Interactive visualization of complex systems for collaborative artificial life research

Inria Bordeaux, Flowers (Clément Moulin-Frier, Gautier Hamon) and Manao (Pascal Barla) teams.

Many systems that we encounter in Nature are self-organized and dynamic, and their study often reveals the emergence of highly-structured morphologies capable of complex behaviors evolved for survival in their environment. In the artificial world, cellular automata (CAs) are among the examples of widely-studied self-organizing systems. For instance, the artificial life (ALife) community has studied the emergence of spatially localized patterns (SLPs) in CAs, giving hints to the theories of the origins of life [3, 9]. Other types of artificial life systems study the emergence of collective behaviors from the local interaction of simple individual agents, e.g. bird flocks or ant colonies (Fig. 1). Beside their interest to simulate emergent phenomena observed in Nature, all these systems have also the ability to generate highly aesthetic dynamic patterns and could benefit from visualization and interaction methods used in Computer Graphics.

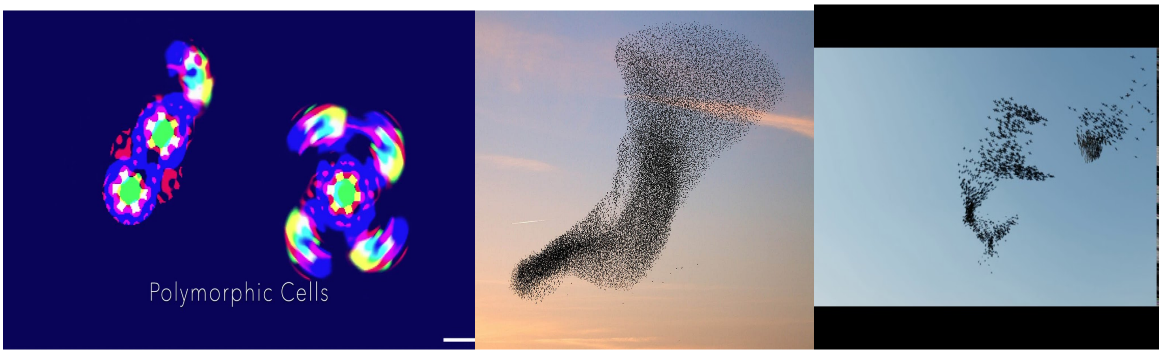

Fig 1. Example of natural and artificial complex systems. Left: SLPs in Lenia, screenshot from https://www.youtube.com/watch?v=HT49wpyux-k ; Middle: A flock of biological birds, from https://medium.com/@adityaananthram/algorithms-in-nature-part-1-e80e80b29719 ; Right: Example of a bird flock simulation, from https://www.youtube.com/watch?v=_5tJ8jwd64Y

In fact, research in ALife is currently experiencing an impressive revival thanks to the use of GPU acceleration for simulating large complex systems. In this context, a family of CAs called Lenia has been recently proposed [1,2,3], extending the standard CA paradigm to continuous time and space and allowing their simulation on multiple color channels and large grids. These systems can be executed on GPUs, either using parallel computing frameworks in Python (e.g. JAX, [4]) or web computer graphic libraries (e.g. WebGL, [5]). Finally, another trend of research in ALife proposes web interfaces allowing users to explore complex systems in a collaborative and open-ended manner [6, 7,8].

In this project, we propose to combine ideas and concepts from these recent trends to implement a software framework with three main objectives: (1) allowing fast simulation of large complex systems accelerated on GPUs ; (2) allowing to interact with the simulated system and to configure its visual aspects in real time through a web interface ; (3) providing tools to facilitate the evaluation, sharing, branching and merging of interesting patterns among different users.

In terms of implementation, a first goal will be to establish the most relevant combination of software components for such a framework. For instance, this could be a client/server structure where the server performs the complex system simulation in Python, then sends output data per time step via J-SON to a webGL client that runs in a browser. Then the three different aspects of the system will be dispatched among students for further development.

References

[1] BWC Chan, Lenia - biology of artificial life (2019).
[2] BWC Chan, Lenia and expanded universe (2020).
[3] Erwan Plantec, Gautier Hamon, Mayalen Etcheverry, Pierre-Yves Oudeyer, Clément Moulin-Frier, Bert Wang-Chak Chan; July 24–28, 2023. "Flow-Lenia: Towards open-ended evolution in cellular automata through mass conservation and parameter localization." Proceedings of the *ALIFE 2023: Ghost in the Machine* (pp. 131). https://doi.org/10.1162/isal_a_00651
[4] James Bradbury, Roy Frostig, Peter Hawkins, Matthew James Johnson, Chris Leary, Dougal Maclaurin, George Necula, Adam Paszke, Jake VanderPlas, Skye Wanderman-Milne, and Qiao Zhang. 2018. JAX: composable transformations of Python+NumPy programs. http://github.com/google/jax , https://jax.readthedocs.io/en/latest/
[5]Alexander Mordvintsev swissgl https://google.github.io/swissgl/#ParticleLife3d , https://github.com/google/swissgl
[6] Jimmy Secretan, Nicholas Beato, David B. D'Ambrosio, Adelein Rodriguez, Adam Campbell, Jeremiah T. Folsom-Kovarik, Kenneth O. Stanley; Picbreeder: A Case Study in Collaborative Evolutionary Exploration of Design Space. *Evol Comput* 2011; 19 (3): 373–403. doi: https://doi.org/10.1162/EVCO_a_00030 , https://nbenko1.github.io/#/
[7] Dirk Brockmann, 2023 Complexity Explorables https://www.complexity-explorables.org/
[8] Morphogen, artbreeder https://www.artbreeder.com/
[9] Beer RD. Autopoiesis and cognition in the game of life. Artif Life. 2004 Summer;10(3):309-26. doi: 10.1162/1064546041255539. PMID: 15245630.