Understanding the mechanisms that leads to Self-Organisation

Team: Krishna Kannan Srinivasan, Connor Harrigan, Jordan Donovan

One of the inspirations for this project is a problem that deals with controlling cellular robots using external electrochemical signaling fields. The cells of the African clawed frog, when manually assembled, exhibit self-organization and repair capabilities when divided at certain sections.(*3) We would like to use the natural dynamics of the cell in a directed manner to a desired target shape.

Cellular Automata is a useful representation to model local changes resulting in global behavior. In particular, the transition rules that exhibit interesting patterns from a given initial condition are very hard to find. This gets almost impossible for a continuous state CA. One of the ways this problem is modeled is using a neural network to model the transition rule.(*1). Using gradient based optimization techniques, the neural network learns the transition rule for a given target shape. One of the more interesting things is that the target shape becomes the stable attractor for the CA. We would like to understand the dynamics of continuous CA with respect to self-organization.

Based on some of the developments in modeling self-organization and morphogenesis models, we can try different representations, existing transition rules and initial conditions to observe the complex behavior.(*4) While the search for new rules and behaviour using neural networks and other search methods is interesting, modeling the tools and understanding the representation used to extract out self-organisation, and ways to direct the process, are topics we are interested to tackle in this project.

In order to model this problem, we can initially consider the continuous states of growth, and cell interaction. And to model cell interaction beyond the immediate neighbors as in the case of diffusion models, we can use graph CA representation(*2). And finally to go beyond the constant update rules for all particles in the CA, we can employ agent based models to simulate the individual cell behaviors with cell interaction, and growth models.

What we hope to accomplish:

1) Lenia offers us a platform to explore continuous state CA's that exhibit self-organization and other complex patterns. We can start to experiment with Lenia and direct our effort to modeling techniques covered in class.
2) We can investigate the stability of self-organization form.(*1)
3) Observe the sensitivity of the transition rule that leads to self-organization.
4) Observe the effect of cell-interaction models that drive self-organization.

References:

1) https://distill.pub/2020/growing-ca/
2) https://arxiv.org/abs/2110.14237
3) https://youtu.be/IahW47YILOg
4) https://chakazul.github.io/lenia.html