

## Quantum-Dot Cellular Automata

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"Quantum-Dot"  
Bentley

## Domino Rally!



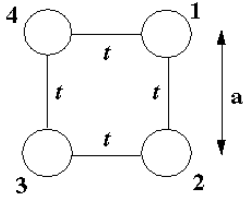
## Fundamentals

- Think building blocks
- Uses arrangements of individual electrons rather than currents and voltages.
- "Compatible with nanostructure computing"....right of course.

## My Computer



## The Fundamental Cellular Unit



- Four quantum dots are positioned at the corners of a square.
- What's a quantum dot?
- Dots are ~20 nm diameter.
- Two electrons are put into the system. They can tunnel between the dots.
- What is tunneling?
- Electrons will occupy opposite corners due to simple Columbic repulsion.
- Must be cooled so tunneling isn't spontaneous.

## Binary Action

- $P = +1$  represents 1
- $P = -1$  represents 0

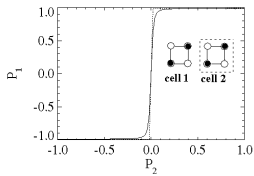


$P = +1$



$P = -1$

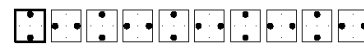
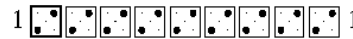
## Cell on Cell Action



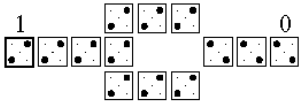
- The cells flip the adjacent cells.

## “Wires” based on these cells

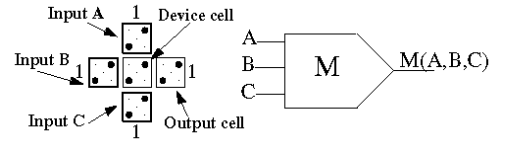
- Different models depending on cell orientation.



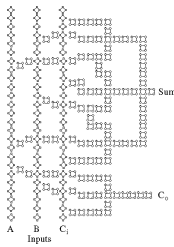
## Inverter



## Majority Gate (AND / OR gate)



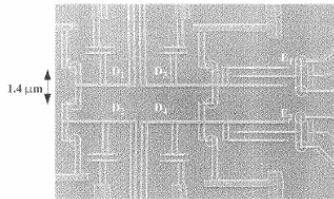
## The Full Adder



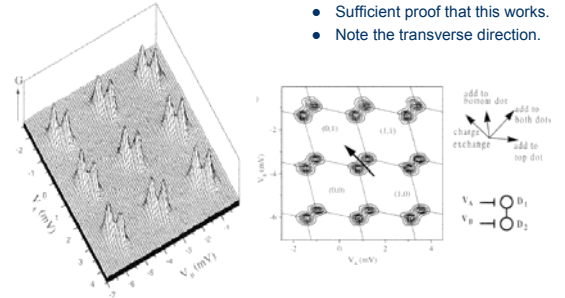
## Input - Output

- Capacitors repel or attract electrons into the desired holes.
- Sensors, made from ballistic point-contacts and from quantum dots themselves
- Only needed at the edge of the array.

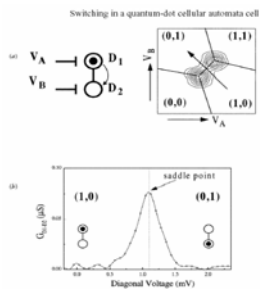
## The Real Thing



## The Input

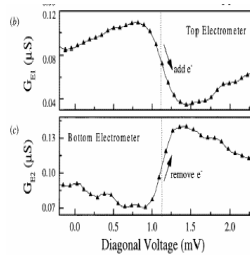


## Switching



- Actually many electrons cause the switch, but the change is equivalent to a single electron switch.

## The Output



- Some thought that the output was actually just the input signal transmitted across cells.
- At first, the coupling capacitors limited output cell polarization. Now they use more tunneling.

## Summary

- Bistable cells code bit information in their internal configuration.
- Physically mediated cell-cell interaction provides coupling between the states of nearby cells.
- Inputs to array are set by physically coercing edge cells to particular states.
- Outputs are read by non-invasively sensing the state of edge cells.
- Computing is accomplished by the mapping between the physical ground state of the array and the logical solution state of the computational problem.

## Hopeful Future

- “The maximum switching speed could be much higher for future devices with optimized designs.”
- Energy propagation and quasi-adiabatic approach. Smaller dots have higher energy.
- “It is reasonable to anticipate the successful operation of larger arrays of QCA cells.”
- Room temperature if small dots are used (reduce capacitances by x10)