



HAL
open science

Designing social simulation to (seriously) support decision-making: COMOKIT, an agent-based modelling toolkit to analyse and compare the impacts of public health interventions against COVID-19

Alexis Drogoul, Patrick Taillandier, Benoit Gaudou, Marc Choisy, Kevin Chapuis, Nghi Huynh Quang, Doanh Nguyen-Ngoc, Damien Philippon, Arthur Brugière, Pierre Larmande

► To cite this version:

Alexis Drogoul, Patrick Taillandier, Benoit Gaudou, Marc Choisy, Kevin Chapuis, et al.. Designing social simulation to (seriously) support decision-making: COMOKIT, an agent-based modelling toolkit to analyse and compare the impacts of public health interventions against COVID-19. 2020. hal-02968321

HAL Id: hal-02968321

<https://hal.science/hal-02968321>

Submitted on 16 Oct 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Designing social simulation to (seriously) support decision-making: COMOKIT, an agent-based modeling toolkit to analyze and compare the impacts of public health interventions against COVID-19

Alexis Drogoul¹ (0000-0002-9685-9199), Patrick Taillandier² (0000-0003-2939-4827), Benoit Gaudou^{1,3} (0000-0002-9005-3004), Marc Choisy^{4,8} (0000-0002-5187-6390), Kevin Chapuis^{1,5} (0000-0003-1743-2224), Huynh Quang Nghi^{1,6} (0000-0003-3608-9580), Nguyen Ngoc Doanh^{1,7}, Damien Philippon¹⁰ (0000-0002-6641-8157), Arthur Brugière¹ (0000-0001-7220-449X), Pierre Larmande⁸ (0000-0002-2923-9790)

1. UMI 209, UMMISCO, IRD, Sorbonne Université, Bondy, France
2. UR 875, MIAT, INRAE, Toulouse University, Castanet Tolosan, France
3. UMR 5505, IRIT, Université Toulouse 1 Capitole, Toulouse, France
4. UMR 5290, MIVEGEC, IRD/CNRS/Univ. Montpellier, Montpellier, France
5. UMR 228, ESPACE-DEV, IRD, Montpellier, France
6. CICT, Can Tho University, Can Tho, Vietnam
7. MSLab / WARM, Thuyloi University, Hanoi, Vietnam
8. UMR 232, DIADE, IRD, Univ. Montpellier, Montpellier, France
9. OUCRU, Centre for Tropical Medicine, Ho Chi Minh City, Viet Nam
10. WHO Collaborating Centre for Infectious Disease Epidemiology and Control, School of Public Health, Li Ka Shing Faculty of Medicine, The University of Hong Kong, Hong Kong Special Administrative Region, China.

In less than 4 months after its emergence in China, the COVID-19 pandemic has spread worldwide. In response to this health crisis, unprecedented in modern history, researchers have mobilized to produce knowledge and models in order to inform and support public decision-making, sometimes in real-time (Adam, D. 2020). However, the social modeling community is facing two challenges in this endeavor: the first one is its capacity to provide robust scientific knowledge and to translate it into evidences on concrete cases (and not only general principles) within a short time range; and the second one is to do it knowing (and anticipating the fact) that these evidences may have concrete social, economical or clinical impacts in the “real” world.

These two challenges require the design of realistic models that provide what B. Edmonds, in response to (Squazzoni & al. 2020), calls the “*empirical grounding and validation needed to reliably support policy making*” (Edmonds, 2020); in other words, spatially explicit, demographically realistic, data driven models that can be fed with both quantitative and qualitative (behavioral) data, and that can be easily experimented in huge numbers of scenarios so as to provide statistically sound results and evidences.

