The Science in Computer Science

In search of new frameworks

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All about the foundations?

- What kind of discipline is computer science (informatics, computer engineering, computing, …)?
  - “What’s in a name” dispute: should this discipline be called a science or not?
  - Sciences of the artificial: sciences in the traditional sense of the word?

The Science in Computer Science

DOI:10.1145/2447976.2447988 Peter J. Denning

Viewpoint
The Science in Computer Science

"*The question of "scienceness" of computing has always been complicated because of the strong presence of science, mathematics, and engineering in the roots and practice of the field.* [...] ***Computing*** *is* ***now accepted*** *as* ***science****. Some of us even believe computing is so pervasive that it qualifies as a* ***new domain of science*** *alongside the traditional domains of physical, life, and social sciences*." (Denning 2013)

DOI:10.1145/2347736.2347737 Vinton G. Cerf

Where is the Science in Computer Science?

of the Artificial.[2] Chapter 8 deals with hierarchy and complexity, touching on the way in which we try to bound complexity through modular and hierarchi-

"*To the degree that some aspects of computing are subject to* ***analysis*** *and* ***modeling****, it is fair to say that there is a* ***rigorous element*** *of* ***science*** *in our field*." (Cerf 2012)

Philosophy of science and beyond

- These (and other) questions cannot be afforded only with the traditional tools of philosophy of science (e.g. the demarcation problem) due to the peculiarity of the discipline
  - Science, engineering, technology, technoscience, ...?
- Other disciplines (both already existing and novel) should be involved
  - Philosophy of technology, philosophy of computing/computer science, philosophy and engineering, ...

A paradigmatic case

- The case of “experimental computer science” is emblematic under many respects
  - Calling for experiments in computing as a way to assess its scientific status
  - Naïve notion of experiment in many cases
  - Full adequacy to the same standards of traditional experimental sciences

Computer science as empirical inquiry


Computer Science as Empirical Inquiry: Symbols and Search

Allen Newell and Herbert A. Simon

*"Computer science is an **empirical discipline**. We would have called it an **experimental science**, but like astronomy, economics, and geology, some of its unique forms of observation and experience do not fit a narrow stereotype of the experimental method. None the less, they are experiments. Each **new machine** that is built is an **experiment**. Actually constructing the machine poses a **question to nature**; and we listen for the answer by observing the machine in operation and analyzing it by all analytical and measurement means available. Each new program that is built is an experiment. It poses a question to nature, and its behavior offers clues to an answer. Neither machines nor programs are black boxes; they are artifacts that have been designed, both hardware and software, and we can open them up and **look inside**. We can relate their structure to their behavior and draw **many lessons** from a **single experiment**."* (Newell and Simon 1976)

Rejuvenating experimental computer science

What is Experimental Computer Science?

Peter J. Denning

*"Let us employ **traditional measures** when assessing experimental computer science. Let us always have a **clear plan** for testing a **clear hypothesis**. Let us not call "hacking" science. These are the criteria by which the rest of the world will evaluate our field's experimental work. If we do not live up to the **traditional standards of science**, there will come a time **when no one takes us seriously**. "*

(Denning 1980)

No excuses

*"**Experimentation** is central to the **scientific process**. Only **experiments test theories**. Only experiments can explore critical factors and bring new phenomena to light so that theories can be formulated and corrected. **Without experiments**, **computer science** is in **danger** of drying up and **becoming an auxiliary discipline**. The current pressure to concentrate on application is the writing on the wall. I don't doubt that **computer science** is a **fundamental science** of great intellectual depth and importance. Much has already been achieved. Computer technology has changed society, and computer science is in the process of deeply affecting the world view of the general public. There is also much evidence suggesting that the **scientific method does apply**. As computer science **leaves adolescence behind**, I hope to see the **experimental branch** of this discipline flourish."*

(Tichy 1998)

