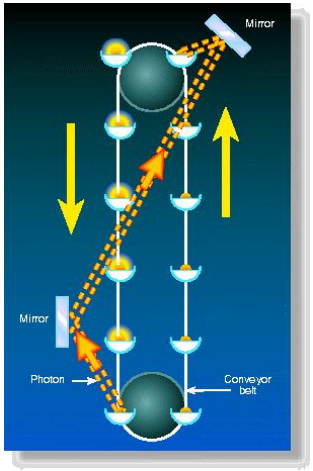
Complexity

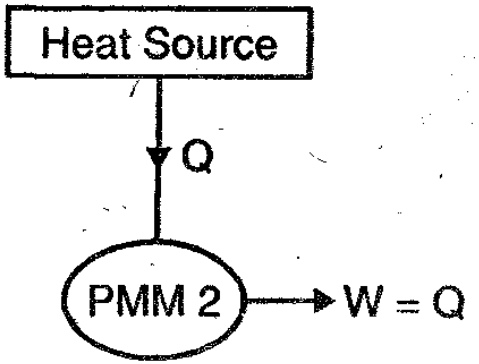
(a constructor-theoretic view)

Chiara Marletto
Wolfson College
University of Oxford

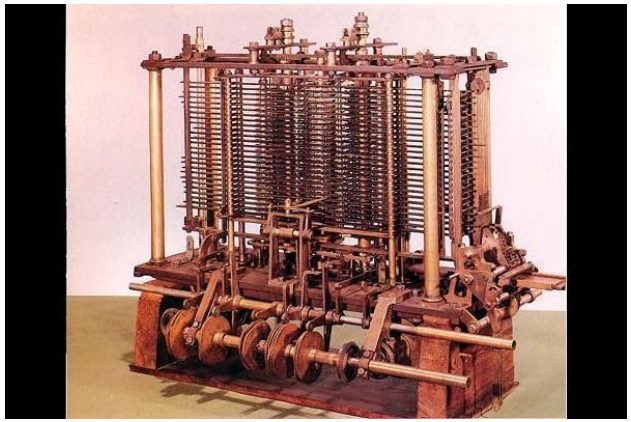
January 2017



Impossible (by the Conservation of Energy)



Impossible (by the 2nd Law)



Possible (?)

Scale-independent

Scale-dependent

The Traditional Conception of Fundamental Physics

Every law must be expressed in terms of *predictions* given the boundary conditions in space-time and the dynamical laws

Constructor Theory

*All laws of physics are expressed as statements about which **tasks** are **possible**, which are **impossible** and why*

Constructor Theory's laws are principles, **constraining** subsidiary theories (e.g. Quantum Theory, General Relativity, …)

Dynamical laws and theories of the initial conditions can be retrieved as emergent consequences of the principles

The fundamental objects of Constructor Theory are tasks, not constructors!

Input Attributes of **Substrates** $\Rightarrow$ Output Attributes of **Substrates**

'attribute' = set of all states in which the substrate has a certain property, according to the subsidiary theory.

A constructor for a task is an object that, whenever presented with the substrates in one of the input attributes, delivers them in (one of) the corresponding output attributes, and retains the property of doing this again.

Constructor

Input Attributes of **Substrates** $\Rightarrow$ Output Attributes of **Substrates**

A task is **impossible** if there is a law of physics forbidding its being performed to arbitrarily high accuracy, **possible** otherwise

Interoperability of information
An example of a scale-independent law

Information medium: a substrate with a set of attributes *X* *(an information variable)* *that can be permuted in all possible ways and that* can be 'cloned'

this means that the task is possible

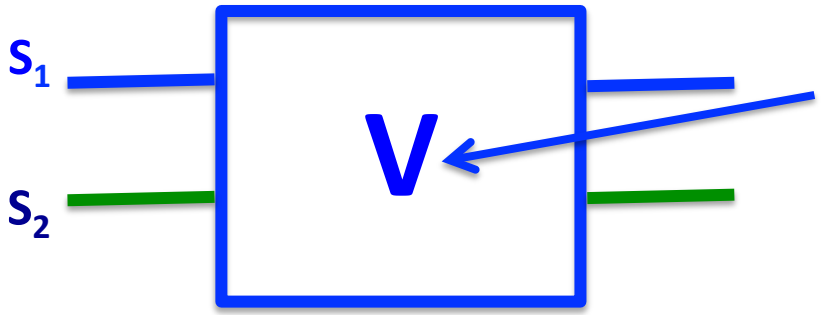
$$\left(\bigcup_{x \in X} x \to \Pi(x) \right)^{\checkmark}, \forall \Pi$$

$$\left(\bigcup_{x \in X} \{ (x, x_0) \to (x, x) \} \right)^{\checkmark}$$

Interoperability Principle for Information

The combination of two information media with information variables X_1 and X_2 is an information medium with information variable $X_1 \times X_2$.

Programmable Constructor



Constructor

information medium with information variable $\{P_1, P_2, \ldots, P_n\}$, with the property that:

is a constructor for the *task* T_{Pk}.

Example: CNot

‘No-design’ laws

Generic resources: substrates available in effectively unlimited numbers.

No-design laws are such that generic resources are allowed to contain only *approximate constructors* for elementary tasks.

"the task of constructing an object X from generic resources is possible"

is fundamentally different from

"the object X occurs at some time *t*"

That a task is possible, under no-design laws, implies that:

1) Good approximations to constructors must be programmable

2) The program consists of a sequence of elementary tasks

3) Von-Neumann's 'Replicator-Vehicle logic' is necessary for self-reproduction.

Irreversibility in constructor theory is expressed in scale-independent terms, as:

"A task T is possible and its transpose is impossible"

This irreversibility is compatible with time-reversal-symmetric laws.

In summary:

What *emergent laws* are depends on the mode of explanation.

There can be exact laws about 'complex' systems

Comments:

1) No need for probability

2) Composition (SWAP and unit task) are assumed to be elementary…but, are they?

B.C.

B.C.


YOU'RE KIDDING... A PERPETUAL MOTION MACHINE?
PATENT OFFICE
YEP. ...THERE'S JUST ONE LITTLE SNAG.
WHAT'S THAT?
IT WON'T START.