Problem Choice in Engineering Research
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The Problem of the Problem

- When is research in basic research relevant?
- When is research relevant?
  - In basic research: Knowledge agreed to be interesting by peer group
  - In engineering research: Solution are used by technologists
- How do we choose our research problems?

The problem of the problem, reformulated

- Problems can be relevant for
  - society
  - technology
  - science
- How do we choose relevant problems?
- Relevant for whom?

Three domains

- Human activity systems
- Human knowledge systems
- One person can act in all three worlds

Society

Technology

Science

Critical pursuit of knowledge: Math, physics, sociology, management science, ...

Invention, development, production, maintenance of useful products & procedures:
  software, software techniques, ...

Business goals, user goals, price, revenue, property rights, patents, norms, values, culture, activities, ...

IS research problem
(Department of management science)

- 1980s
  - Complaints about lack of empirical rigour
  - Papers about empirical methods for IS research

- 1990s
  - Empirical papers

- 2000s
  - Complaint about lack of relevance
  - Attempt to include design in IS research

SE ``research'' problems
(Department of computer science)

- 1990s
  - Complaints about lack of validation
  - Papers about how to do experimental and case study research

- 2000s
  - Increasing number of papers validate their solution
  - Complaints about transfer of solutions to practice
The engineering cycle

- Problem investigation
  - What are the stakeholders and their goals G?
  - What is the environment E of the future solution?
- Solution design
- Solution validation
  - What are the solution properties of S?
  - Does this solve our problem? E and S imply G
- Solution implementation
- Implementation evaluation

Two kinds of science

- Society
  - (physical, biological, social)
- Technology
  - (physical, digital, social, biological artefacts)
- Engineering science
- Natural science

Study of nature: basic science & applied science implication of linear model

But which problems to investigate/solve/evaluate??

(Non)distinctions

- Engineering science and natural science are both curiosity-driven
- Sponsoring of all science is utility-driven
- Subject of engineering science is utility-driven artefact (product or procedure)
- Engineering science aims for applicable results
  - conditions of practice not abstracted away
  - modeling and simulation; law of similitude

Domain of SIKS

- Designing novel artefacts
- Validating them
- Evaluating their use

Problem choice in technology

- Goals, Information, Investments
  - Inventions
  - Science
  - Technology

- From failures
- From performance extrapolation
- From reverse salient
- From requirements flowdown
- From expected failure/expected demand

Artfact development (normal, radical)
Knowledge growth

SIKS
Problem choice in engineering science

Research data etc.

1. BoK about technology
2. Theoretical performance improvements & limits
3. Theories of measurement
4. Computational techniques
5. Approximation techniques

Inventions

Goals, Info, Instruments

Knowledge

Science

Technology

Artefact development (Normal, radical)

Knowledge growth

Innovations

Puzzles

1. Can this be done?
2. How does it work?
3. How to measure?
4. How to compute accurately?
5. How certain?

Discussion

Sources of SIKS problems

• Design goals:
  – From failures
  – From performance extrapolation
  – From reverse salient
  – From requirements flowdown
  – From expected failure

• Knowledge questions:
  – Can this be done?
  – How does it work?
  – How to measure?
  – How to compute accurately?
  – How certain?

Design questions at ICSE02 (Mary Shaw reformulated by me)

- Problem domain is software technology
- Design goal not always clear
- Source of design goal usually not indicated
- Curiosity-driven engineering

Research questions at ICSE02 (Mary Shaw reformulated by me)

- s.o.t.p. of X?
- s.o.t.a. of X?
- Does X exist? (s.o.t.
- Model of X?
- Kinds of Xs?
- Properties of X?
- Relationships among Xs?
- s.o.t.p/a of X?
- How does it work?
- Why does it fail?
- How to measure/compute?
- How certain?

Epistemological questions not an issue either except at empirical conferences

Knowledge problems in the engineering cycle (could turn into research problems)

- Practical problem investigation
  - Stakeholders? Goals?
  - Phenomena? Causes?
- Solution design
  - Available solutions? BoK?
  - How does it work?
  - Performance limits?
- Solution validation
  - Solution properties?
  - Effects on E?
- Implementation
  - Resources?
  - (Recursion)
- Implementation evaluation
  - Implementation properties
  - Effects on E?
  - S & E imply G?
Problem choice in engineering science

- Known solutions?
- How do they work?
- Performance improvements & limits?
- Solution properties?
- Effects on environment?
- ...of designs & of implementations

Technology

Science

Artefact development
(Normal, radical)

Knowledge growth

Inventions

Goals

Invest

Goals, Information, Investments, Inventions, Innovations

Artefact development
(Normal, radical)

Knowledge growth

Inventions

Goals

Invest

Goals, Information

Sponsoring

Knowledge

Puzzles

• Known solutions?
• How/why do they work?
• Performance improvements & limits?
• Solution properties?
• Effects on environment?
• ...of designs & of implementations

Problem choice in IS projects (1)

- VITAL/COOP
  - Domain: Value networks
  - Goal: To develop techniques for designing coordination processes and IT support for value networks
  - Source: Failure of E-commerce
- QUIDS/QuadRead
  - Domain: Software systems/large administrative applications
  - Goal: To find empirically validated relations among architecture decisions and some quality attributes; to quantify these relations where possible
  - Source: Extrapolation (poor performance of current guidelines), potential failure (pressure to improve quality, potential to find nuggets by means of empirical studies)
- CARES/COOPSMOS
  - Domain: Cross-organizational ERP implementation
  - Goal: To develop cost-quality trade-off techniques
  - Source: Extrapolation of single-company techniques; potential failure (more Xorg implementation, possible usefulness of techniques from other domains)
- MOCA
  - Domain: Embedded systems
  - Goal: To develop modeling guidelines for design and verification of embedded systems, taking physical environment into account
  - Source: Failure of current guidelines (total dependence on genius of modeler); Potential failure (software everywhere, hope to find useful guidelines), desire to transfer verification technology to practicing software engineers

Problem choice in IS projects (2)

- IPID
  - Domain: Intrusions in IT networks
  - Goal: To relate low-level to high-level intrusion events
  - Source: Failure of current techniques, absence of governance loop
- Privacy in healthcare (NvN)
  - Domain: Telemedicine
  - Research goal: So.t.p. in privacy protection in telemedicine
  - Source: Potential failure wrt certain norms of privacy
- VISPER
  - Domain: Physical and digital security policies
  - Goal: To integrate their specifications
  - Source: Potential failure (development of mobile technology, possibility of integrated language)
- VRIEND
  - Domain: Security in decentralized networks
  - Goal: To develop decision support for cost-effective policy specification and implementation
  - Source: Potential failure (increase of virtual networks, lack of attention to security)

Problem choice in IS projects (3)

- ADEPT
  - Domain: Process management
  - Goal: To advance s.o.t.a. of PM
  - Source: Extrapolation of current technology
- COREPRO
  - Domain: Release management of electrical components in auto development
  - Goal: To provide consistent RM
  - Source: Failure of current RM at DaimlerChrysler
- ECOPOST
  - Domain: Evaluation of process support IT
  - Goal: To evaluate impact financially/economically
  - Source: Extrapolation of current practice; potential failure (increasing pressure from business, potentially useful techniques available)
- SEINE
  - Domain: Interoperability of IT in health care
  - Goal: To detect and resolve semantic inconsistencies
  - Source: Potential failure (things work more or less but may deteriorate; continuing hope for solution, now with semantic web technology)