movements:
 - The **virus diffusion** among different hosts
 - The interactions between individuals in **different environments**,
e.g. houses, schools, hospitals, nursing homes, factories
- Web-site of the Model: <https://terna.to.it/simul/SIsaR.html>
You can run the model **directly online**
or download *SIsaR_0.9.5.4.2.nlogo* and run it locally with **NetLogo**.



S.I.s.a.R. model

- A realistic set of political interventions (e.g., national and local government decisions) can be defined in a **Script** in the interface



The screenshot displays the S.I.s.a.R. model interface, which is a complex dashboard for simulating and managing a system. It features several key components:

- Left Panel:** A vertical sidebar containing numerous buttons and controls for navigating and configuring the model.
- Central Area:** A grid of visualization windows. On the left, there is a map showing a geographical layout of nodes. To the right, there are several line graphs and histograms, likely representing the progression of the model's variables over time.
- Right Panel:** A large text area containing a script, which is used to define specific political interventions. A red arrow points from a text box at the bottom to this script area.
- Bottom Center:** A red-bordered box containing the text "Policies defined in a Script", which is the subject of the bullet point above.

Vaccination campaign

General accepted idea: the **administration of the vaccine** to people can be helpful to **prevent infections**.

A **vaccination campaign** makes it possible to immunize people.

The vaccine is **not immediately available** to the whole population.

Vaccination campaign

The current simulation introduces such **vaccination strategies** as a public health policy intervention.

A choice has to be made about **which parts of the population** to vaccinate first, as a matter of **health policy**.

AI and ABM: experiment with **GA to suggest the best parameters** in performing a vaccination campaign based on the S.I.s.a.R. model.

Experiments

A GA algorithm defines the percentage of groups to be involved first.

Scenarios:

- ***baseline***. Nothing is done to avoid the virus diffusion

Similarly to Italian government vaccine campaign, 2 scenarios:

- ***immuneInfecting***. Once agents have become immune they can be contagious.
- ***immuneNoInfecting***. Agents immune are not contagious.

GA parameters

The GA parameters setting concerns the **percentage of people** to be vaccinated in each round of the campaign.

The population can be divided into **categories of interest (groups of people considered in the experiments by age or by type)** for the implementation of vaccinations.

BehaviourSearch tool to explore GA, with a limit of 300 runs.

GA parameters

Group	Description
g1	Three sub-categories related to nursing homes: i. health fragile people in nursing homes ii. nursing home operators iii. healthcare operators
g2	Teachers of public and private schools
g3	Workers with medical fragility
g4	Plain workers
g5	Fragile people without special characteristics
g6	Regular people not young not worker not teacher
g7	Young people excluding special activity cases

