Emergent Dynamics in Heterogeneous Life-Like Cellular Automata

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Some Motivation and Related Work

The well-known Game of Life has been studied extensively over the last decades.

Except for very specific conditions, it does not necessarily show open-ended behaviour. Furthermore, it is limited in its robustness. Extensions to GoL have begun to deal with that:
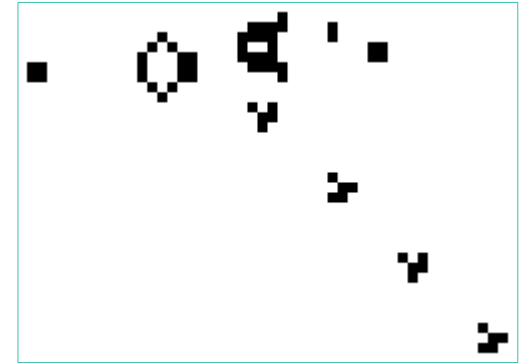
https://en.wikipedia.org/wiki/Conway's_Game_of_Life

- Genelife[1,2], HetCA (Heterogenous Cellular Automata)[3,4], SproutLife[5], evolife[6]

We are contributing a different framework, where aliveness and computation are conceptually separated:

Our Approach

The Game of Life has been extended in the following way:

> *Grid State*:
>> *Life-like rules*: Rather than the classical **B2/S23**, all variations of **B/S** are possible, totaling in 2×2^9 combinations.
>> *Heterogeneity* : Different cells can have different rules.
>> *Mutation and Inheritance*: At birth, the rules of a cell may be inherited with mutation from another cell in its neighborhood.
> We refer to the present rules as the *genotype* and to the resulting *grid state* as the *phenotype*

Our Approach

❯ *Cell State:*

   ❯ *Life-span:* After birth, each cell has a counter increasing over time, denoting its *Cell State* or *age*.
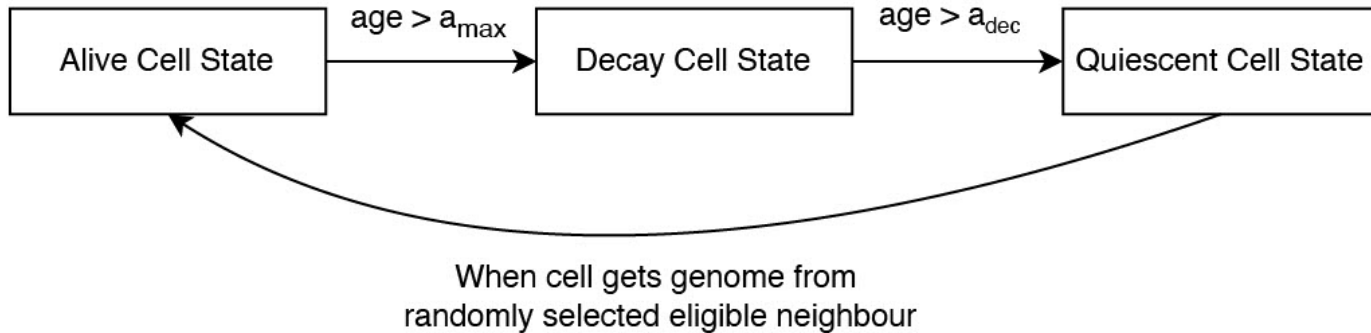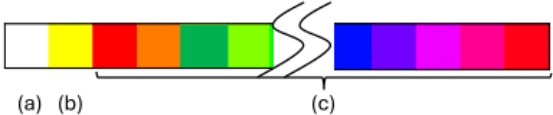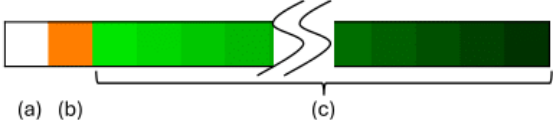

Figure: Life Cycle of a cell's *Cell State*

Table: Qualitative Phenotypic and Genotypic Measures

[YouTube video link](#)

Qualitative results for a_{max}=10, a_{dec}=15 on a grid size of 50x50

Measures

The behaviour of the Cellular Automata is measured both qualitatively and quantitatively.

