Temperature 1 Simulation of Temperature 2 aTAM Systems using Active Tiles

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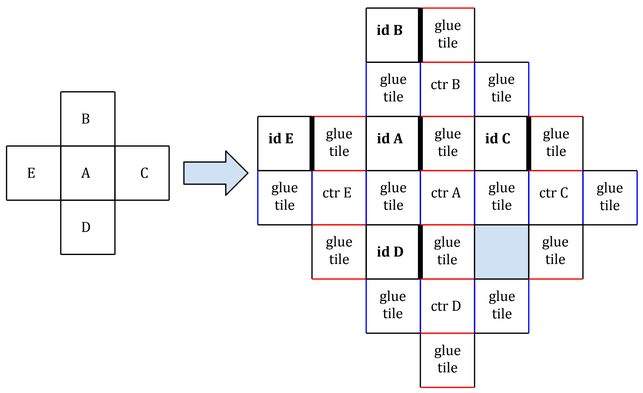
Abstract

The standard abstract Tile Assembly Model (aTAM) in 2D can be augmented to Active aTAM by allowing the presence of inactive binding sites and signal pathways on tiles: binding sites that are activated only by attachment to a corresponding signal-carrying tile [2, 4]. We note that the physical realization of DNA based tiles with such a signaling mechanism has been confirmed experimentally [3]. The active 2D tile assembly model admits Turing universal computation at temperature 1 (not yet confirmed for the 2D aTAM though known to hold for temperature 2 [5]). We establish a direct comparison between the aTAM and the Active aTAM: we show how to construct a 2D temperature 1 active tile assembly system that simulates the dynamics of a given 2D temperature 2 standard (aTAM) tile assembly system. The simulating system preserves the relative geometry of the original tile assemblies but doubles their size (in each of the two dimensions).

The Intuitive Idea



The aTAM tile assembly on the left is “simulated" in the Active aTAM on the right; heavy lines indicate sites of attachment between two tiles; blue and red lines indicate presence of active but not necessarily matching binding sites; thin black lines indicate the absence of any binding sites. The identity of the original tile is encoded in the upper left corner, outside its “body,” which consists of a center tile that directs signal transmission (signals not shown) and to which four tiles representing glue labels are attached. The glue label tiles are, in fact, shared between the tile and its neighbor on a given side, thus creating an overlapping net representing the original tiling. If there is a mismatch in the simulated tiling between adjacent labels, the corresponding location in the simulating tiling will contain a label tile corresponding to one of the two labels (the particular one determined by the order of the assembly process).

References

[1] N. Jonoska and D. Karpenko Active Tile Self-Assembly, Part 1: Universality at Temperature 1, *International Journal of Foundations of Computer Science*, to appear.

[2] N. Jonoska and D. Karpenko Active Tile Self-Assembly, Self-Similar Structures and Recursion. *Available on Arxiv:* `http://arxiv.org/pdf/1211.3085v1.pdf`

[3] J. E. Padilla, J. Chen, N. Jonoska, and N. C. Seeman, A Signal-Passing DNA Strand Exchange Mechanism for the Active Self-Assembly of DNA Nanostructures, in preparation.

[4] J. Padilla, M.J. Patitz, R. Pena, R.T. Schweller, N.C. Seeman, R. Sheline, S.M. Summers, and X. Zhong. Asynchronous Signal Passing for Tile Self-Assembly: Fuel Efficient Computation and Efficient Assembly of Shapes. UCNC 2013, LNCS 7956 (2013) 174–185.

[5] E. Winfree. Algorithmic Self-Assembly of DNA. *Ph.D. Thesis. California Institute of Technology* (1998).

Acknowledgement

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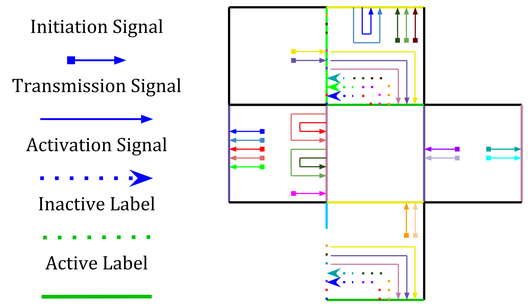
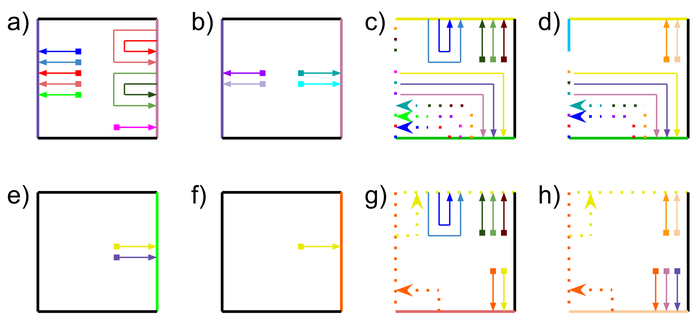
Legend and Example Fit

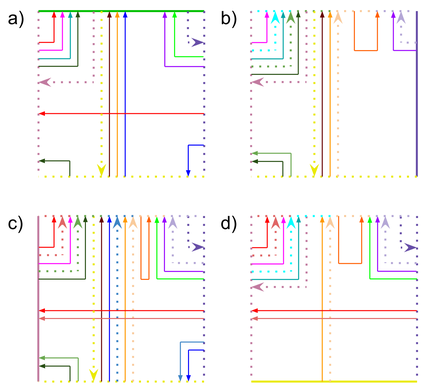


Key Tile Types



a) horizontal strength 1 label tile: contains only two active labels ($+x$ and $-x$ sides); the signals sent to the left check for all possible collaborations with $-y$, $-x$, and $+y$ neighboring label tiles; the signals sent to the right check for all possible collaborations with a $+y$ neighboring label tile on the other side; the looping signals confirm attempted collaborations from its label tile neighbors on the right. **b) horizontal strength 2 label tile:** initiates signals to the left and right indicating its identity. **c) vertical strength 1 label tile:** has two active labels ($+y$ and $-y$ sides), initiates signals to check for collaborations with all possible $-x$ and $+y$ neighboring label tiles and confirms signals from potential $+x$ neighbor label tiles. It also transmits all possible collaborations of its neighbors to its $-x$ side (as indicated with inactive labels) and transmits signals sent by the identity tile (shown in e)). **d) vertical strength 2 label tile:** functions analogously to b) and c). **e) identity tile** resulting from the collaboration of $+x$ and $+y$ strength 1 label tiles: corresponds to a unique tile in the simulated set and sends signals to the center tile to activate the remaining $-x$ and $-y$ sites with labels corresponding to the appropriate sites on the simulated tile. **f) decider-identity tile:** paired uniquely with some decider tile (such as in g) or h)). **g) decider tile** resulting from the collaboration of $+x$ and $-x$ strength 1 label tiles and representing a strength 1 $+y$ label; **h) decider tile** resulting from a $-y$ strength 2 label tile and representing a strength 2 $+y$ label. The decider tiles perform the function of an identity tile and the $+y$ label of the corresponding simulated tile whenever a center tile is missing a label tile on its $+y$ side.

Center Tiles



Each of the center tiles is paired uniquely with some label tile, as indicated by a single active label on one of their sides. The inactive $+x, -y, -x$ tile sides can be activated via signals from an identity tile. The $+y$ tile sides in b), c), and d) contain inactive labels for all possible decider tiles.

Example Simulation