An agent-based decision support for a vaccination campaign

Motivation

Agent-based business processes simulation

AI techniques for decision making

ABM case study: Piedmont Region

First results

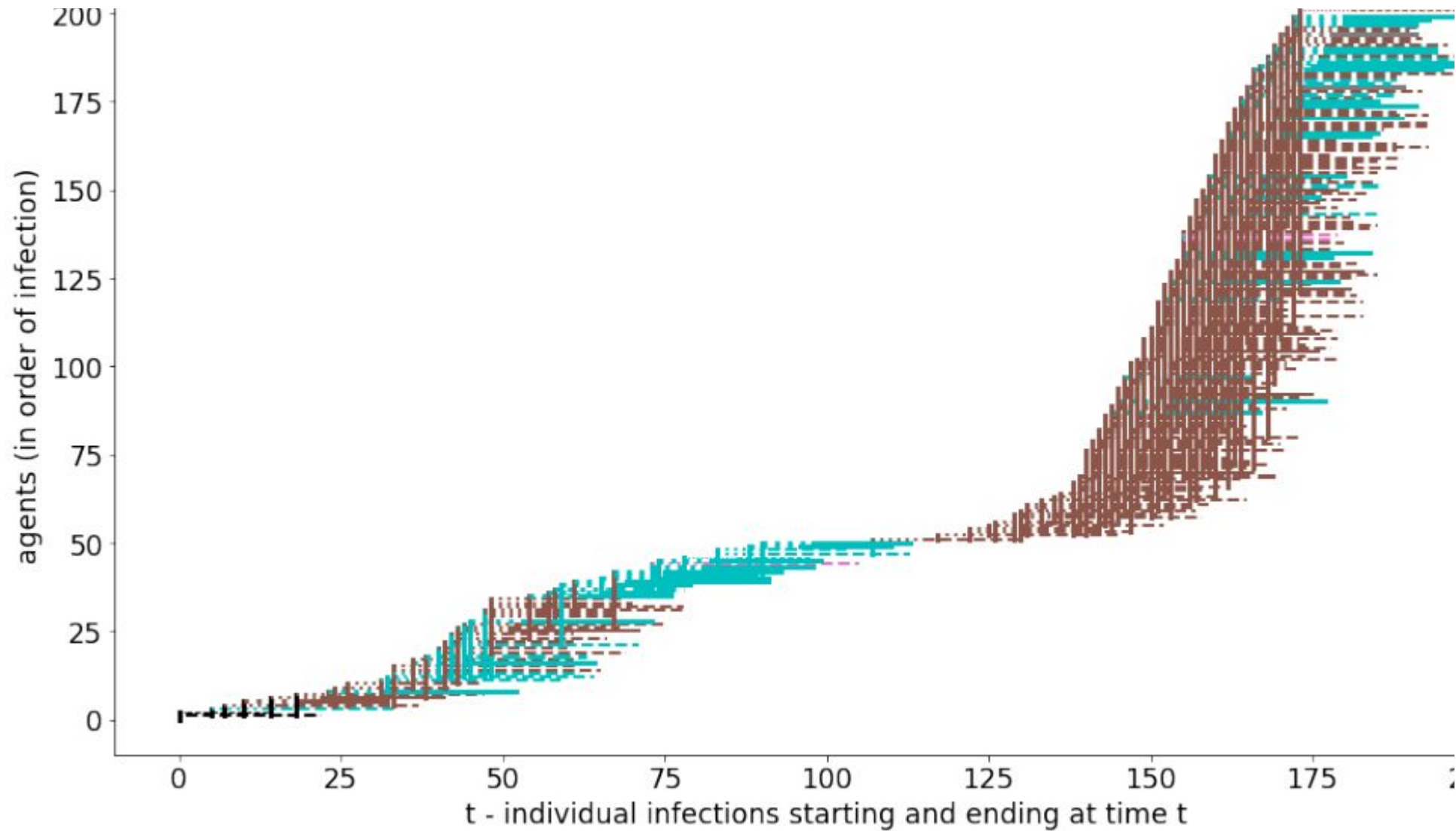
Future work

First results

The **number of the infected agents** at the end of the simulation:

- *baseline* (the model without any vaccination campaign): 325,000 infected [7.5% of the whole regional population]
- *ImmuneInfecting*: more than 215,000 infected
- *ImmuneNoInfecting*: more than 200,000 infected