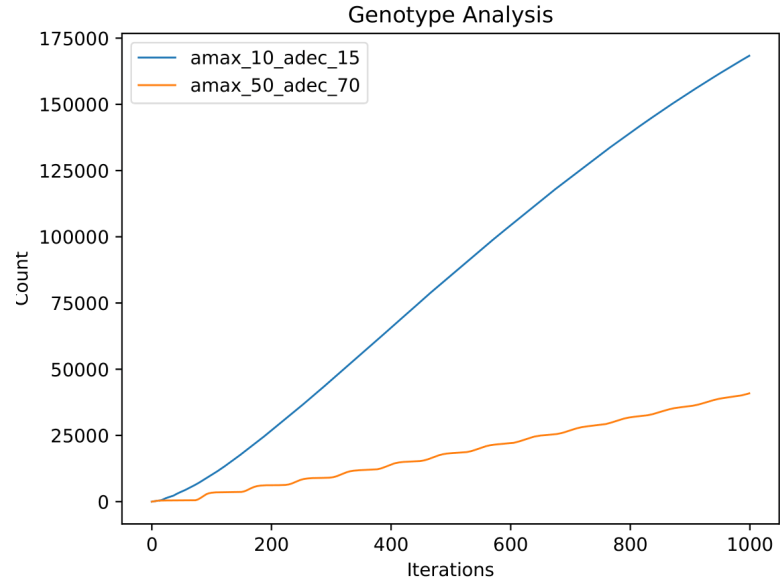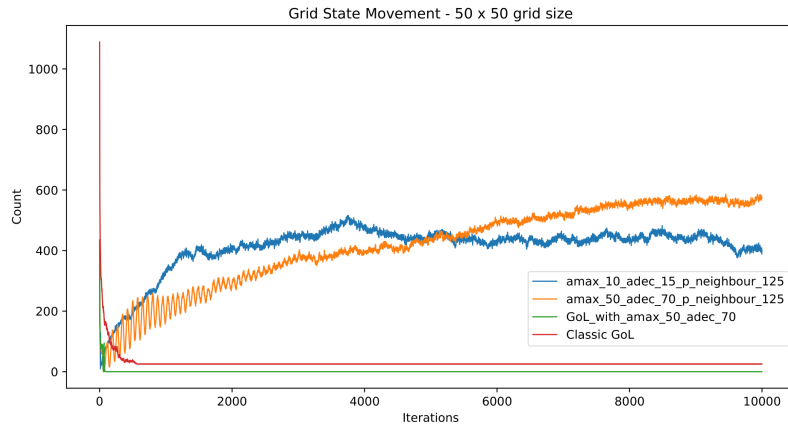| Measure |
| --- |
| Cumulative number of discovered rules |
| *Grid state* fluctuation |
| Number of alive, decay, and quiescent cells |
| Number of cells in state 0, 1, and quiescent |

Table: Quantitative Phenotypic and Genotypic Measures
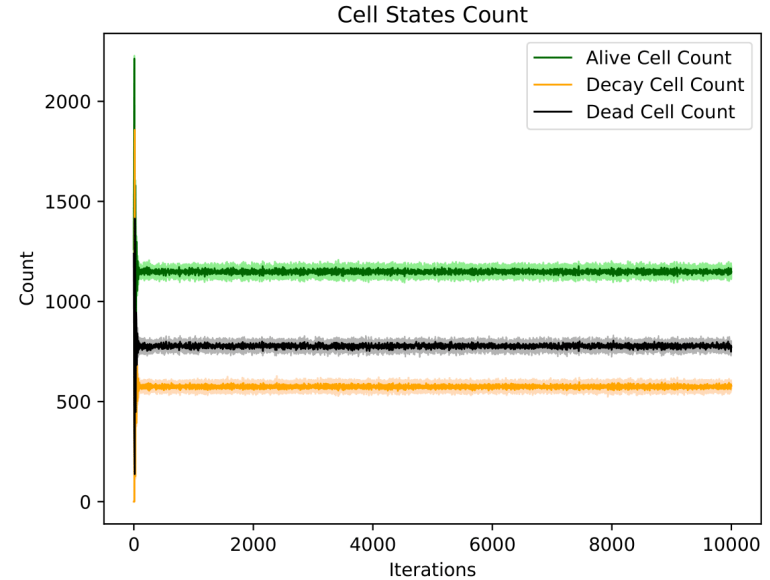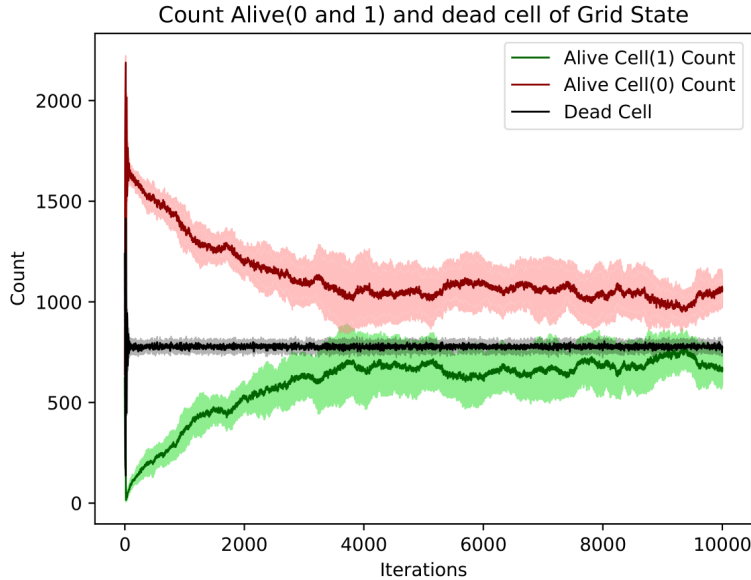
State counts for a_{max}=10, a_{dec}=15 on a grid size of 50x50, averaged over 10 runs

