We generate a **formal representation** of all possible **states** and **state transitions** of AI **agents interacting** on a **grid**

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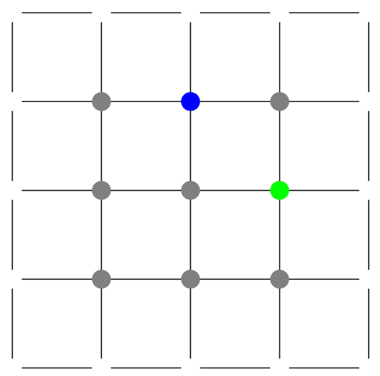
Abstract

Gridworlds are a popular and powerful test-bed for artificial intelligence (AI) algorithms, especially in reinforcement learning and associated AI safety problems. To describe how AI agents behave in such gridworlds, we consider gridworlds as reconfigurable systems and construct their state complexes. These state complexes reveal the underlying structures and patterns in the system's possible reconfigurations. This work incorporates the concepts of gridworlds, reconfigurable systems, and state complexes to show structures and patterns found in the state complexes of example gridworlds.

Gridworlds

● agent ● object ● floor ○ wall



Gridworlds are simplified, grid-like environments in which each *cell* of the grid may be assigned a *label*. In the example above, these labels are agent, object, floor, and wall. Such environments can be used to test and develop AI algorithms, particularly in reinforcement learning (1).

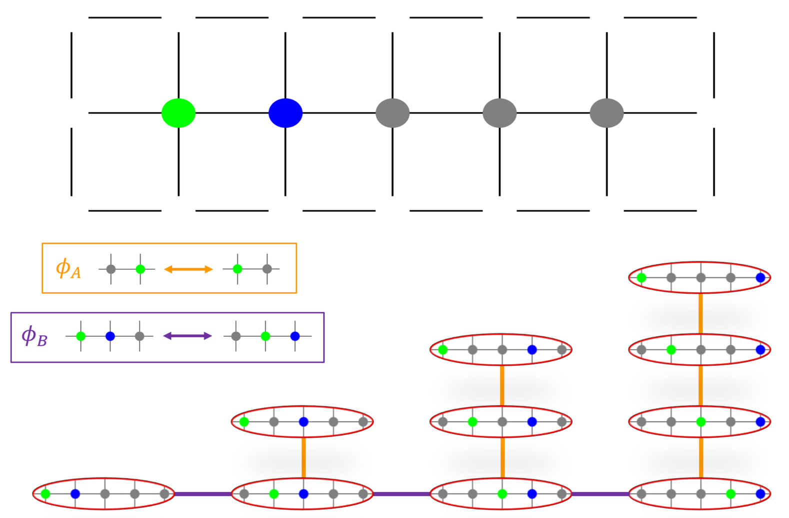
Reconfigurable Systems

Ghrist & Peterson (2) define reconfigurable systems as a collection of labels on a graph, where local rearrangements of the labels represent reconfigurations of the system.

From (2): G is a graph. A is a set of possible labels on the vertices of G.
A *generator* ϕ is a collection of three objects:

- the *support*, $SUP(\phi) \subset G$
- the *trace*, $TR(\phi) \subset SUP(\phi)$
- a *relabelling* for the vertex set $TR(\phi)$

State Complexes

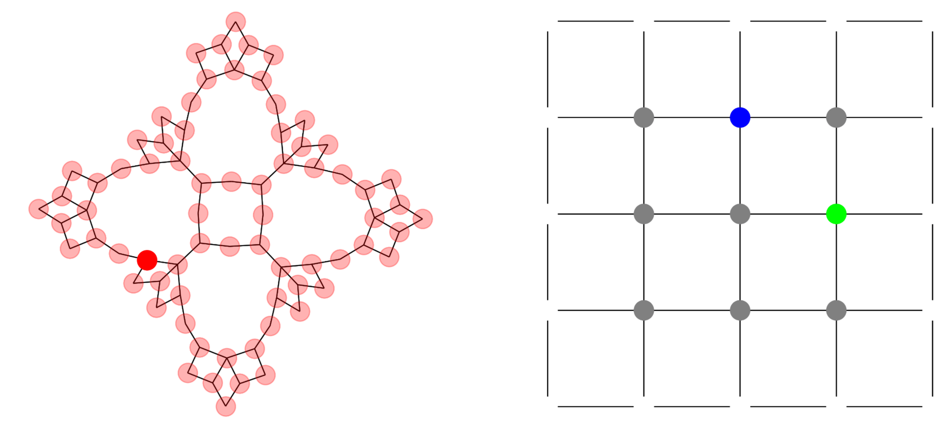


Ghrist & Peterson (2) define a state of a reconfigurable system as a choice of labels (chosen from A) for every vertex of G.