The benefits of more science in CS

DOI:10.1145/1953122.1953139 Clayton T. Morrison and Richard T. Snodgrass

Viewpoint

Computer Science Can Use More Science

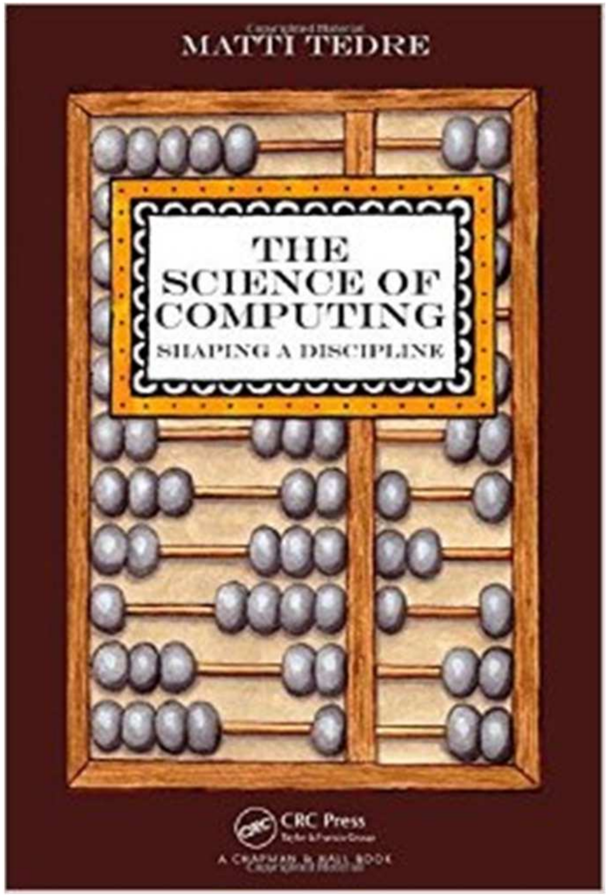
"*These examples and other extant computer science theories emphasize that by embracing the methodology of developing and evaluating predictive models **through experimentation** over **multiple members** of a class of software systems, a **more complete understanding** of such artifacts will emerge.* […] *How can these benefits be realized? How might we change what we do? We can adapt our already very skilled hypothesis testing in debugging and broaden it by **asking more general questions*** […] *The pristine presentations of **scientific reasoning** and the tremendous successes of such reasoning in other fields may appear to the practicing computer scientist as out of reach. But many of our colleagues have started down this path, the **tools are accessible**, and the **promise is great**.*"

(Morrison and Snodgrass 2011)

Enlarging the debate

- The many faces of experiments in computing
- From epistemic experiments to directly action-guiding experiments
- Engineering ontology and epistemology
- From the engineering sciences to the technosciences
- Design experiments and beyond

The many faces of experiments in computing



"*At least **five views** are somewhat prevalent: **experiment** as a **demonstration of feasibility**, experiment as a **trial run**, experiment as a **field test**, experiment as a **comparison between competitors**, and the **controlled experiment**. Many would object against calling, for instance, feasibility demonstrations 'experiments,' arguing that the term 'experiment' has a special meaning in science. They are right. But if one looks at **how authors in computing have used the term**—not how it should be used—those five uses are easily found*"

(Tedre 2015)

Two types of experiments

"*An* ***experiment*** *is* ***directly action-guiding*** *if and only if it satisfies the following two criteria: (1) The* ***outcome*** *looked for should consist in the attainment of* ***some desired goal of human action****, (2) and the* ***interventions*** *studied should be potential* ***candidates*** *for being performed in a* ***non experimental setting*** *in order to achieve that goal. These criteria are satisfied for instance in a* ***clinical trial****.* [...] *In contrast, an epistemic experiment aims at providing us with* ***information*** *about the* ***workings*** *of the* ***world we live in****. Therefore, the outcome looked for is one that provides such information, and it need not coincide with anything that any sensible person would wish to happen except as part of the experiment itself* [...] *Both* ***historical*** *and* ***philosophical accounts*** *of experiments and experimental method have been almost exclusively devoted* ***to epistemic experiments*** *in science, and surprisingly little has been written on directly action-guiding experiments.*" (Hansson 2015)

