On State

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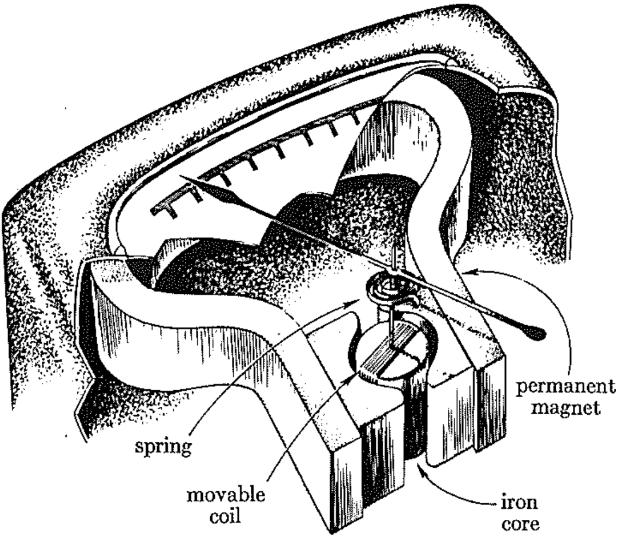
Outline

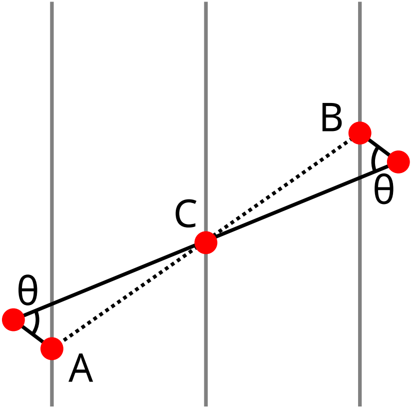
- Computers
- Modeling
- Math
- State

Part 1—Computers



Malmstadt, Enke, and Toren: *Electronics for Scientists*, 1963


SHOW



$$C = \frac{A + B}{2}$$

$$2C_y = A_y + B_y$$

$$\log A_y B_y = \log A_y + \log B_y$$

$$2 \log C_y = \log C_y^2$$

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- Constructive analog computers simulate phenomenon
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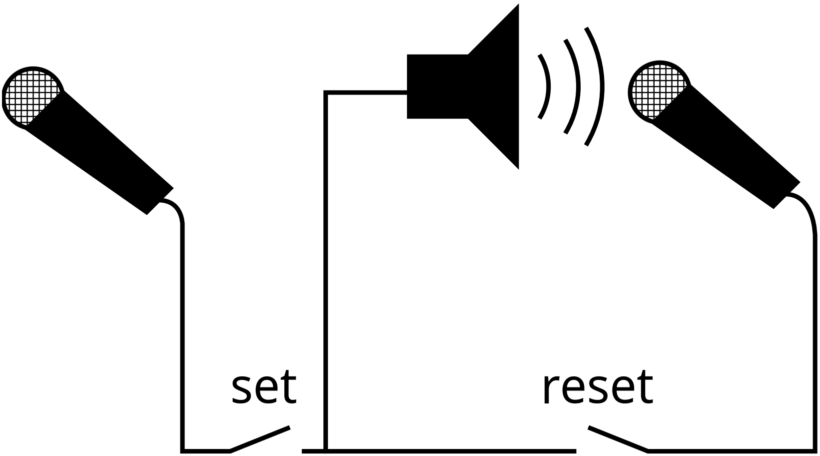
- Analytic computers can be mechanically coupled
    - We can call this composition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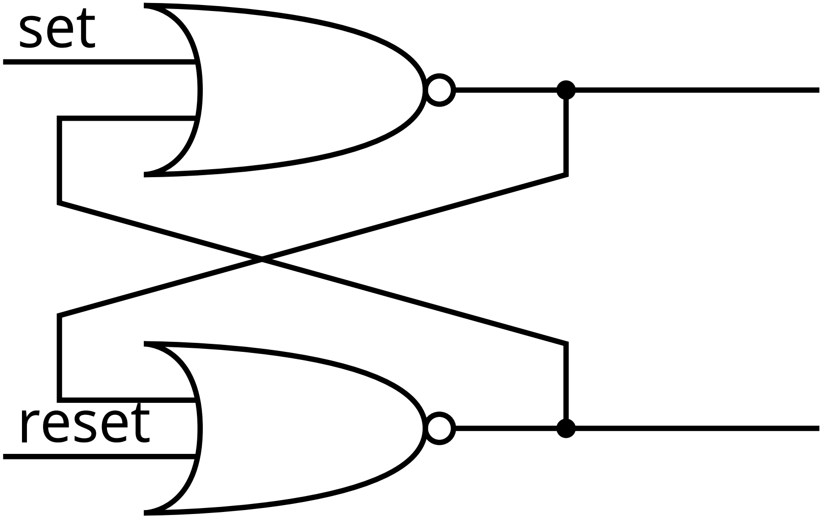
set
reset

