

AssemblyCA: A Benchmark of Open-Endedness for Discrete Cellular Automata

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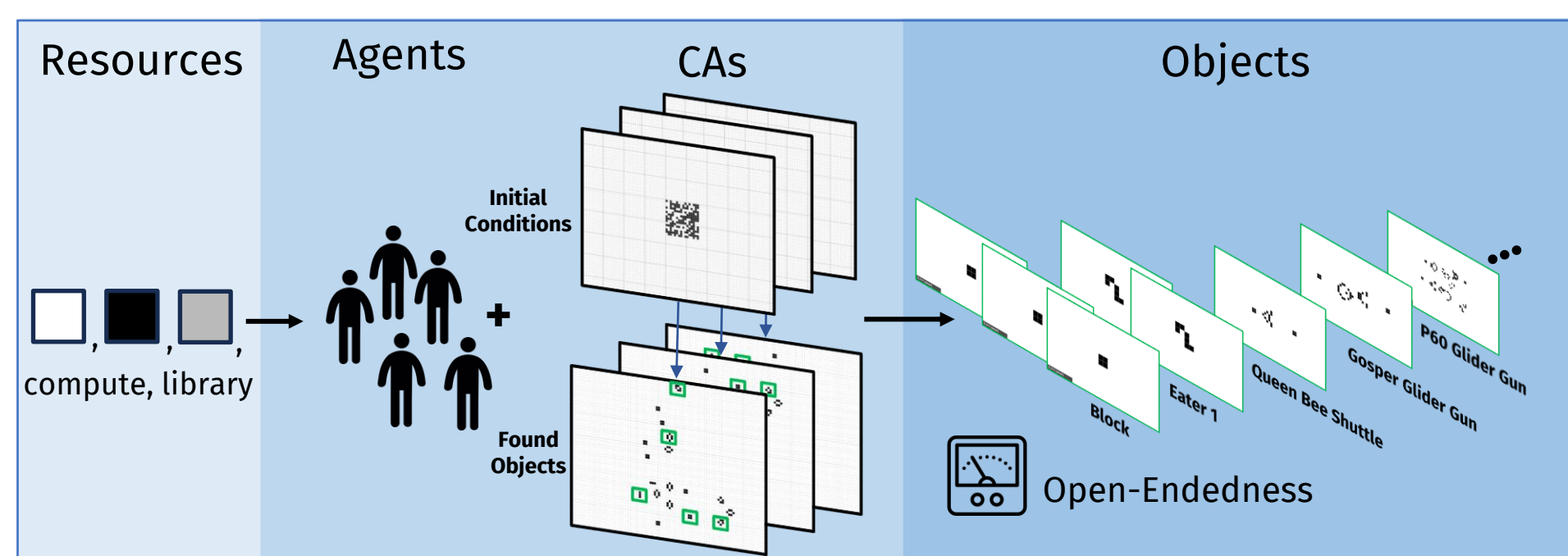