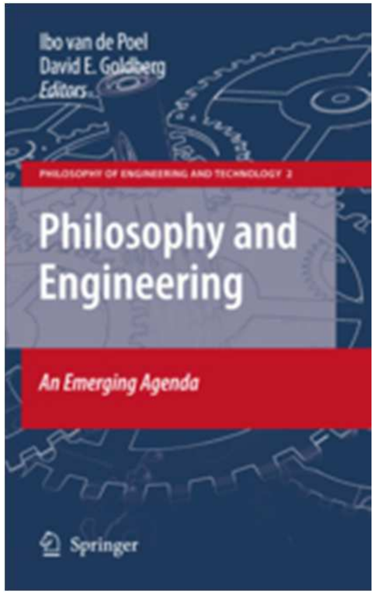
Directly action-guiding experiment

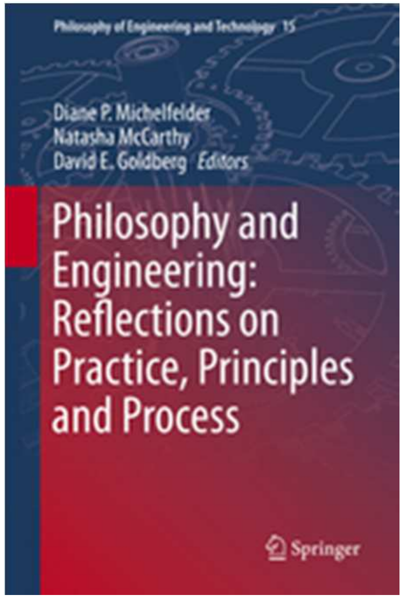
- Non-academic origin
- Driven by practical needs
- Technological form of experimentation
- Already performed in prescientific times
  - Extensive experiments on the composition of glass performed in the early Islamic period in Eastern Syria (VII-IX cent.)
- Early renaissance
  - Skilled craftsmen had a major role for the development of experimental science (not only for experimental equipment, but also for experimental methodology)

Engineering and technology

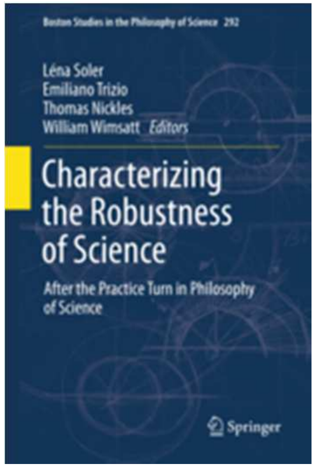
"*As a first approximation we might characterize* ***engineering*** *as an* ***activity*** *that* ***produces technology***. ***Producing*** *here is to be understood* ***very broadly****, including such activities as research, development, design, testing, patenting, maintenance, inspection, and so on. As we will see below, this is a first approximation at best. Nevertheless, it has the virtue of suggesting an agenda for philosophical reflection on engineering that is* ***distinct*** *from at least the* ***traditional philosophy of technology****. It means a shift away from philosophical reflection on technology as such, technological objects and the social, cultural, and political impacts of these toward* ***attention on what engineers actually do****.*"

(van de Poel 2010)





Engineering sciences: continuity with natural ones



"***Engineering sciences***, which is ***scientific research*** in the ***context*** of ***technological applications***, is an example of a science in the context of application. Its purpose is scientific research that contributes to the ***development*** of ***technological devices***, ***processes***, and ***materials***. Usually, the proper (or improper) functioning of devices, processes, and materials is understood in terms of phenomena that produce (or are detrimental to) their ***desired behaviour***." (Boon 2012a)

"*Hence, the engineering sciences aim at* ***creating*** *or* ***intervening*** *with the* ***phenomena*** *that are* ***manifestations*** *of* ***technological (mal)functioning***. *That is, they aim to produce, change, control, or prevent these observable or measurable phenomena. [...] Nevertheless, these scientific practices usually* ***investigate*** *phenomena of interest in* ***ways*** *that are very much* ***similar*** *to the approaches of* ***experimental practices*** *in the* ***natural sciences*** *—yet, with the difference that the 'ultimate' purpose of these research practices are the* ***phenomena*** *and their* ***technological production***, *rather than theories.*" (Boon 2012b)

Engineering: different ontologies but same tools

*"Although **engineering** often draws on science, it **is not science**, and is not merely applied science. [...] What distinguishes engineering from technology is **methodology** – a systematic approach for the use and growth of **objective knowledge** about how the **physical world** can be made to meet **requirements**"*

