What would a science of software engineering look like?

Jim Herbsleb
Science of Software Engineering

- Does SE research have impact?
- Science creates impact?
- What sort of science do we need?
- How to move forward?
Does SE Research Have Impact?
No One Seems Confident . . .

  - Bottom line: There is considerable, demonstrable impact in a number of areas, often takes many years, and seems to arise from continued interaction, not tech transfer

- Bertrand Meyer (2010):
  - “many of the advances in software engineering have come out of non-university sources . . . Academic research has had its part, honorable but limited.”

No One Seems Confident . . .

- Lo, Nagappan, and Zimmerman (2015):
  - “We believe that embedding practitioner feedback into conferences . . . can provide great value to the software engineering community.”

- Lionel Briand (2012):
  - SE should be in engineering, not computer science; hard to establish tight collaborations with industry;
  - “Software engineering isn’t a branch of computer science; it’s an engineering discipline relying in part on computer science, in the same way that mechanical engineering relies on physics.”

Science Creates Impact?
There's not much chemistry going on here!

Jim

Likes to mix things up, put them on alcohol flame
See if they catch fire or (YES!) explode
Knows nothing, cares nothing about chemistry
This may be very useful. This is not science.
Predictive Analytics:
To Bleed or not to Bleed . . .

• Bleeding common medical practice
• Late 18th century
• Francois Joseph Victor Broussais
  • Promoted bleeding of “affected organ”
• Pierre-Charles-Alexandre Louis
  • Actual data collection about outcomes
  • Bleeding is not such a great idea
• The first clinical trial?
Prediction is not Good Enough

- Joseph Lister – outcomes of antiseptic surgery in Edinburgh
  - Mortality rates decreased from 45.7% to 15%
  - Technique based on Louis Pasteur’s “germ theory”
- Clinical trial is important, is not enough!
  - Science to understand disease processes
- SAYS NOTHING ABOUT DEVELOPING NEW TREATMENTS!
- Left with trial-and-error
Analgesics . . .

- Tea from willow barks works!
  - A few digestive side effects 😞
- Oak bark doesn’t work at all
- Hemlock bark
  - Oops, let’s not try that again . . .
Science May Not Have Immediate Application

- Must be freed from demand for immediate applicability
- Suppose medical research demanded that each paper advance practice?
  - Medical research would never have had much impact
  - No germ theory, no understanding of physiological systems, etc.
- Time horizon of years, decades, more
- Gradually build deep, reliable understanding
The demand for immediate relevance rather than overall contribution . . . a hypothetical rejection letter:

Drs. Watson and Crick:

I regret to inform you that we are unable to accept your paper.

I personally find it very interesting that the DNA molecule has the shape of a double helix held together by paired bases. But the reviewers felt that you have not demonstrated any practical application for this discovery, so it was decided that the contribution was insufficient.
Science is about Theory

- What are the entities?
- What are the relationships?
- How do these entities and relationships explain the observed phenomena?


What sort of science?
What Science Do We Need?

• Many fields of engineering
  • Need a science to describe, explain, and predict the properties of materials and compositions

• In software engineering
  • What does our science need to do?
  • Our materials are abstractions: programs, patterns, etc.
  • Describe, explain, and predict behavior of artifacts
    • Computer science
  • Describe, explain, and predict behavior of people creating artifacts
    • Human Science of Software Engineering
If Only We Had Known . . .

- Problem: people finding the right experts at a remote site
- Solution: Expertise Browser
What Didn’t We Know?

- Transactive Memory Systems
- Theory from Organizational Behavior
Transactive Memory Systems (TMS)

- Group level phenomenon
- Arises naturally
- Specialization + index
  - People take responsibility for group knowledge and memory in some area
  - Everyone shares an index of “who knows what”
  - Origins in people watching each other work
- Very powerful impacts on how well groups function
TMS: Benefits and Conditions

- Specialization gives better performance
- Better coordination, agree on responsibilities
- Facilitates adaptation to new situations or tasks
- Facilitates creativity
- Develops under right conditions
  - Observe each other working
  - Communication

If We Had Known?

- Rather than support isolated search for one individual on one occasion
- Build a system that would effectively provide TMS for the whole organization
- What would we call it?
  - Maybe ... GitHub?
  - Activity traces, profiles, consistent across repositories
Socio-Technical Coordination

Technical coordination is a Constraint satisfaction problem (CSP) over decisions

Decisions and Constraints

Decisions distributed over people (DCSP)

Social algorithm to solve DCSP


Distributed Constraint Satisfaction

- Decisions are represented as $n$ variables $x_1, x_2, \ldots, x_n$
- Values from finite, discrete domains $D_1, D_2, \ldots, D_n$.
- A set of constraints that operate over the variables serve to limit possible values that can be assigned to other variables.
- Formally, constraints $p_k(x_{k1}, x_{k2}, \ldots, x_{kn})$ can be represented as predicates defined on the Cartesian product $D_{k1} \times D_{k2} \times \ldots \times D_{kj}$.
- Distributed constraint satisfaction problem, two relations
- Each variable $x_j$ belongs to one agent $i$, represented as the relation $\text{belongs}(x_j, i)$.
- Agents only know about a subset of the constraints:
  - $\text{known}(P_i, k)$, meaning agent $k$ knows about constraint $P_i$.


Solving a DCSP

- Computational agents’ actions
  - Make decisions, backtrack
  - Send message (decision, constraint)
  - Create link (change network topology)
  - Edit a shared object
  - Predict other agents’ behavior
- When agents are human
  - Execute a social algorithm


Validated Congruence Model

Decision network structure

Social Algorithm

Congruence between decision network and social algorithm

Bugginess

Productivity
Many Questions Remain . . .

- We only showed that for a few types of social algorithm, it works when the right people use it
- What about match of mechanisms to dependency types?
- What about match of mechanisms to decision pace?
Scale Up . . .

- Looked at coordination in relatively small tasks (a few people, 1-2 weeks)
- How about coordination across an ecosystem?
Socio-Technical Ecosystems

- Constraints: changes that break code
- Study showed several different social algorithms
  - Snapshot consistency (R/CRAN)
  - Rigid backward compatibility (Eclipse)
  - Semantic versioning (node.js/npm)

The Science We Need

- Software engineering is in need of a science beyond computer science.
- I nominate “human science of software engineering” to fill the role.
- We are moving in this direction anyway, let’s acknowledge it and speed it up!
How to move forward?
Barriers to Human Science

- The universal principle of interdisciplinary contempt
- DPHB* principle: everything I don’t understand is simple
- Intellectual worth is evaluated on a single dimension
  - From math to BS
- Not all statistical models are just about prediction
  - Theory seen as mere decoration and distraction on top of statistical model
  - Statistics used to test relations between theoretical constructs
  - Not just associations among variables
- Border defense, antibodies
  - Is that really computer science?
- Necessity to argue for practical application of each result

*Dilbert’s pointy-haired boss
What Next?

• I’m “preaching to the choir” in this room
• The kinds of things we are all doing are the future of the field
• Remember, science is for the longer term, years, decades, generations
• Push back on demand for immediate impact!
• Make theory central!
• Push for funding a portfolio of research
Q&A