A Complex Systems Manifesto

Last updated: 2022/08/27, 23:54:10 EDT

Principles of Complex Systems, Vols. 1, 2, & 3D CSYS/MATH 300, 303, & 394, 2022-2023 | @pocsvox

Prof. Peter Sheridan Dodds | @peterdodds

Computational Story Lab | Vermont Complex Systems Center Santa Fe Institute | University of Vermont

000 Licensed under the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License.

Outline

Defining Complexity

A Manifesto

References

Definitions

Adjective:

Definitions

PoCS

@pocsvox

Manifesto

Defining Complexity

A Manifesto

References

Complicated versus Complex:

- line complicated: Mechanical watches, airplanes, ...
- Engineered systems can be made to be highly robust but not adaptable.
- But engineered systems can become complex (power grid, planes).
- They can also fail spectacularly.
- Explicit distinction: Complex Adaptive Systems.

000 ୬ ବ ୍ ୧୦ f 24 PoCS Definitions @pocsvox Manifesto A working definition of a Complex System: Defining Complexity Bistributed system of many interrelated (possibly) networked) parts with no centralized control A Manifesto exhibiting emergent behavior-'More is References Different'^[1] Other features/aspects: Explicit nonlinear relationships. Presence of feedback loops. 🚳 Being open or driven, opaque boundaries. 🚳 Memory. 🗞 Modular (nested)/multiscale structure. A Mechanisms range from being purely physical to (in 18 purely algorithmic in nature. PoCS **Examples of Complex Systems:** @pocsvox Manifesto Defining Complexity human societies A Manifesto References 🚳 financial systems Complex: (Latin = with + fold/weave (com + plex)) 🚳 cells 🚳 ant colonies 🚳 fluids, weather 1. Made up of multiple parts; intricate or detailed. systems 2. Not simple or straightforward. 🗞 ecosystems \delta power grids

i.e., everything that's interesting ...

lanimal societies

🚳 social insects

🗞 geophysical

systems

🚳 Internet + Web

🚳 brains

🚳 forests

disease ecologies

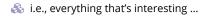
PoCS @pocsvox	Relevant fields:
Manifesto	

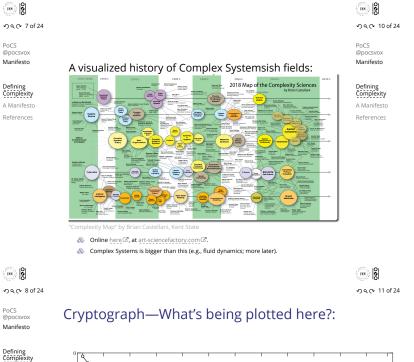
Defining Complexity

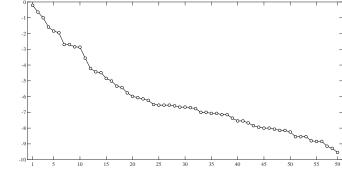
A Manifesto

PoCS @pocsvo> Manifesto

lnformation	 Cognitive Sciences Biology Ecology Geociences Geography 	 Medical Sciences Systems Engineering Computer Science Data Science 	A Manifesto References
-------------	---	---	---------------------------







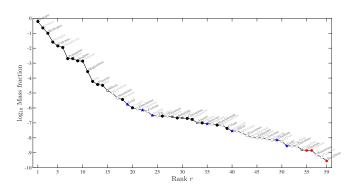
() (N



A Manifesto

References

Fractional weight of typical human body by atomic species:



We are a somewhat difficult LEGO[™] set:

- \clubsuit Written on the box: "Nearly 10^{27} of 29 kinds of pieces!"
- Solution 2014 was bromine shown to be an essential trace element.^[4]
- & 6 elements make up \approx 99% of the body's elements: Oxygen, carbon, hydrogen, nitrogen, calcium, and phosphorous.
- & Next 5 elements make up \approx 0.85%: Potassium, sulfur¹, sodium, chlorine, and magnesium.
- Remaining 18 necessary elements are trace elements.
- Sould be worse: A box with three packets containing up guarks, down guarks, and electrons.

¹Naturally varies with evilness

Best to see people as more than some kind PoCS @pocsvox of cleverly cooled quark soup: Manifesto

"It was hard to deal with people when a tiny part of you saw them as a temporary collection of atoms that would not be around in another few decades."

—Susan Sto Helit C (who is a "little bit immortal")



Thief of Time" **a** 🖸 by Terry Pratchett (2002).^[5]

Reductionism:



- (ca. 460 BC ca. 370 BC)
- 🗞 Atomic hypothesis
- & Atom \sim a (not) temnein (to cut) Plato allegedly wanted his books
- burned.

