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Twitchy Cells

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1. INTRODUCTION

Led by Professor Shankar Srinivas in the Department of Physiology, Anatomy and Genetics at the University of Oxford, The Srinivas Group (Srinivas 2024) is studying the emergence of patterning and morphogenesis of the early mammalian embryo. In particular, they are looking at how concentrations of calcium ions activate contractions in cells, how they generate structured waves of contractions, and how these rhythmic motions lead to the development of the heart (Tyler et al. 2016).

The author was invited to collaborate with the Srinivas Group to develop a digital artwork inspired by their research. The aim is to create a work based on simulation of biological processes that could help promote discussion of ideas within the research group as well as with other researchers and the public.

2. IMPLEMENTATION

Rather than directly visualising the specific patterns of cellular contraction observed in mammalian embryos, the aim of this project has been to explore the wider range of emergent patterns that might be achieved using a naive simulation of cells that can contract and interact with their neighbours.

The initial implementation used the codebase that the author previously developed for his Cellular Forms work (Lomas 2014). This work explored the emergence of organic structure through simulation of growth by cellular division. The simulation system allows dynamic interactions between cells through forces such as electrostatic repulsion as well as linear and torsion springs and simulates the generation and exchange of chemicals that can affect cell behaviour.

For this work the initial configuration for the cells are points randomly distributed on the surface of a sphere and connected together as triangles using Delaunay Triangulation (Renka 1997).

Cells are triggered to contract when the level of a simulated chemical (the 'potential level') exceeds a specified threshold. When they contract, the rest length that is used for calculating spring force connections is reduced causing a localised contraction. When a cell contracts, its potential level is reset to zero and it increases the potential level in its immediate neighbours so that they may also be induced to contract. The aim is to enable the generation of structured waves of contraction where each cell can trigger its neighbours.

After contracting, each cell gradually expands back to its rest size using a simple decay rate parameter. The potential level in each cell also increases back to a rest value using another decay rate.

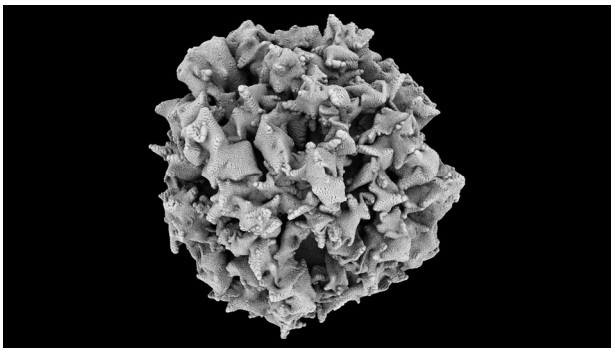

Figure 1: *Example form generated by Twitchy Cells*

The initial implementation using the Cellular Forms codebase was used to quickly develop a system that could be presented to the research group for discussion. This was enabled through the re-use of existing code for dynamic interactions between cells as well as for simulating chemical transfer between cells. However, the code is quite old and uses a GPU ray-tracer written by the author which is significantly slower than what can now be achieved using dedicated ray-tracing hardware, typically taking seconds to render each frame.

After reviewing the results with the research group, it was decided to implement a real-time version to

enable user interaction. This was achieved by re-implementing the system using CUDA for the simulation stages and NVIDIA's OptiX library (Parker et al. 2010) for optimised GPU ray-tracing using RTX hardware.

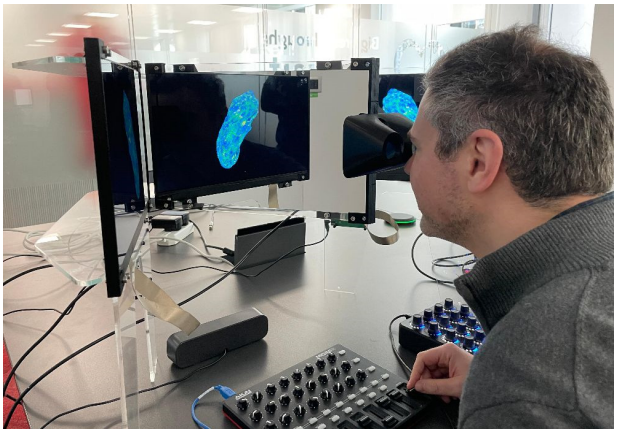

Figure 2: *Testing the interactive system using a custom Wheatstone 3D stereo viewer and MIDI controllers.*

To enhance user perception of how interactions affect the cells it was decided to explore sonification of the data generated by the simulation. Three different approaches to sonification were explored, which can be combined to create a richer structured sound:

- Mapping the potential levels in each cell to different frequency oscillators.
- Mapping the contraction level in each cell to different frequency oscillators.
- Physics-based sound synthesis using a damped spring system oscillator that is given an impulse every time a cell is triggered to contract.

3. RESULTS

Within the research group the work appears to be successfully generating discussion, in particular around what types of mechanism may be necessary for the emergence of patterns through cell movement, and what types of control are needed to guide those patterns to create desired structures.

One problem with the initial implementation was that a lot of fine tuning was necessary to create waves of contracting cells. The system appeared to have a critical threshold, below which a few cells would twitch randomly, and above which all cells would be over-stimulated in a storm of activity. To promote the generation of structured waves of activity it was decided to alter the system so that after each cell contracts there is a short period of time during which it has a reduced response to taking up potential chemical generated by its neighbours. This appears to work well, allowing a much wider range of parameter settings to generate structured waves of contractions. The research group thinks cells having a variable response like this is biologically justifiable.

Initial tests appear to show that the inclusion of audio significantly enhances user interaction, particularly through frequency changes that reflect the rate of cell activity. Members of the research group have also expressed a preference for lower frequency drone-like sounds reminiscent of heart beats.

We are looking to explore different ways of presenting the simulation results, including use of auto-stereo displays such as the Looking Glass Portrait, and custom Wheatstone 3D stereo viewers.

Next steps include testing with users in a number of contexts, such as pop-ups at the Department of Physiology, Anatomy and Genetics at Oxford as well as other venues such as EVA and the Oxford Science & Ideas Festival. In particular, we wish to explore a variety of different physical arrangements for presenting the work, as well as exploring what features of the simulation should be exposed to allow meaningful user interaction.

4. REFERENCES

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