Motivation

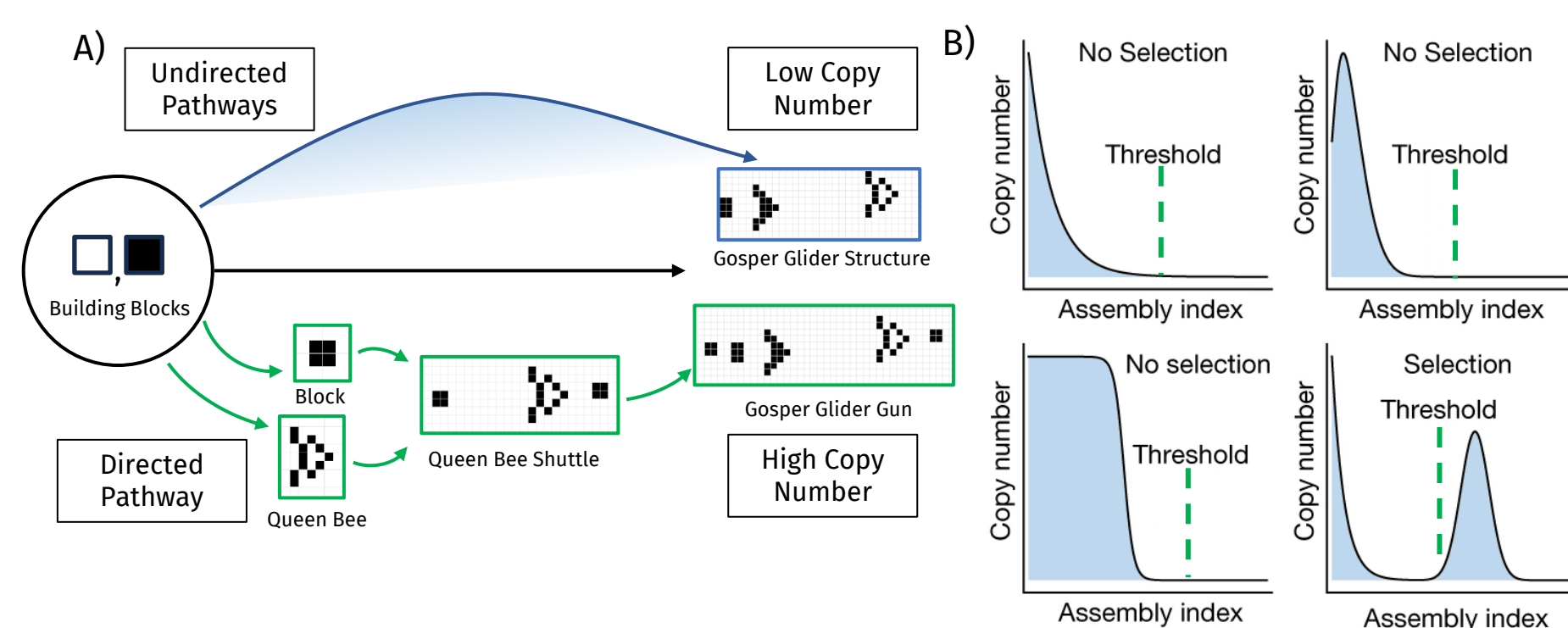
- There is no consensus procedure to characterize whether a set of agents are undergoing open-ended evolution.
- The measures of open-endedness (OE) as diversity or complexity ignore historical contingency of the objects, which is a prerequisite for OE.
- None of the OE measures are suited for dynamic patterns like cellular automata (CA).
- A benchmark for complexity generation facilitates robust advancements in open-ended learning

Introduction

Consider a set of agents able to modify CA initial conditions and execute them to find objects. These agents execute a CA and insert black, white, or higher-level cells on this CA, or modify already found patterns to find new patterns in the output. The obtained objects by these agents are quantified by their assembly space and the number of copies found by each agent.