John Dalton 🖸



- Developed atomic theory
- First estimates of atomic weights

Ludwig Boltzmann C, 1844–1906. Atomic Theory.



PoCS

@pocsvox

Manifesto

Defining Complexity

A Manifesto

References

(in)

Defining Complexity

A Manifestr

References

U/H 8

• ୨ ୦ (୦ 15 of 24

"Boltzmann's kinetic theory of gases seemed Defining Complexity to presuppose the reality of atoms and molecules, but almost all German A Manifesto philosophers and many scientists like Ernst Reference Mach and the physical chemist Wilhelm Ostwald disbelieved their existence."

"In 1904 at a physics conference in St. Louis most physicists seemed to reject atoms and he was not even invited to the physics section. Rather, he was stuck in a section called "applied mathematics," he violently attacked philosophy, especially on allegedly Darwinian grounds but actually in terms of Lamarck's theory of the inheritance of acquired characteristics that people inherited bad philosophy from the past and that it was hard for scientists to overcome such inheritance."

(III) See: epigenetics 2. ∙∕) q (२ 18 of 24

Albert Einstein 🖸 1879–1955



🗞 Annus Mirabilis paper: 🗹 "the Defining Complexity Motion of Small Particles Suspended in a Stationary Liquid, as Required A Manifestr by the Molecular Kinetic Theory of References Heat"^[2, 3]

Showed Brownian motion followed from an atomic model giving rise to diffusion.

Jean Perrin 🕝 1870–1942

l 1908: Experimentally verified Einstein's work and Atomic Theory.

Feynmann:

Snared from brainpickings.org ☑

"If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generation of creatures, what statement would contain the most information in the fewest words?



"I believe it is the atomic hypothesis that all things are made of atoms-little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another. "In that one sentence, you will see, there is an enormous amount of information about the world, if just a little imagination and thinking are applied."

୬ ର. ତ 17 of 24

PoCS

PoCS

@pocsvox

Manifesto

୬ ୦ ୦ ୦ ୩ ୦ m 24

@pocsvox

Manifesto

PoCS

@pocsvo>

Manifesto

Defining Complexity

A Manifesto

000 • n q (+ 20 of 24

> PoCS @pocsvo> Manifesto

Defining Complexity A Manifesto References

(III) ୬ ବ ଦ 21 of 24

PoCS @pocsvo Manifesto

Defining Complexity

A Manifesto

References

1. Systems are ubiquitous and systems matter.

The Science of Complex Systems Manifesto:

- 2. Consequently, much of science is about understanding how pieces dynamically fit together.
- 3. 1700 to 2000 = Golden Age of Reductionism: Atoms!, sub-atomic particles, DNA, genes, people, ...
- 4. Understanding and creating systems (including new 'atoms') is the greater part of science and engineering.
- 5. Universality C: systems with quantitatively different micro details exhibit qualitatively similar macro behavior.
- 6. Computing advances make the Science of Complex Systems possible:
 - 6.1 We can measure and record enormous amounts of data, research areas continue to transition from data scarce to data rich.
 - 6.2 We can simulate, model, and create complex systems in extraordinary detail.

(in |S

PoCS @pocsvo Manifesto

Defining Complexity

A Manifesto

References











References I	PoCS @pocsvox Manifesto	Refere
 [1] P. W. Anderson. More is different. <u>Science</u>, 177(4047):393–396, 1972. pdf [2] A. Einstein. Über die von der molekularkinetischen theorie der 	Defining Complexity A Manifesto References	[4] A. S. R. V. Broi
wärme geforderte bewegung von in ruhenden flüssigkeiten suspendierten teilchen. <u>Annalen der Physik</u> , 322:549–560, 1905.		of co arch <u>Cell</u> ,
 [3] A. Einstein. On the movement of small particles suspended in a stationary liquid demanded by the molecular-kinetic theory of heat. In R. Fürth, editor, <u>Investigations on the theory of the Brownian motion</u>. Dover Publications, 1956. pdf^C 	ි මී නලල 23 of 24	[5] T. Pr <u>Thie</u> Harı

ences II

PoCS @pocsvox Manifesto

> Defining Complexity A Manifesto References

S. McCall, C. F. Cummings, G. Bhave, Vanacore, A. Page-McCaw, and B. G. Hudson. omine is an essential trace element for assembly collagen IV scaffolds in tissue development and chitecture. ll, 157:1380–1392, 2014.

Pratchett. nief of Time. ArperTorch, 2002.

୍ଞା 👸