Natural History of Computation
What is “to compute”?  

Alan Turing's model of computation

C-T thesis:

“Everything computable is computable by a Turing machine.”
What is “to compute”? models

- Boolean Circuits
- Finite State Machines
- Register Machines
- Boolean Algebra
- Diophantine Equations
- Turing Machines
- Non-deterministic TM
- Interacting Machines
- $\Lambda$-Calculus
- Fractran
- Tilings
- DNA-computing
- Tag Systems
- String Rewriting
- Cellular Automata
- Graph Automata
- Neural Network
- Hopfield Networks
- Boltzmann Machines
- Factor Graphs
- Chemical Reaction Networks
- Quantum computing
- ...
What is “to compute”?

Reduction. Interpretation of symbols.
What is “to compute”?

Need of a new model? Observations

1. Finite sets and finite steps. Fortnow & Turing: finite physical resources.

2. Continuous signals and transitions. Fortnow & Turing: measurements limits → everything is discrete.


http://ubiquity.acm.org/article.cfm?id=1880067.
What is “to compute”?

“So why are we having a series now asking a question that was settled in the 1930s? ... Some people outside of computer science might think that there is a serious debate about the nature of computation. There isn’t.”
Lance Fortnow. The enduring legacy of the Turing machine Ubiquity, November 2010. http://ubiquity.acm.org/article.cfm?id=1921573

“... we regard challenges to C-T as not only perfectly legitimate but highly desirable... challenges to established theories force their acolytes to re-examine basic tenets that until then have been complacently unquestioned, in turn reinvigorating those theories where they are not overthrown.”
What is “to compute”?

Reductionists: confident of the unsinkability of the standard model.

Remodelers: new models of computation (real-world processes or theoretical).

Impressionists: distrustful of the science. Seek philosophy to clarify perceptions.

Incomputability theorists: paradigm-change. Harmony between theory and observation.

Analog computation
Why now?

Is Moore's law coming to an end?

- Problems: Control of OFF state limited by tunnelling. Cross-talk.
- To go smaller: radical new technology (qubits in several guises).
- Will more make it better? Neurons are slow, noisy, low power, and not that densely packed.

Different embodiment → natural computation (e.g. as in neural)
Cybernetics

The scientific study of control & communication in the animal and the machine.

Norbert Wiener 1894 - 1964

Claude Shannon 1916 - 2001

- Feedback
- Information
- Pattern formation
- Self-replication
+++Divide By Cucumber Error. Please Reinstall Universe And Reboot +++

- And cogwheels and springs?

- Well, the ants aren't very good at differential analysis so ...
Another view of “to compute”

Physics: metaphor, analogy.
Maths & Logic: reduction.
An implementation

1. Define encoding.
2. Feed inputs to dynamical system ("many" DoF).
3. Combine responses linearly.

"Reservoir Computing" or "Liquid State Machines"

Liquid State Machines can simulate any time invariant fading memory operator.

Embodiment: ASN

Sillin et al. (2013). A theoretical and experimental study of neuromorphic atomic switch networks for reservoir computing. doi:10.1088/0957-4484/24/38/384004
Embodiment: ASN
A game, to leave with a smile...
1st Game

Rule:
If a card has a vowel on one side, then it must have an even number on the other side.

Which cards would you need to check, in order to determine whether this rule is being obeyed?
Rule:
If a person is drinking alcohol, then they must be at least 18.

Who would you need to check, in order to determine whether this rule is being obeyed?
¡Remember your answers!
Rule:

If a card has a vowel on one side, then it must have an even number on the other side.

Which cards would you need to check, in order to determine whether this rule is being obeyed?
Rule:
If a person is *drinking alcohol*, then they must be *at least 18*.

Who would you need to check, in order to determine whether this rule is being obeyed?
Discussion

"...if a machine is expected to be infallible, it cannot also be intelligent. There are several theorems which say almost exactly that."

- Alan Turing. Talk at the Mathematical Society Feb. 20, 1947
Thank you for your time!

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