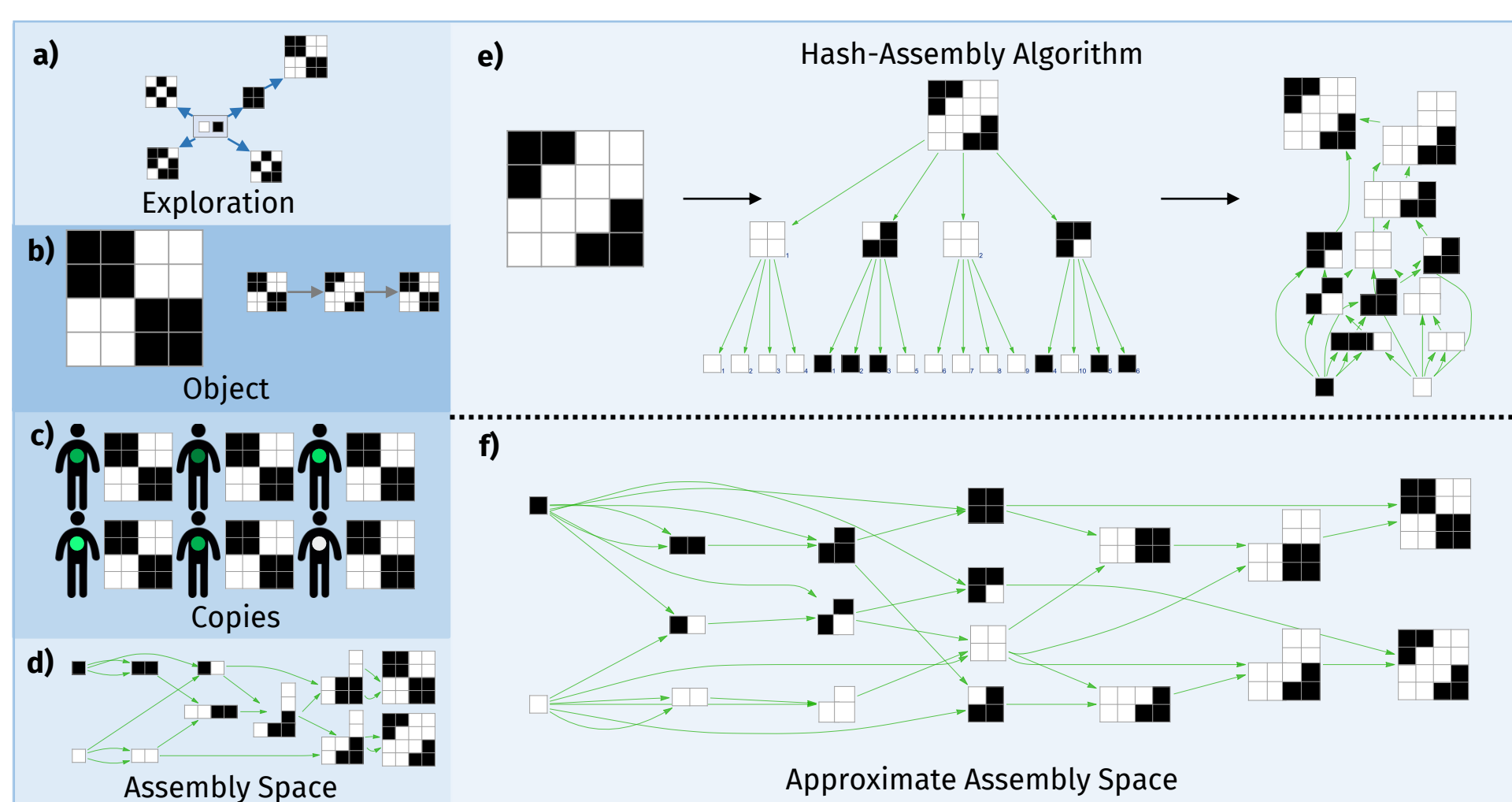


AT(assembly theory) quantifies the amount of selection needed to build complex objects abundantly. Given a pool of building blocks and lower complexity objects a system that explores the object-space with an undirected process is not selective, when this occurs complex objects are produced in low number. On the other hand, a directed process is one that utilizes already build objects to generate complex objects in high numbers.



