Reflections on 40+ years of software engineering research and beyond

an insider's view

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Outline of the talk

• A journey through 40+ years of software engineering research, mostly observed through ICSE

• What did we produce?

• How can their success (impact) be "defined"?

• How can it be measured?

• What can we learn from past?

• Can we do better?

• Will the paradigms followed in the past survive in the future?
Part 1: Looking backwards

- Where does ICSE come from?
- What can we learn by mining ICSE data?
A bit of history

• The roots are in the NATO meetings in Garmisch-Partenkirchen (1968) and Roma (1969)
• **ICSE** started in 1975, this is the 31-st
  – first conference called ICSE is actually ICSE2
    • ICSE1 was NCSE---1st National Conf on Software Engineering, Sept 1975
  – became annual in 1987
• **TSE** started in March 1975
• **ESEC** started in 1987, **FSE** started in 1993, they joined in 1997
• **TOSEM** started in January 1992
Mining ICSE data

• International Conference on Software Engineering
  – How much international?
  – How are the different engineering research stakeholders (academia, industry) represented?
    • scientific leadership, contributors

• Paper demographics
  – Is ICSE an attractive venue?

• Research areas
  – How did they evolve?
ICSE PCs: industry/academia

%Industry

%Academia
Total number of accepted papers

average 44
ICSE papers: geographical distribution

- Rest of World: 1%
- Asia Pacific: 10%
- Europe: 24%
- North America: 65%

ICSE 2009
Papers: industry vs. academia

- **average 1976-1994**
  - AC 56%
  - IND 44%

- **average 1995-2008**
  - AC 83%
  - IND 17%

- **average**
  - AC 70%
  - IND 30%
Preliminary findings

ICSE is nurtured by an international community

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High number of submissions, high selection rate

There is a consensus that ICSE is a prestigious venue
Preliminary findings

• Industry participation decreased over time
  – research labs of large corporations disappeared
  – ICSE became more research oriented
    • initially: tool fair
    • then: tutorials
    • now: workshops
  – now mostly co-authored papers (academia/industry)
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![Graph showing the percentage of topics over years from ICSE 2002 to ICSE 2008](graph.png)
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![Graph showing topics over time]
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**Chart: ICSE 2009**
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![Graph showing trend over years](image)
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Programming languages
Some findings

• Large variety of topics
• Trend from "methodology oriented", informal approaches to systematic and formally-based approaches
• Increased attention on empirical evaluations
• Still little on paradigmatic examples or domain-specific approaches
Can we identify our best products?

• Which criteria to follow?
  – Quantitative
    • Citation count
    • Downloads count
    • Others?
  – Qualitative
    • Most influential -10 years?
    • Others?
Quantitative criteria

• Citation count
  – date of count Jan-March 2009
  – source Google Scholar
  – version (conference/journal) both (if j expands c)
  – precision ???

• Number of downloads
  – date, period Jan-March 2009, 12 months
  – source ACM digital library
  – version conference
  – precision ???
Outstanding products based on citations

1. Program slicing (ICSE'81) 2120
2. Statemate: a working environment for the development of complex reactive systems (ICSE'88) 1170
3. N degrees of separation: multi-dimensional separation of concerns (ICSE'99) 997
4. Bandera: extracting finite-state models from Java source code (ICSE'00) 791
5. Software processes are software too (ICSE'87) 688
6. Managing the development of large software systems: concepts and techniques (ICSE'87) 667
7. Executable object modeling with statecharts (ICSE'96) 622
8. Designing software for ease of extension and contraction (ICSE'78) 605
Citations vs expert judgment

**most influential papers**

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How do we compare with others?

Citations of most influential papers

ICSE 2009
#Downloads (-12 months)?

From ACM DL


2. Managing the development of large software systems: concepts and techniques (ICSE'87): 705---667 cit

3. New directions on agile methods: a comparative analysis (ICSE'03): 567---161 cit

4. Program slicing (ICSE'81): 520---2120 cit

5. Quantitative evaluation of software quality ICSE'76: 495---212 cit

6. Static detection of cross-site scripting vulnerabilities ICSE'08---396---8 cit

7. Analysis and testing of Web applications ICSE'01: 375---195 cit

8. Aspect-oriented programming and modular reasoning: ICSE'05: 300---32cit
Findings: #citations vs. #downloads

• Time factor (both #citations an #downloads)
  – my Jan-March numbers are different from the current ones
  – how can you compare #cit of a 20 years and a 2 years old paper?
• No significant correlation between citations and downloads
• #citations and #downloads express different merits
  • example: a highly downloaded paper may be useful in practice, but does not inspire further research
• #downloads demonstrates longevity of ICSE contributions
  • 3 out of the top 5 highest #downloads are papers over 20 years old, one is more than 30
Findings: #citations vs. expert judgment

- Citations and expert judgment are better correlated, according to the ICSE experience
  - most highly cited papers have been recognized as influential
  - ...but several influential papers have low citations
What do the numbers tell us? Do they indicate impact?