It is difficult to deny these requirements but it is easier said than done. What we have witnessed, instead, these last 4 months, is an explosion of agent-based toy models representing, *ad nauseam*, the spread of the virus or similar dynamics within artificial populations without space, without behaviors, without friend nor family relations, without social networks, without even remotely realistic activities or mobility schemes; in short, populations of artificial agents devoid

of everything that makes a human population slightly different from a mixture of homogeneous particles. How we, as a community, can claim to inform policy makers, in such a critical context, with such abstract and simplistic constructions is difficult to justify. Are public health decision makers really *that* interested, these days, in models that help them to understand the general principles, the inner mechanisms or hidden dynamics of this crisis ? Or would they feel better supported if we could answer their questions on which interventions, at which place, at which spatial and temporal scale and on which populations, would have the best impact on the pandemic ?

We tend to forget, however, that agent-based modeling (ABM), among other benefits, does not oppose these two objectives when building a model. And from the outset of the crisis, many of us were quick to advocate a modeling approach that would:

1. Be as close as possible to public decision making by having the possibility to answer to concrete, practical questions;
2. Be based on a detailed and realistic representation of space, as the spread of the epidemic is spatial and public health policies are also predominantly spatial (containment, social distancing, reduction of mobility, etc.) ;
3. Rely on spatial and social data that can be collected easily and, above all, quickly, and not be too dependant on the availability of large datasets (which may not be opened nor shared depending on the country of intervention) ;
4. Make it possible to represent as faithfully as possible the complexity of the social and ecological environments in which the pandemic is spreading;
5. Be generic, flexible and applicable to any case study, but also trustable as it relies on inner mechanisms that can be isolated and validated separately;
6. Be open and modular enough to support the cooperation of researchers across different disciplines while relying on rigorous scientific and computational principles;
7. Offer an easy access to large-scale experimentation and statistical validation by facilitating the exploration of its parameters;

This approach is currently being implemented by an interdisciplinary group of modellers, all signatories of this response, who have started to design and implement on the GAMA platform a generic model called COMOKIT, around which they now wish to gather the maximum number of modellers and researchers in epidemiology and social sciences. Being generic here means that COMOKIT is portable for almost any case study imaginable, from small towns to provinces or even countries, the only real limit to its application being the available RAM and computing power¹.

COMOKIT is an integrated model that, in its simplest incarnation, dynamically combines five sub-models:

1. a sub-model of the individual clinical dynamics and epidemiological status of agents

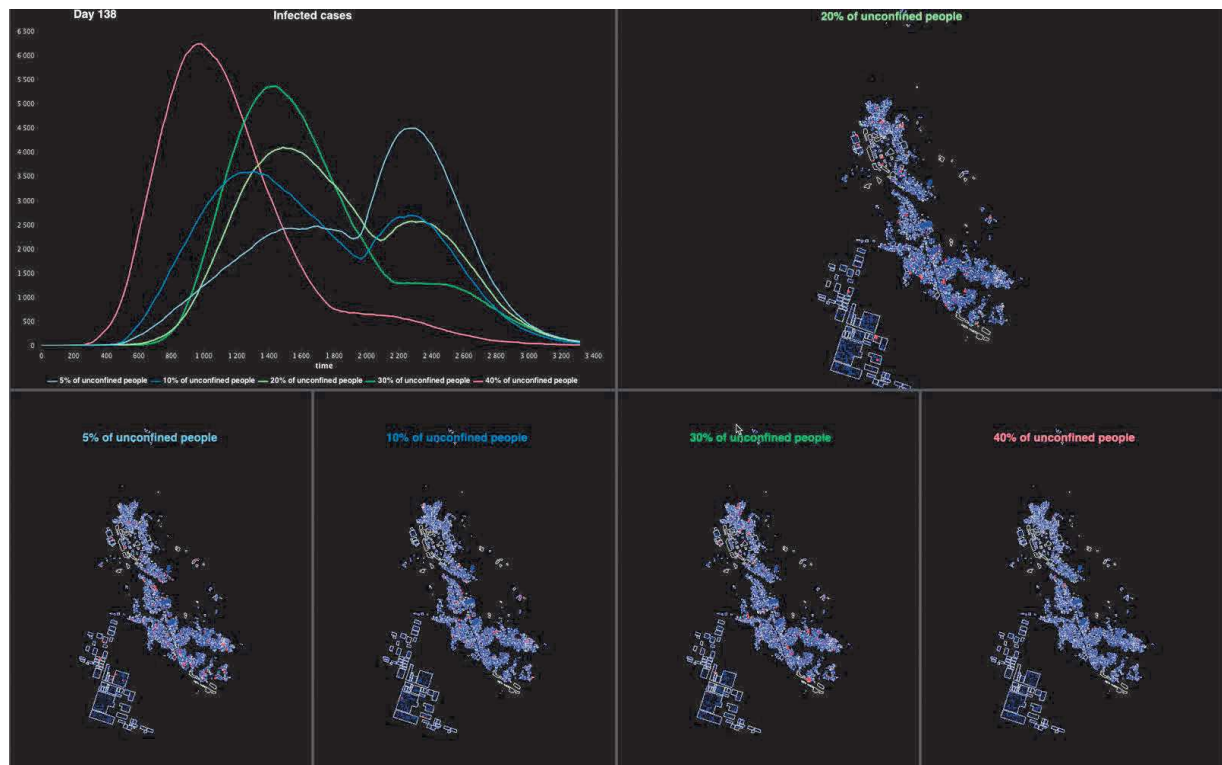
¹ To give a very rough idea, it takes approximately 15 mn and 800Mb of RAM on one core of a laptop to simulate 6 months of a town of 10.000 inhabitants, at a 1 hour step, while displaying a 3D view and charts.