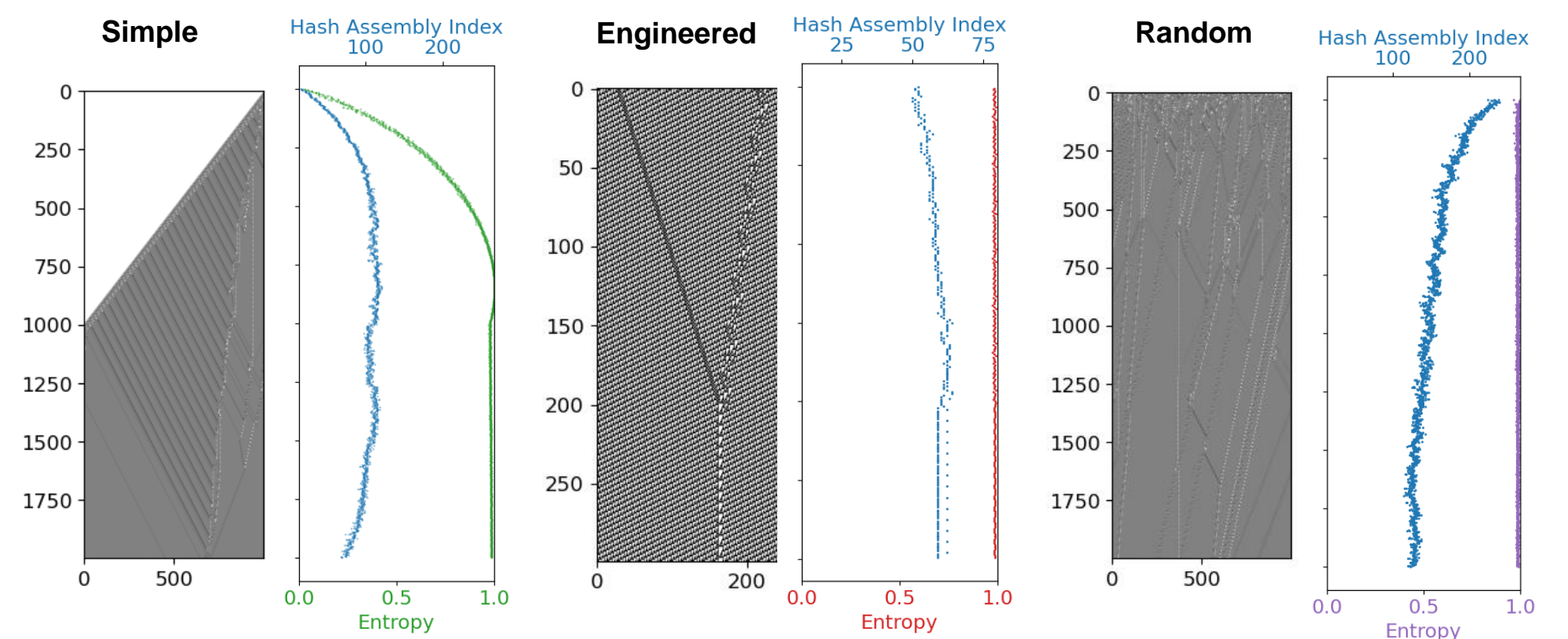
Benchmark

The assembly theory quantities are defined and approximated in a CA.



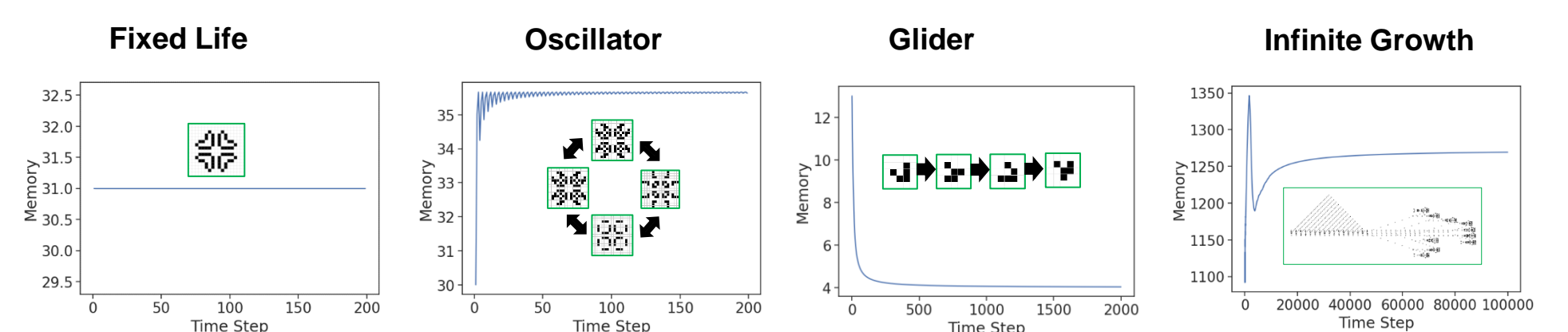
Testing

The time evolution of a one-dimensional CA is compared looking using the tools from information theory and assembly theory.