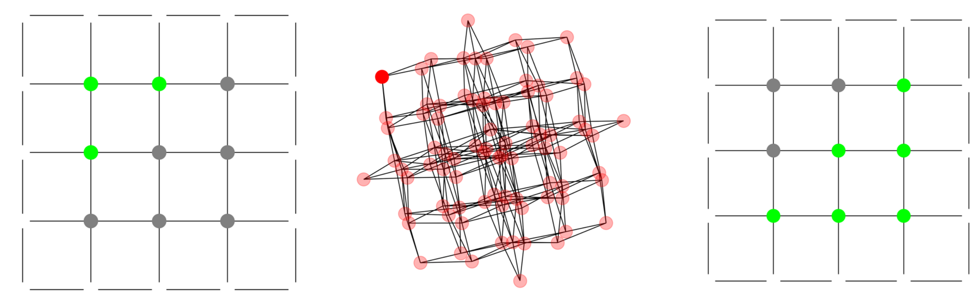
$$s_i : V(G) \to A$$

The state complex S is a graph with vertices corresponding to states, with edges connecting a pair states differing by a single generator.

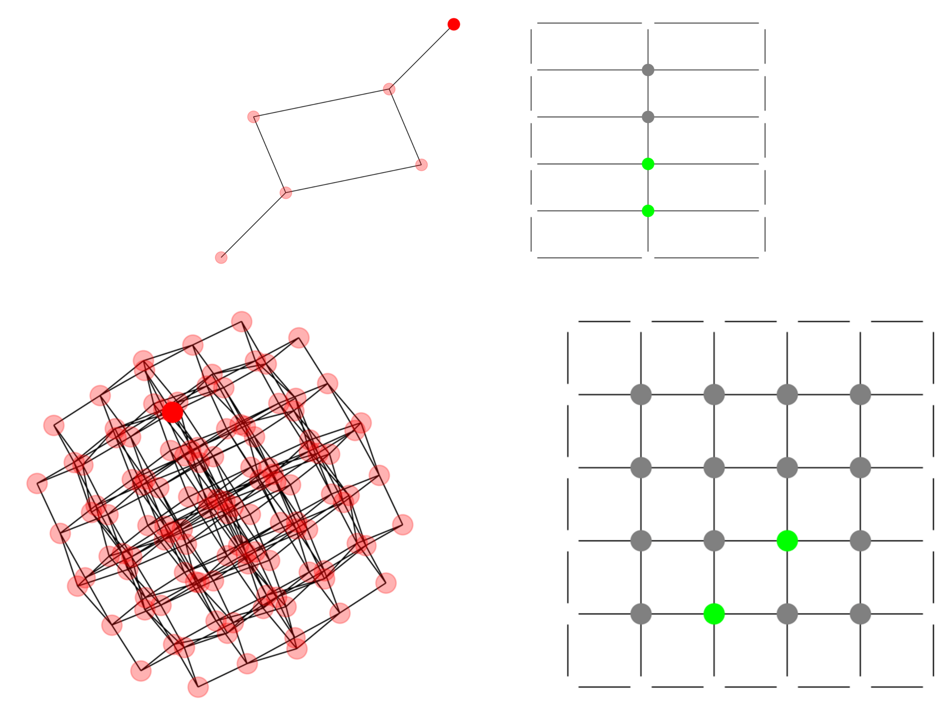
S.C.s of Gridworlds



State complexes often capture symmetries in a gridworlds' geometry or labelling, as shown in these examples. The petal-like state complex above shows different scales of geometry; for each position of the object there exists a subgraph of 8 verticies (representing the 8 possible locations of the agent) which is connected to as many other subgraphs as is possible for the agent to push or pull the object to a different location from the current location represented in that subgraph.



We also find that some state complexes are subgraphs of others.



Future Research

We are currently exploring patterns and theoretical aspects of state complexes that hold across gridworlds of arbitrary size, geometry, and labelling. For example, an upper bound for the total number of states of a gridworld without objects is $\binom{n}{k}$ where n is the total number of non-floor and non-wall labels and k is the total number of agent labels. Such information may be useful to incorporate into AI algorithms or for analysis of the efficiency, accuracy, or safety of such algorithms in gridworlds.

References

(1) J. et al. Leike. AI safety gridworlds. *arXiv*, 1711.09883, 2017.

(2) R. Ghrist and V. Petereson. The Geometry and Topology of Reconfiguration. *Advances in Applied Mathematics*, 38(3):302–323, 2007.

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