2. a sub-model of agent-to-agent direct transmission of the infection,
3. a sub-model of environmental transmission through the built environment,
4. a sub-model of policy design and implementation,
5. an agenda-based model of people activities at a one-hour time step.

It allows, of course, to represent heterogeneity in individual characteristics (sex, age, household), agendas (depending on social structures, available services or age categories), social relationships and behaviors (e.g. respect of regulations).

COMOKIT has been designed as modular enough to allow modelers and users to represent different strategies and study their impacts in multiple scenarios. Using the experimental features provided by the underlying GAMA platform (Taillandier & al. 2019) (like advanced visualization, multi-simulation, batch experiments, easy large-scale explorations of parameters spaces on HPC infrastructures), it is made particularly easy and effective to compare the outcomes of these strategies. Modularity is also a key to facilitating its adoption by other modelers and users: COMOKIT is a basis that can be very easily extended (to new policies, people activities, actors, spatial features, etc.). For instance, more detailed socio-psychological models, like the ones described in ASSOCC (<https://simassocc.org/the-simulation/>) (Ghorbani & al. 2020), could be interesting to test within realistic models. In that respect, COMOKIT is both a framework (for deriving new concrete models) and a model (that can be instantiated by itself on arbitrary datasets).

Finally, COMOKIT has been thought of as incrementally expandable: because of the urgency usually associated with its use, it can be instantiated on new case studies in a matter of minutes, by generating the built environment of an area and its synthetic population using a simple geolocalized boundary and reasonable defaults (which can of course be parametrized, or even, in the case of the population generation, be driven by a plugin called Gen* (Chapuis & al. 2018)). When more detailed data becomes available (about the population, peoples' occupations, economic activities, public health policies, ...) the same model can be fed with it in order to refine its initial outcomes.



A screenshot of the experiments' UI in COMOKIT: six scenarios of partial confinement are being compared with respect to the number of cases during and after a 3 months-long period. Son Loi case study, 9988 inhabitants from the 2019 Vietnamese census.

Up to now, COMOKIT has been implemented and evaluated on two cases of city confinement in Vietnam (i.e. Son Loi (Thanh & al. 2020) and Thua Duc). In these cases, which have served as testbeds to verify the correctness of the individual sub-models and their interactions, we have compared the impacts of a number of social-distancing strategies (e.g. with a ratio of the population allowed to move outside, for various durations, to various geographical extents, by activities, and so on), and other non-pharmaceutical interventions such as advising the population to wear masks, or closing the schools and public places. These studies have shown in particular that the process of ending an intervention is as much impactful as the process of starting it, in particular to avoid a second epidemic wave.