Results

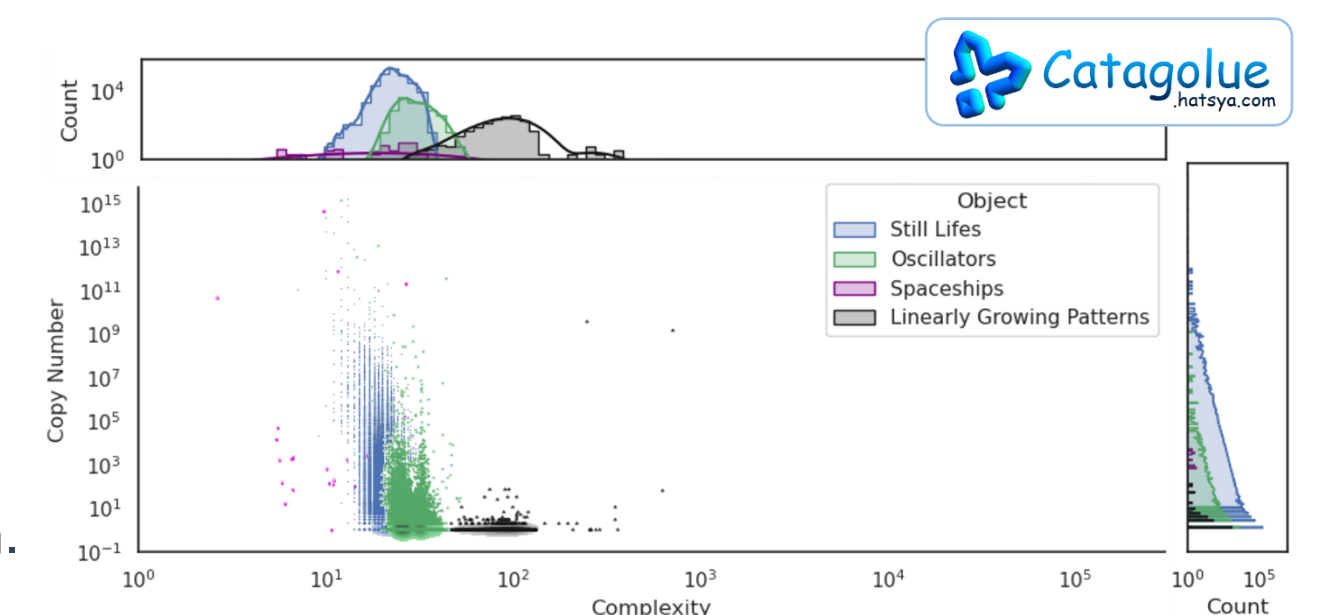
Memory or complexity over time-step is computed for several patterns with different dynamical behaviors. We see that the complexity measure can characterize objects with vastly different stability timescales.



Three experiments were performed with the aim of showing systems with different degrees of open-endedness:

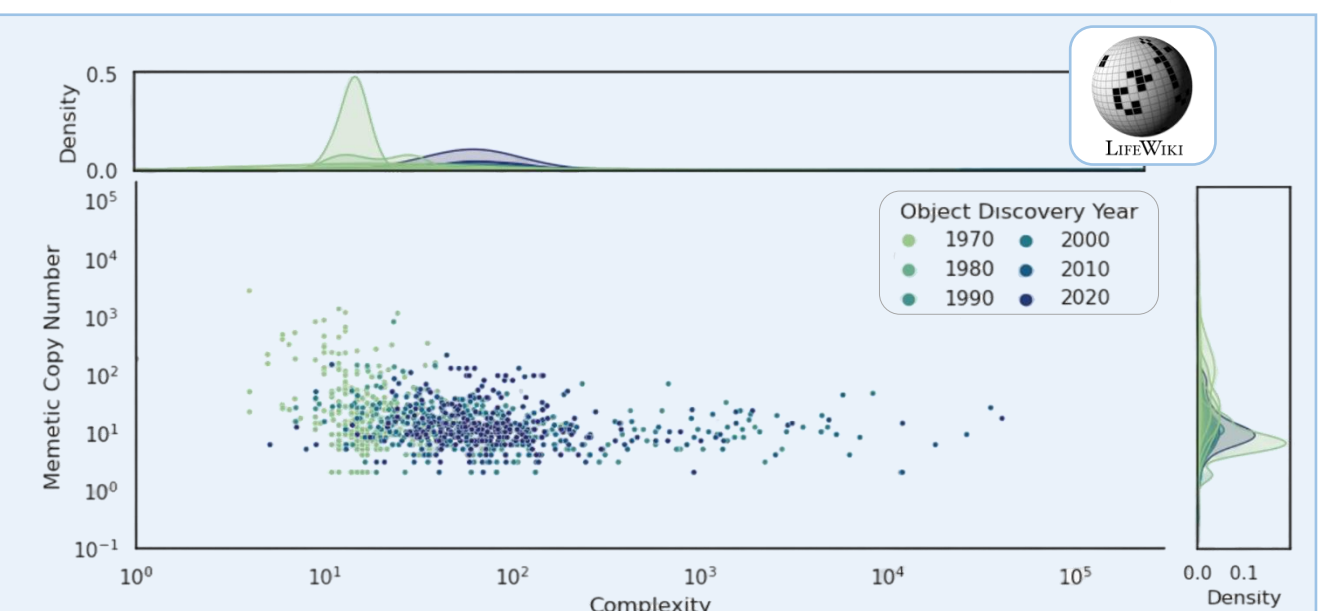
Undirected Process:

