

Particle Logic 2.0

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Abstract— This introduces the first *pizza problem*, an challenge of unknown complexity that is accessible to all lab members. A successful completion of one part of this problem entitles the solver and a guest to a free tutorial and meal at Prof. Becker’s home – learn how to make hand-tossed pizza!

In previous work [1], [2], [3], [4], our lab showed the computational universality of swarms of micro- or nano-scale robots in complex environments, controlled not by individual navigation, but by a uniform global, external force. Consider a 2D grid world, in which all obstacles and robots are unit squares, and for each actuation, robots move maximally until they collide with an obstacle or another robot. We demonstrated components of *particle computation* in this world, designing obstacle configurations that implement AND and OR logic gates: by using dual-rail logic, we designed NOT, NOR, NAND, XOR, XNOR logic gates. With the help of 2×1 robots we designed FAN-OUT gates, which is necessary for simulating the full range of complex interactions that are present in arbitrary digital circuits. Using these gates we are able to establish the full range of computational universality as presented by complex digital circuits. As an example we connect our logic elements to produce a 3-bit counter. We also demonstrated how to implement a data storage element.

The following are open projects for our lab:

- 1) our current memory element is not good enough for a journal submission. It is not conservative. I’d like to represent state (true or false) by the position of a 2×1 slider. This slider may require more than 1 CW cycle.
- 2) a collection of obstacles and 2×1 sliders that work as a one-cycle delay:

OUTPUT: every other CW cycle a 1×1 block comes out. Currently we get a new compo-

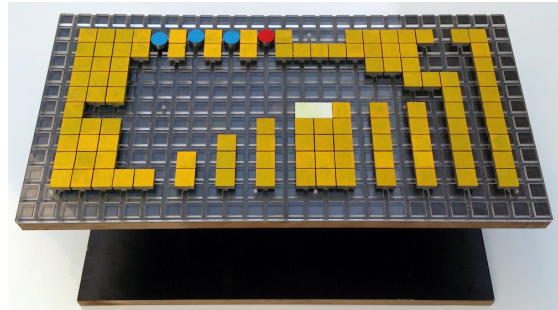


Fig. 1. Gravity-fed hardware implementation of particle computation. The reconfigurable prototype is setup as a FAN-OUT gate using a 2×1 robot (white). This paper proves that such a gate is impossible using only 1×1 robots. See the demonstrations in the video attachment <http://youtu.be/EJSv8ny31r8>.

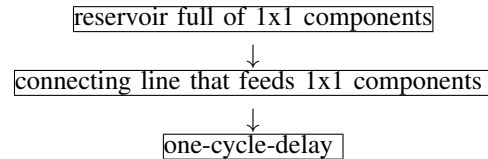


Fig. 2. a collection of obstacles and 2×1 sliders that work as a one-cycle delay

nent every CW cycle. We’d like to get one every other cycle, or concatenate these to get a 1×1 output every n cycles.

- 3) *Preferential Assembly* Add tiny magnets to some of the edges of the sliders so that sliders preferentially assemble if two sliders with mating arrangements hit each other.
 - how many *species* or *slider varieties* can we construct?
 - our round sliders rotate, and don’t have preferential orientations. We could weight one side of the sliders. Could octagonal sliders work in our present system? Would they rotate?

- 4) Develop theory showing that we can use a CW cycle and deliver a polyomino part to a destination, and then with another CW cycle hit this part at an arbitrary location with an additional 1x1 part. I want to show that we can build arbitrary shaped polyominoes, or prove that certain shapes cannot be constructed. For instance, using our sliders with magnets, can we construct an ‘o’-shaped arrangement using eight 1x1 sliders?
- 5) read about [Sandor’s aTAM theory](#) and see if anything practical can be made of it.

REFERENCES

- [1] A. Becker, E. Demaine, S. Fekete, G. Habibi, and J. McLurkin, “Reconfiguring massive particle swarms with limited, global control,” in *International Symposium on Algorithms and Experiments for Sensor Systems, Wireless Networks and Distributed Robotics (ALGOSENSORS)*, Sep. 2013.
- [2] A. Becker, E. Demaine, S. Fekete, and J. McLurkin, “Particle computation: Controlling robot swarms with only global signals,” in *IEEE International Conference on Robotics and Automation (ICRA)*, 2014.
- [3] A. Becker, E. D. Demaine, S. P. Fekete, G. Habibi, and J. McLurkin, “Reconfiguring massive particle swarms with limited, global control,” in *Algorithms for Sensor Systems*, ser. Lecture Notes in Computer Science, P. Flocchini, J. Gao, E. Kranakis, and F. Meyer auf der Heide, Eds. Springer Berlin Heidelberg, 2014, pp. 51–66. [Online]. Available: http://dx.doi.org/10.1007/978-3-642-45346-5_5
- [4] H. M. Shad, R. Morris-Wright, E. D. Demaine, S. P. Fekete, and A. T. Becker, “Particle computation: Device fan-out and binary memory,” in *IEEE International Conference on Robotics and Automation (ICRA)*, 2015 (under review).