- Delay lines shift output to the future
- Allows intertemporal composition
- Ramps up dimension

So now our machine:

- Computes proportions on inputs
- Delays outputs to the future
- Allows outputs to be reused as inputs
- Displays output as magnitudes

Part 2—Causality

Consider the following:

- Ice cream sales are higher in summer

Consider the following:

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- Crime is higher in summer

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- Ice cream sales are higher in summer
- Crime is higher in summer
- Therefore, ice cream causes crime

Interventionist Theory of Causality

- A cause is a “handle” that controls outcomes
- An effect is an outcome changed by an intervention
- Most practical application is counterfactual (“imaginary”)

Intervention and science

- An ideal experiment has:
  - One variable that undergoes manipulation
  - Some variables observed for changes
  - All other variables remain the same
- Called *ceteris paribus*, “all things equal”

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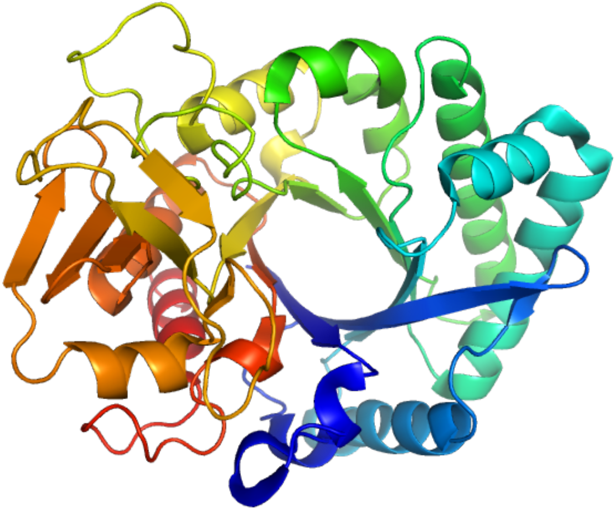
If Jaws kills Bond, is he responsible for the latter's death?



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- Linked amino acids are extruded from a ribosome into a watery environment
- Their sidechains interact with the water and with each other
- Imagine replacing the fifth amino acid with a different one
- How does the outcome change?

We like things to be:

- Low factor
- Feedforward
- Orthogonal

Part 3—Hippasus

$$
\begin{array}{rrrr}
9 & 9 & 9 & 9 \\
 & & 1 & 1 \\
\hline
 & & &
\end{array}
$$

$$
\begin{array}{rrrr}
9 & 9 & 9 & 9 \\
 & & 1 & 1 \\
\hline
9 & & &
\end{array}
$$

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$$

$$
\begin{array}{rrrrr}
 & 9 & 9 & 9 & 9 \\
 & & & 1 & 1 \\
\hline
 & {}^{1}9 & {}^{1}9 & 0 & \\
\hline
1 & 0 & 0 & 0 &
\end{array}
$$

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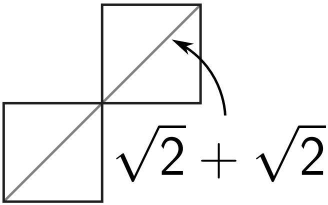
 & & & 1 & 1 \\
\hline
1 & 0 & 0 & {}^{1}0 & 0 \\
\hline
1 & 0 & 0 & 1 & 0
\end{array}
$$

What about $\sqrt{2} + \sqrt{2}$?

$$\begin{array}{cccccc} 1 & . & 4 & 1 & 4 & 2 & \ldots \\ 1 & . & 4 & 1 & 4 & 2 & \ldots \\ \hline 2 & . & 8 & 2 & 8 & 4 & \ldots \end{array}$$

