How Artificial Life Researchers Can Help Address Complex Societal Challenges

Hiroki Sayama[1,2]

[1]Center for Collective Dynamics of Complex Systems, Binghamton University, State University of New York, USA
[2]Waseda Innovation Lab, Waseda University, Japan
sayama@bingahmton.edu

Abstract

The global COVID-19 pandemic has given rise to an unprecedented level of complex societal challenges to the humanity. Meanwhile, it also has created a huge demand for scientific expertise in modeling, simulation and analysis of epidemic and other socio-economical dynamics, to which Artificial Life researchers can make great contributions. This extended abstract presents a brief overview of projects the author has been working on in response to COVID-19 since early 2020, summarizing the lessons learned and identifying unique skills and abilities of Artificial Life researchers that have potential to help address various societal challenges.

Introduction

The COVID-19 pandemic has given rise to an unprecedented level of complex societal challenges to the humanity at all scales. This crisis also affected the Artificial Life community significantly. John Horton Conway, the creator of the iconic Game of Life cellular automata, succumbed to COVID-19 in April 2020 (Levine, 2020; Baker, 2020). Many universities where ALife researchers work have been physically closed for a prolonged period. As such, the annual ALIFE conferences in 2020[1] and 2021[2] were also forced to go virtual.

In the meantime, COVID-19 has created a huge societal demand for rapid responses from scientific communities, not only in medical and pharmaceutical domains but also in mathematical, computational and complex systems domains in terms of modeling, simulation and analysis of epidemic and other socio-economical dynamics (Sayama, 2020a; Siegenfeld & Bar-Yam, 2020). Artificial Life researchers can make great contributions to meeting this emerging societal demand.

In what follows, I present a brief overview of several projects I have been working on in response to COVID-19 since early 2020, in the hope that they may provide anecdotal yet concrete examples of the "ALife 4 Society" activities (Siqueiros-García et al., 2018; Penn, 2018) that go beyond purely academic research and thereby motivate other ALife researchers to engage in similar effort.

Project Examples

1. Apex prediction in local community (March-April 2020)

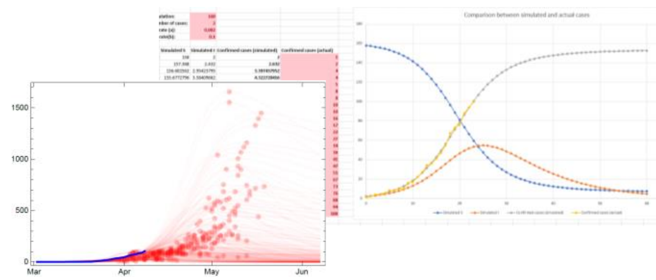

Figure 1: Apex prediction in local community (back: initial prototype in Microsoft Excel; front: more sophisticated version in Mathematica exploring parameter variations).

My first COVID-19 related project was to predict when the apex of COVID-19 infection would occur in the local community and how high it would be, in a very early stage of the pandemic (Fig. 1). This was in response to the request coming from Broome County in Upstate New York, USA, where Binghamton University is located. It was technically nothing more than simple parameter fitting of the standard Susceptible-Infectious-Recovered (SIR) model to the local epidemiological data, but such basic modeling skills were still highly valuable expertise for decision makers and administrators in local communities (and the prediction result turned out to be fairly accurate[3]).

2. Traffic modeling of university campus (May-June 2020)

In response to the request from the Binghamton University administration, we developed a high-resolution agent-based model of pedestrian traffic patterns on the Binghamton University campus (Sayama & Cao, 2020). As there was no direct behavioral data available, we developed a synthetic model of people's movements on campus utilizing several indirect datasets of Fall 2019, including: campus road/path networks (manually extracted from Google Earth); individual students' residence hall locations and class registrations (fully anonymized); course schedules and classroom locations; employees' office locations and FTEs; locations of food courts; bus arrival/departure frequencies; parking lot locations and occupancy rates; and others. The final model simulated detailed movements of more than 17,000 agents (individual students/faculty/staff and vehicles/buses) on a multilayer transportation network of roads and pedestrian pathways.

[1] https://vermontcomplexsystems.org/events/ALIFE-2020/
[2] https://www.robot100.cz/alife2021/
[3] Broome County COVID-19 Map: https://bit.ly/3vpFQn3

Figure 2: Agent-based simulation of pedestrian traffic on the Binghamton University campus. Left: Visualization of agent movements (green dots: individual agents; blue dots: vehicles; green discs: indoor space occupancies; blue discs: parking lot occupancies). Right: Heatmap showing the simulated density of close contact incidents. See (Sayama & Cao, 2020) for more details.