Fluctuations and exploration on a grid size of 50x50, averaged over 10 runs

> Oscillation, especially in the early iterations and a growing amount of state 1.

> Steadier, but still varying behavior of the grid states, state 1 is present throughout.

> A steady exploration of the genotypic space.

Long-term dynamics in the genotype and phenotype.
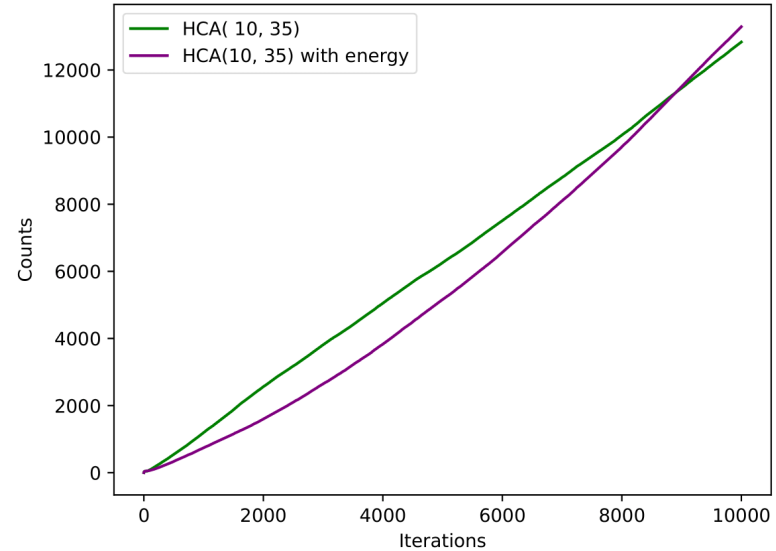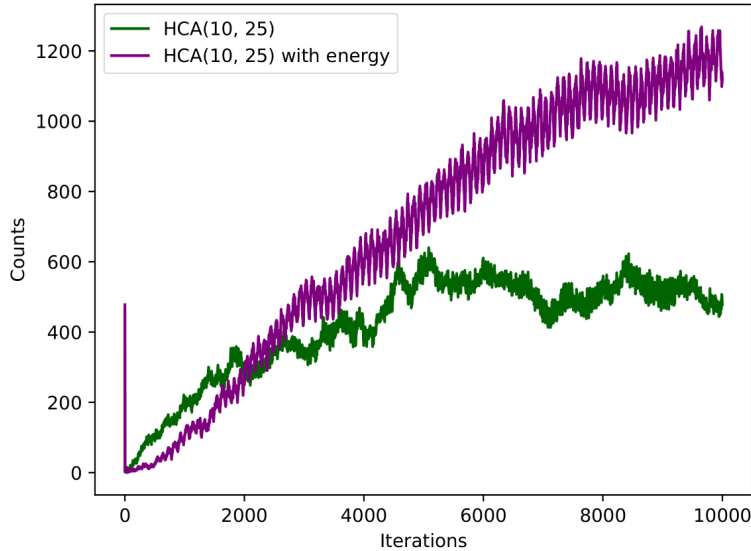
Fluctuation and exploration for a_{max}=10, a_{dec}=25 on a grid size of 100x100, averaged over 5 runs
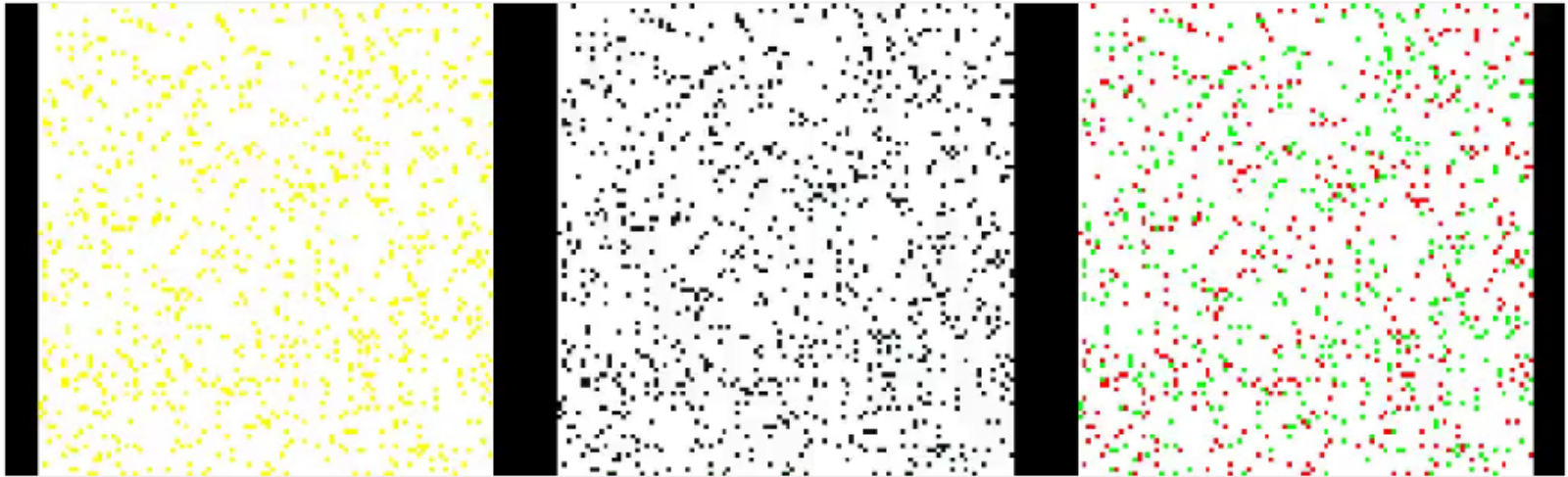
[YouTube video link](#)

Qualitative results for a_{max}=10, a_{dec}=25 on a grid size of 100x100

Questions?

References

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› Shapiro, A.: Sproutlife (2022), https://github.com/ShprAlex/SproutLife [Accessed: (June 2, 2024)]

› Zamaraev, A.: Evolife (2016), https://github.com/a5kin/evolife [Accessed: (June 2, 2024)]

Experimental Setup – Original Experiment

Parameter	Value
Eligible Cell State to Inherit Genomes	[Alive]
Probability Initial Alive Cell State	0.5
Probability Alive Cell State with Value 1	0.5
Inheritance Probability	0.125
Mutation Probability P_{mut}	0.2
a_{max}	10, 50
a_{dec}	15, 70
Initial Rule	B3S23

Experimental Setup – Original Experiment

Parameter	Value
Eligible Cell State to Inherit Genomes	[Alive]
Probability Initial Alive Cell State	0.1
Probability Alive Cell State with Value 1	0.5
Inheritance Probability	0.125
Mutation Probability P_{mut}	0.02
a_{max}	10, 50
a_{dec}	15, 70
Initial Rule	B3S23
Energy Parameter	**Value**
Energy	25
Energy Depletion Per Iteration	1
Energy Distribution Ratio	0.02
Energy Interval	50

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