(Staples 2014)

*"So, **engineering** has its **own kind of knowledge** which is similar but different to knowledge in science. [...] Engineering also has its own ways of growing knowledge, which are again similar but different to those in science. **Engineering epistemology** can be explored **by adapting** frameworks already established in the **philosophy of science**."*

(Staples 2015)

Adapting frameworks

*"The **first thesis** of this paper is that because the nature of engineering is different to science, and theories in engineering are different to theories in science, so the **growth of knowledge in engineering** is **different** to the **growth of knowledge in science**. The **second thesis** is that **methodological issues** in the **epistemology of engineering** can be treated by **adapting frameworks** already **established** in **the philosophy of science**. I have used critical rationalism and Popper's three worlds framework, adapted as described in a previous paper."*

(Staples 2015)

An engineering way of being in science

*"Both **science** and **techoscience** involve an interplay of **representing** and **intervening**. Science is defined by its orientation to the epistemic ideal of purification [...]. **Technoscience** is defined by its **neglect** or abandonment of this **work** of **purification**. [...] **Technoscience** is therefore a kind of research where **theoretical representation** and **technical intervention** cannot be held apart even in thought. [...] This proposal is an invitation **to philosophers of science** to **take seriously** the notion of "**technoscience**" in order to bring to light a range of **questions** that have been **neglected so far** even in the context of the philosophy of experiment, of modeling, of scientific practice."*

(Nordmann et al. 2011)

J Gen Philos Sci (2011) 42:365–383
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DISCUSSION

Matters of Interest: The Objects of Research in Science and Technoscience

Bernadette Bensaude-Vincent · Sacha Loeve · Alfred Nordmann · Astrid Schwarz

Crisis of the traditional control

*"Because the **conditions** are **controlled**, **experiments** may be **replicated** in order to test the "internal" validity of the outcomes.* [...] *The **experimenter** somehow is able **to intervene** in the system (s)he is experimenting on. The notion of intervention has a clear meaning: the experimentalist **is not part of the system** on which the experiment is conducted.* [...] *In other words, the **experimentalist** operates from a **center of command** and **control outside** the experimental system. I will refer to these ideas as the **traditional control paradigm for experiments**. In my opinion, the notions of an intervention and of a center of command and control **become problematic** in the case of the **new technologies** that are treated as social experiments or involve complex socio-technical systems."*

(Kroes 2014)

Design experiment

"***Design experiments*** *differ significantly from randomized controlled experiments. Design experimentation starts with the presumption that the* ***world*** *is a* ***messy place*** *and that experiments* ***will not be able to isolate*** *the effect of single variables.* [...] *The focus of a design experiment is not to definitively accept or reject a hypothesis, but rather* ***to iteratively refine the intervention*** [...]. *The ultimate purpose is not to test general theory, but to probe the* ***possibility*** *and* ***limits*** *of the* ***intervention****. Design experiments do* ***not*** *create a sharp* ***distinction*** *between* ***researchers*** *and* ***subjects****: instead, the* ***practitioners often become experimenters****."*

(Ansell 2012)

Progressive refinement

*"Design experiments do not fully control the conditions in which the experiment occurs, as laboratory experiments attempt to do. Design experiments adopt a strategy of '**progressive refinement**' where a beta version of the experiment is first introduced and then progressively improved.* […] *Instead, the goal of experimentation is to identify the range of variables that affect the outcomes of interest. Nor do design experiments seek to test a single well-defined hypothesis; instead, the goal is to develop a **wider profile** of the **effects** of the **overall design**."*

(Ansell 2012)

Stretching traditional concepts

- Stretching (and not adapting) the traditional notion of experiment
  - From exploratory experiments (Franklin 2005) to explorative experiments
- Explorative experiments (Schiaffonati 2015)
  - Experiments that are forms of directly action-guiding experimentation
  - Experiments that are not devoted to hypothesis testing
  - Experiments in which the control of the experimental factors cannot be fully managed from the beginning, but is in part carried out after the artefacts have been inserted into their environment
  - Experiments that involve the testing of technical artefacts (engineering disciplines)

Thank you for your attention