Computation in the Wild: Reconsidering Dynamic Systems in Light of Irregularity

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Thesis Outline

Introduction

- Motivating example: Peak et al.'s plant cell stomatal coordination
- Metrics: Langton's λ and measures of robustness

Previous Work

- Motivation and Applications
  - Stomatal Patchiness
  - Inspiration for Novel Computing Models
- Criticality and the Emergence of Computation
  - Edge of Chaos
  - Metrics
- Robustness in Face of Irregularity
  - Redundancy in Decentralized Systems
  - Alternative Spatial Representations of CA (Penrose, Voronoi)
- Summary

Adapting Criticality Measures to Irregular Grids

- λ Rule Table Mappings to Irregular Grids
  - Preserving "directionality" with both Moore and von Neumman neighborhoods
  - Mapping variable neighborhood sizes to the fixed neighborhood sizes of λ rule tables
- Transition Rule Mappings to Irregular Grids
  - Conway's Life: weighting neighborhood influence by Euclidean distance or edge length
  - Mapping Local Majority and 2DGKL transition rules to variable neighborhood sizes

System Design

- Grid Generation
  - Control over density, periodicity, and orientation of generated grids
  - Delaunay Triangulation/Voronoi Diagrams
  - Penrose Tilings (Thin/Thick Rhombs and Kites/Darts)
  - Voronoi Quadrilaterals
  - Controlled Degradations of Grids

- Stencil Mapping
  - Translation between regular and irregular Rule Table Transitions
  - Orientation-Based Stencils
  - Distance-Based Stencils
- Simulation (Optimizations)
- Reference to Code?

Experimental Setup and Goals

- Voronoi Diagrams
  - GoL: Do we see an increased difficulty for supporting coherent Game of Life structures on Voronoi diagrams?
  - *Testing Interconnectivity: Are there differences in CA behavior on Voronoi grids simply due to different average connectivity or because of other properties?
  - *Equivalence Classes: Can some equivalence between neighborhood definitions of regular and irregular grids be established?
- Penrose Life
  - Can we replicate the results of Hill et al. and Owens and Stepney?
  - Are there discernible differences in CA behavior between periodic and aperiodic tilings?
- Majority Task
  - Do CA rule tables that solve the majority task on regular grids robustly still do so on irregular grids?
  - *Do the same effects of temporal and spatial noise Messinger et al. aiding task performance occur within the irregular grids?
- Lambda
  - Do we see sharp "phase transition" regions in lambda-entropy experiments on irregular grids similar to the results on regular grids?
  - What impact, if any, do boundary conditions (periodic vs. "dead") impact measurements of λ and entropy?

Results

- Majority Task
  - Initial results show that local majority task performance on irregular Voronoi diagrams are equivalent to local majority task performance on regular grids
- Penrose Life
  - Replication of Penrose experiments on both Kite/Dart and Thin/Thick Rhombus Penrose tilings agree with the results produced by Owens and Stepney
  - Initial results indicate both a quantitative and qualitative difference between Kite/Dart and Rhomb grids in terms of oscillating structures, ash, and average lifetimes
- Lambda
  - Replication of Lambda entropy experiments agree with results produced by Wootters and Langton
  - Lambda entropy experiments on irregular grids yield results that appear to correspond to behavior seen on regular grids

Discussion

- Quantitative Comparison between Irregular and Regular Grids
  - Impacts of variations of neighborhood size on task performance of cellular automata
  - Rough equivalence between regular grids and irregular grids in entropy, lambda measurements
- Robustness and Viability of Irregular Grids
  - Irregular grids handling "dead" boundary conditions
- Future Work

References

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[3] Susanna M Messinger, Keith A Mott, and David Peak. Task-performing dynamics in irregular, biomimetic networks. *Complexity*, 12(6):14–21, 2007.

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