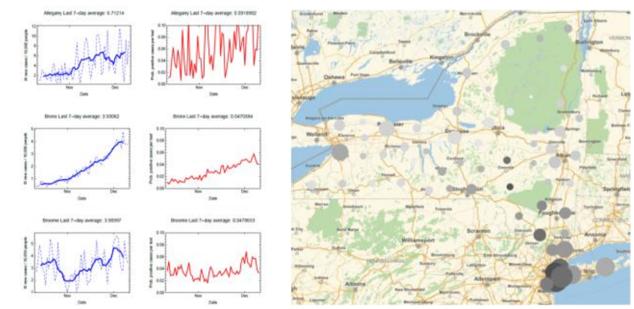

Figure 3: New York State county-level monitoring of COVID-19 activities. Left: County-by-county visualizations of the number of positive cases (blue) and positive test rates (red). Right: Geographical visualization of county-level COVID-19 activities (darker: higher) across New York State. Data are collected from the NYS Health Department website.

This model was used to predict where and when most close contacts would occur on campus and how much density reduction would be needed to suppress community infection (Fig. 2). The simulation results were reported to the University administration to help their campus reopening planning and communication with the campus community.

3. Epidemic modeling of university campus (June-September 2020) I also developed another high-resolution agent-based model of epidemic spreading on the campus student population to evaluate the effectiveness of various surveillance testing plans and to estimate the need for quarantine/isolation spaces.

4. New York State county-level COVID-19 activity monitoring (April 2020-present) In response to the request from the University President, I have been generating and reporting county-by-county visualizations of COVID-19 activities in New York State (Fig. 3). Such geographical visualizations help spatial understanding of the pandemic.

5. Nationwide/worldwide COVID-19 activity visualization (April 2020-present) Along the same line of the aim and motivation as in 4 above, I have been generating geographical animations of COVID-19 activities for the contiguous US and the world (Fig. 4) (Sayama, 2020b) and publicly releasing them via social media every week. The COVID-19 activity of each region is visualized according to the number of new positive cases (in size) and its epidemic stage (in color; red = growing, blue = shrinking; see (Sayama, 2020b) for more details). This has been featured in several international news outlets (DW News, 2020a/b; WELT, 2020; Seeker, 2021).

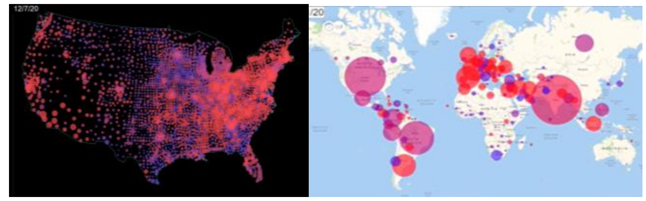

Figure 4: Snapshots of animations of COVID-19 activities within the contiguous US (left) and over the world (right). Disc sizes and colors represent the number of new COVID-19 cases and the epidemic stage, respectively. Data are collected from Johns Hopkins University COVID-19 data repository (Dong et al., 2020). See (Sayama, 2020b) for more details.

Lessons Learned

In these and other projects, many important lessons have been learned, which may be summarized as follows:

1. We should not consider what *ALife* can do as a discipline, but what *we* can do as skilled individual professionals.
2. Real situations are here and not in theoretical space.
3. Our knowledge about complex societal challenges is close to nothing, and therefore, we should always listen, learn, and collaborate.
4. We must particularly listen to and learn from professionals in the frontline; they are more expert than "experts."
5. There are so many constraints in the real world.
6. Things keep changing in a matter of days.
7. People need to make decisions, no matter what.

Finally, through these valuable learning experiences, I have also realized that we, as Artificial Life researchers, have several unique advantages when facing real-world complex societal challenges, as summarized below:

1. We have *advanced technical skills of modeling, simulation and visualization*, which are highly useful.
2. We are experienced with studying complex interactions among *heterogeneous agents* at multiple scales (including *mesoscopic scales* that are important for real-world applications).
3. We look at *spatio-temporal patterns* that are often ignored in other more traditional scientific domains.
4. We are inherently *interdisciplinary* and thus used to learning a broad range of topics and can understand values and difficulties of interdisciplinary collaboration.
5. We care about *specific details* of each situation, not just seeking generality or universality.

Combination of these properties shared among the members of the ALife community is quite unique and valuable, which I strongly believe have great potential to help address various complex societal challenges in the coming years.

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