First results



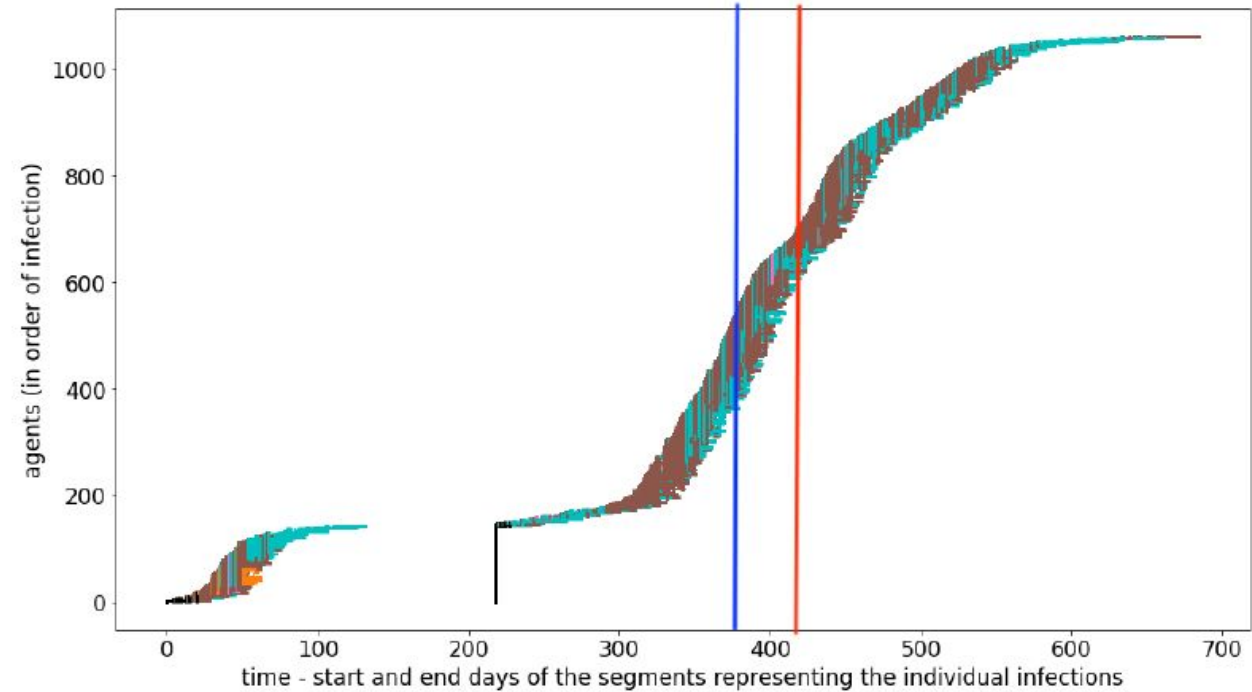
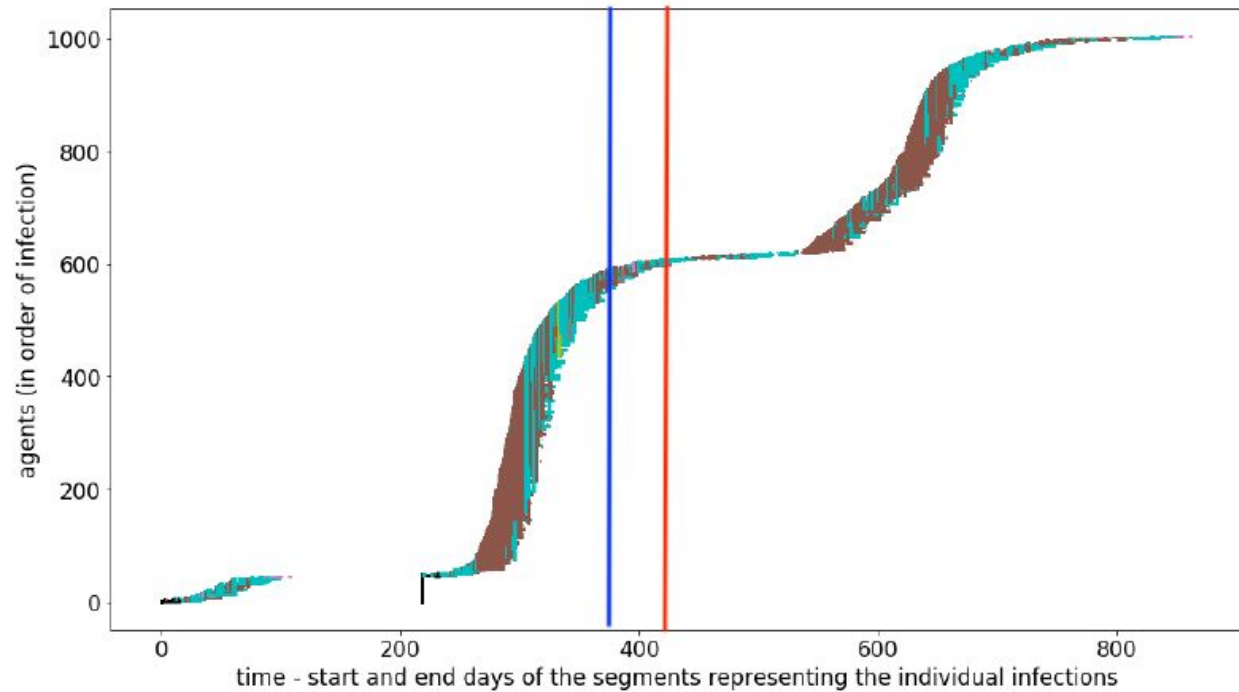
First results