Soup searches where initial conditions are set at random, and objects are found when the CA has reached stabilization.

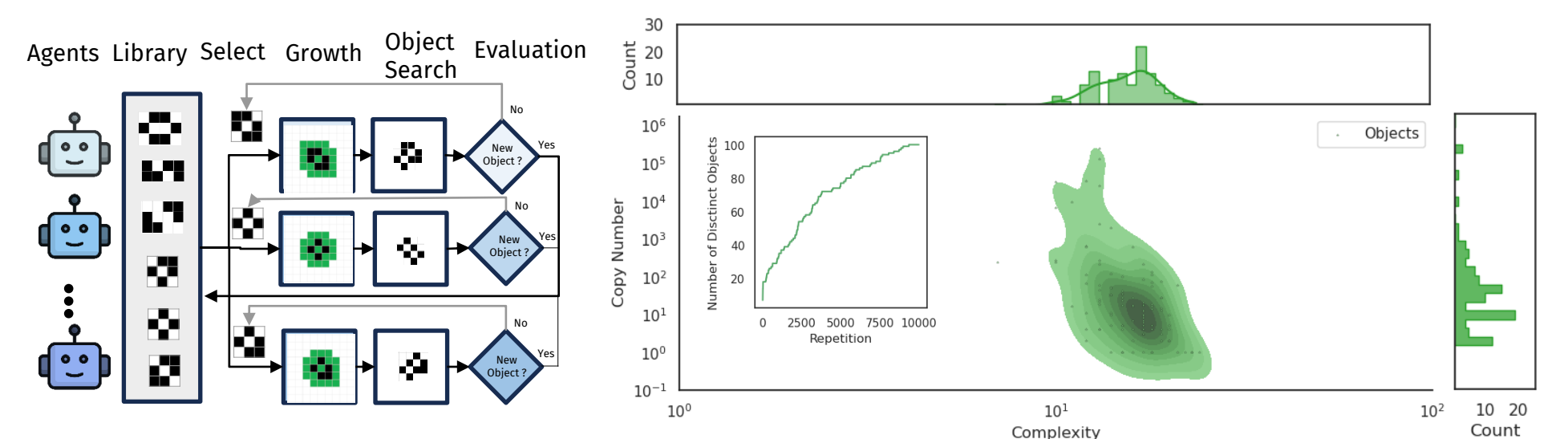


Open-Ended Process:

Objects found by the community of Game of Life CA practitioners in the 50-year collection of the LifeWiki database.



Algorithmic Process: A group of agents search for novel patterns given a starting library. They select a random object, modify it and search for new patterns. If a new pattern is found it is added to the library.



Conclusions & Future Work

- The benchmark is a good proxy of the intuitive idea of unlimited complexity and novelty of an open-ended system.
- The assembly measures can characterize historical contingency unlike other measures of complexity.
- The benchmark can classify systems as more or less Open-ended.
- Future work aim to develop elaborate agents that can discover CA objects in an open-ended way, such as LLM-based CA object explorers.



References

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