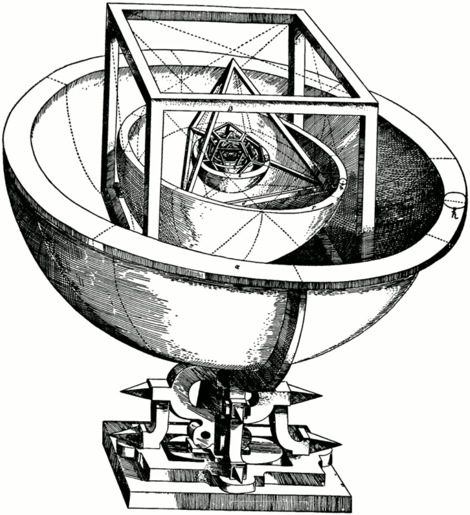
- The answer is an infinite loop, i.e., $\perp$
- This argument is illustrative but bad...



- Of course, some caveats:
  - Accuracy of projector?
  - Accuracy of measurement?
  - Accuracy of rasterization?
- The idealization breaks down
- Not the same as “failure”

$\frac{1}{2} + \frac{2}{3}$	Compute GCD $= 6$
$\frac{1}{2} \cdot 6 + \frac{2}{3} \cdot 6$	Multiply by GCD
$3 + 4 = 7$	Add integers
$\frac{7}{6}$	Divide by GCD

$1+\sqrt{2}$	Compute GCD $=\infty$
$1\cdot\infty+\sqrt{2}\cdot\infty$	Multiply by GCD
$\infty+\infty=\infty$	Add integers
$\frac{\infty}{\infty}=?$	Divide by GCD



Part 4—State

Continuous math

- “What the world does”
- Always-already stateful
- Evades formalization
- Mutually entailed
- So quite hard to work with

Discrete math

- “How we talk about the world”
- Indirectly and weakly stateful
- Evades realization
- *Ceteris paribus* to the ground
- Easy to work with, but…

Analog computers

- Application-specific
- Near-instantaneous action
- Accuracy depends on mechanism
- Precision is a design decision

Digital computers

- Actually analog computers
- Application is set theory

Digital computers

- Actually analog computers
- Application is set theory
- State required to solve discrete math
- Hence lambda calculus

The punchline

- Can't salvage *ceteris paribus*
  - Computers need bookkeeping
  - Delay lines ratchet up dimension
  - Arbitrary intertemporal composition
  - So complex systems

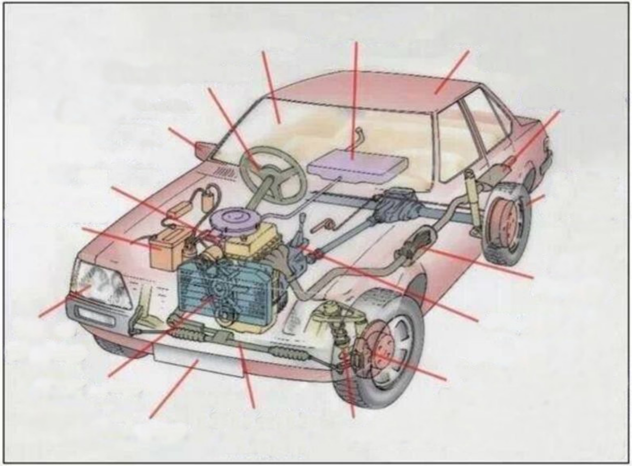
The punchline

- Can't salvage *ceteris paribus*
  - Computers need bookkeeping
  - Delay lines ratchet up dimension
  - Arbitrary intertemporal composition
  - So complex systems
- Can't defer state to real world
  - No "symbolic math" phenomenon
  - Other computer designs are possible, but...

What are the practical issues?

- Large number of factors
- Dependency feedback
- Action at a distance

Know Your Car



Some ideas—globals

- Write-in-one-place globals
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    - So no name aliasing
    - Easy to visually track
  - Only writable at event top level
    - All writes nearby in code

Some ideas—locals

- Scope-bound mutability
  - Fully mutable within declaring scope
  - Fully immutable in other scopes
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    - Ought to be easy to reason about
    - Works for any data structure

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    - Works for any data structure
- Scoped collection access
  - Access introduces a scope
  - Collection blacklisted from accessor scope
  - Member only resident in accessor scope
  - Collection and member(s) not rebindable
    - Prevents aliasing

Conclusion