We compare the effect of choosing the vaccination quotas via GAs with two predetermined strategies in *immuneInfecting* and *immuneNoInfecting*

- Key dates:
 - in the calendar of the model Feb. 12th, 2021 is effectively the **starting point** of the vaccinations in the region (day 373 in the model);
 - the **day of the effectiveness** of the initial vaccinations is Mar. 22nd, 2021 (day 413) i.e. 40 days later the starting day of the vaccination.

First results

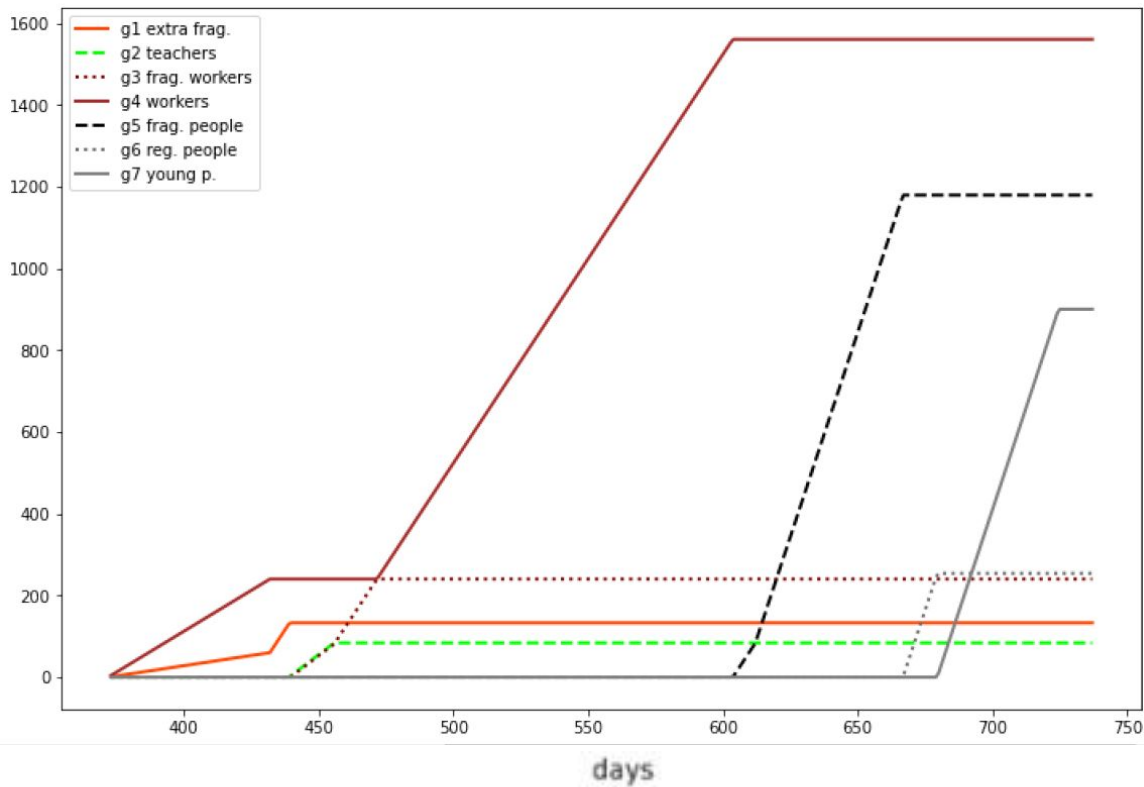
Two experiments results



Vaccinated people still spreading the infection

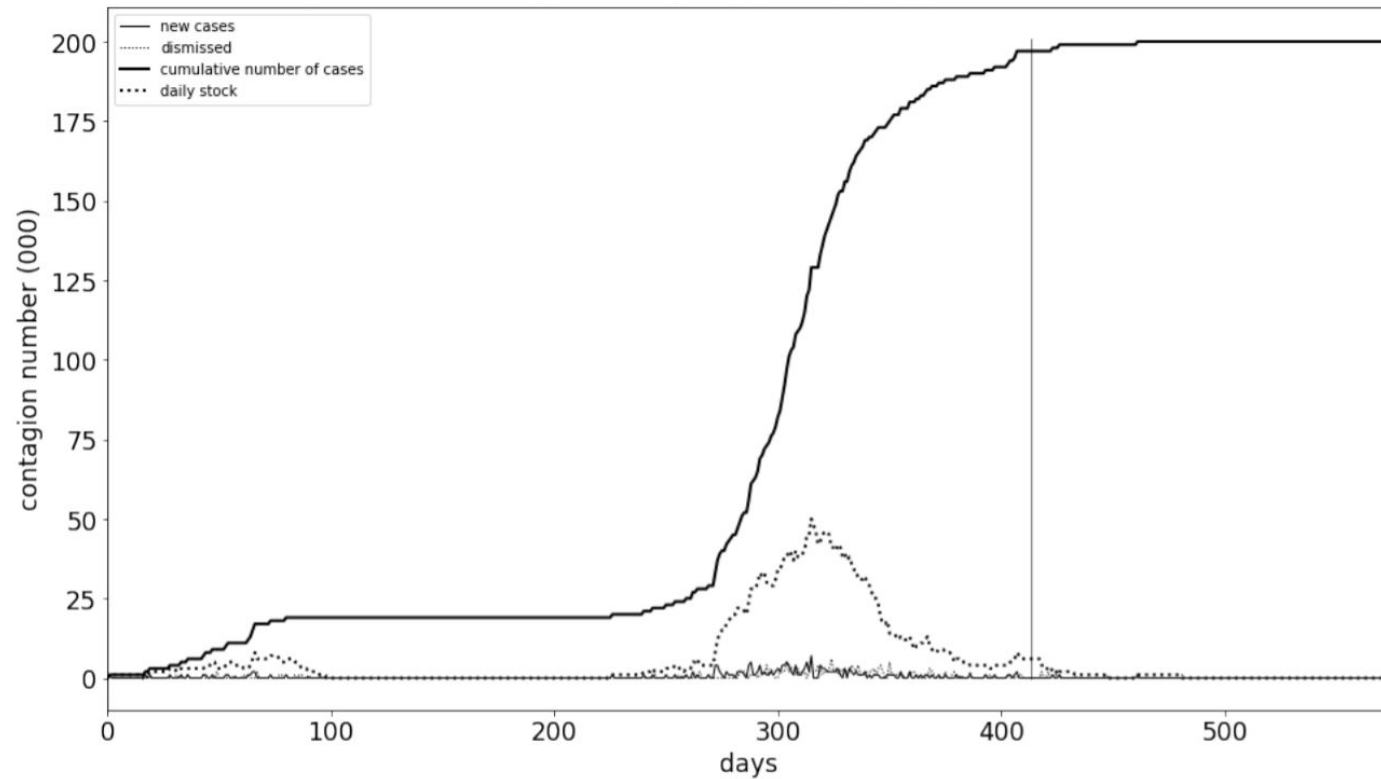
The **vaccination sequence** for each group

y axis: n°of vaccinated subjects



[if vaccination is complete: horizontal line]

y axis: n°of contagions



[vaccination symptomatic series]

An agent-based decision support for a vaccination campaign

Motivation

Agent-based business processes simulation

AI techniques for decision making

ABM case study: Piedmont Region

First results

Future work

Future work

We aim:

- to improve the experiments by using an HPC platform
- to explore the results under scenarios:

Lockdown. A more restricted scenario for fragile people and workers

immunelntecting50. Once agents have become immune they can be contagious at random (50% of cases)