A Distributed Multi-Layered Cellular Automata Approach to the Hierarchical Structural Organization of Multi-Robot Systems

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Abstract

In previous work, we applied single and multi-dimensional cellular automata to robot formation control and provided an extensive classification of structures that can be represented by the approach (Mead et al. 2009). We now consider a new category of physical organization—hierarchical structures. Such complex structures are those that can be decomposed into subcomponents that have their own structural specifications (which can also be further decomposed) and physical relationships to one another.

We represent the i^{th}-layer of an n-layer structure ($0 \leq i \leq n$) as a cellular automaton, and represent each subcomponent (a complex substructure or an atomic unit) of that layer as a cell within the automaton. The state of each cell is governed by a strict set of rules that pertain to the spatial relationships the cell must establish and maintain with neighboring cells. If a cell is a substructure (as opposed to an atomic unit), it forms a disjoint cellular automaton in the (i^{th} - 1)-layer; that is, if an automaton in i^{th} layer contains M cells, and m of those cells are substructures, then that automaton will require m disjoint automata in the (i^{th} - 1)-layer. A single cell in each automaton is designated as a *seed*; this cell accumulates and processes state information within its automaton (using the approach described in Beer et al. 2010), and sends it to the corresponding cell in the layer above it, thus, representing the state of that cell. Each cell state contains information regarding discrepancies in desired and actual relative component poses; by correcting for these physical errors, the desired overall structure can be formed (Mead 2008).

Hierarchical organizational structures could be applied to multi-array Space-Based Solar Power or even marching bands (Mead 2008); however, the approach is not limited to formation control. For example, multi-component modular or reconfigurable robots could also be specified and constructed. This layered cellular automata method seeks to establish a novel class of complex multi-robot coordination.

References

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