We need you: social scientists, epidemiologists, modelers, computer scientists, web designers...

As the epidemic moves to countries with more limited health infrastructure and economic space, it becomes critical to devise, test and compare original public interventions that are adapted to these constraints, for instance interventions that would be more geographically and socially targeted than an entire lockdown of the whole population. COMOKIT, which is used since the beginning of April 2020 within the Rapid Response Team of the Steering Committee against COVID-19 of the Ministry of Health in Vietnam, can become an invaluable help in this endeavor.

However, it must become even more realistic, reliable and robust than it is at present, so that decision-makers can build a relationship of trust with this new tool and hopefully with agent-based modelling in general.

All the documentation (with a complete ODD description and UML diagrams), commented source code (of the models and utilities), as well as five example datasets, are made available on the project's webpage² and Github repository³ to be shared, reused and adapted to other case studies. We strongly encourage anyone interested to try COMOKIT, apply it on their own case studies, improve it by adding new policies, activities, agents or scenarios, and share their studies, proposals, and results. Any help will be appreciated to show that we can collectively contribute, as a community, to the fight against this pandemic (and maybe the next ones): analysing the sub-models, documenting them, proposing access to data, fixing bugs, adding new sub-models, testing their integration, proposing HPC infrastructures to run large-scale experiments, everything can be helpful!

References

- (Adam, 2020) Adam, D. (2020). Special report: The simulations driving the world's response to COVID-19. *Nature*.
- (Chapuis & al. 2018) Chapuis, K., Taillandier, P., Renaud, M., & Drogoul, A. (2018). Gen*: a generic toolkit to generate spatially explicit synthetic populations. *International Journal of Geographical Information Science*, 32(6), 1194-1210.
- (Edmonds, 2020) Edmonds, B. (2020) Good Modelling Takes a Lot of Time and Many Eyes. *Review of Artificial Societies and Social Simulation*, 13rd April 2020. <https://rofasss.org/2020/04/13/a-lot-of-time-and-many-eyes/>
- (Ghorbani & al. 2020) Ghorbani, A., Lorig, F., de Bruin, B., Davidsson, P., Dignum, F., Dignum, V., van der Hurk, M., Jensen, M., Kammler, C., Kreulen, K., Ludescher, L. G., Melchior, A., Mellema, R., Păstrăv, C., Vanhée, L. and Verhagen, H. (2020) The ASSOCC Simulation Model: A Response to the Community Call for the COVID-19 Pandemic. *Review of Artificial Societies and Social Simulation*, 25th April 2020. <https://rofasss.org/2020/04/25/the-assocc-simulation-model/>
- (Squazzoni & al. 2020) Squazzoni, F., Polhill, J. G., Edmonds, B., Ahrweiler, P., Antosz, P., Scholz, G., ... & Gilbert, N. (2020). Computational Models That Matter During a Global Pandemic Outbreak: A Call to Action. *Journal of Artificial Societies and Social Simulation*, 23(2), 1-10.
- (Taillandier & al. 2019) Taillandier, P., Gaudou, P., Grignard, A., Huynh, Q.N., Marilleau, N., Caillou, P., Philippon, D., Drogoul, A. (2019) Building, Composing and Experimenting Complex Spatial Models with the GAMA Platform. *Geoinformatica* 23, 299-322.
- (Thanh & al. 2020) Thanh, H. N., Van, T. N., Thu, H. N. T., Van, B. N., Thanh, B. D., Thu, H. P. T., ... & Nguyen, T. A. (2020). Outbreak investigation for COVID-19 in northern Vietnam. *The Lancet Infectious Diseases*.

² <https://gama-platform.org/covid19>

³ <https://github.com/COMOKIT/CoVid19>