- Does the number of paper citations indicate impact of a piece of work?
- Do citations of papers in a journal/proceedings indicate impact of a venue?
- Do citations of one's research measure impact of that research?
Part 2: A side road on numbers/citations

Joint Committee on Quantitative Assessment of Research
Report CITATION STATISTICS
Intl Mathematical Union (IMU)
in cooperation with Intl Council of Industrial and Applied Math (ICIAM)
and the Institute of Mathematical Statistics (IMS), 6/12/2008

R. Adler, J. Ewing, P. Taylor (Eds.)
A side road on numbers/citations

Informatics Europe
Report RESEARCH EVALUATION FOR COMPUTER SCIENCE
Viewpoint article in CACM, April 2009
Eds. B. Meyer, C. Choppy, J. Staunstrup, J. van Leewen (Eds.)

Also D. Parnas, CACM nov 2007
STOP THE NUMBERS GAME
Facts

• Numbers increasingly used to assess/rank
  – papers
  – journals and conferences---the (in)famous *impact factor*
  – individuals

• Motivations
  – different stakeholders need to evaluate research
  – peer review can be subjective
  – peer review is expensive
  – *numbers are simple and objective* simplistic and misleading
Findings

• Much of the modern bibliometrics is flawed (statistics improperly used)

• Objectivity and accuracy illusory
  – *the meaning of a citation can be even more subjective than peer review*

• **Sole** reliance on citation data provides incomplete and shallow understanding of research
  – *only valid if reinforced by other judgments*

  _numbers are not inherently superior to and cannot substitute complex judgement_
Why are citations counted?

From Thomson Scientific

"The value of information is determined by those who use it...the better way to measure the quality of work is by measuring the impact it makes on the community at large"

The statement makes an implicit equivalence assumption

#citations = impact
Citations vs impact

• Is the equality

\#citations = impact

justified? (When) does it work?

• It presupposes a highly rational and uniform model of reference giving, but this is NOT true
The complex sociology of citations

Average citations per article

citation practices differ substantially among disciplines
The complex sociology of citations

- Citations are of two main kinds
  - REWARD
    - intellectual dependency on the cited
  - RHETORICAL
    - a way to carry out a scientific conversation
      - reference included to show that topic is of interest to someone else or to prove that the author knows the literature
      - the cited explains some result, not necessarily of the cited author
      - the cited represents another approach, or is an example of…
The complex sociology of citations

• Most citations are rhetorical
• Reward citations can be of many kinds
  – currency, negative credit, operational information, persuasiveness, positive credit, reader alert, social consensus
• Obliteration effect
  – incorporated into other work, which is cited
An example

• The impact of MESA on system design, by HC Lauer, EH Satterthwaite, ICSE'79
  – 60 cit (highest of '79), 19 downloads … one of the few papers on MESA

  BUT

• Its impact evidenced by indirection
  – Implementing remote procedure calls, by Birrell&Nelson, ACM TOCS 1984, 1840 citations
    • explicitly states its debt to MESA
If impact is the question, are (citation) numbers the answer?

• Citation data and statistics provide some valuable information
  – very high citation numbers tell more than smaller but only a limited and incomplete view of research quality
• Statistics derived from them often poorly understood and misused
• Expert judgment cannot be eliminated
• Research too important to measure only with a coarse tool
Lost in the journey?

- We started by looking back at SE research through ICSE as a magnifying lens
- We tried to assess what we accomplished by identifying our impactful results
- We got trapped by the number game

Should we look for better assessment methods? Why?
Should we care?

• Our social responsibility is to care about *impact* of research
  – *understanding*
  – *measuring*
  – *improving*

• If we don't, others will do
  – governments, funding bodies
    • accountability, "return" to taxpayer or donor
  – universities, schools, departments
    • competition (CS versus other sciences, SE versus other CS areas)
Part 3: Where do we go from here?

Towards
• understanding
• measuring
• improving
impact of SE research
Do we understand what impact is?
How can we measure it?

- Not quite
- A notable counter-example
  - IMPACT project
    - aims at demonstrating **impact of SE research on practice**
    - focuses on specific research areas in SE
  - an initiative of ACM SIGSOFT
    - the SIGSOFT Impact project.webarchive
  - area leaders responsible for research
  - backed by sound science history methodology
Published results

Some key findings/confirmations

• SE research has had impact on SE practice
• Maturation needs time
  – 15-20 years between first publication of an idea and widespread availability in products
• Substantially different mechanisms have been successful at causing impact
  – people are key to knowledge transmission
    • people movement
    • almost all impact traces lead back to PhD theses
Problems with impact definition/measurement

• Scholarly assessment of impact of SE research on practice is a difficult and expensive
  – it is research
• Substantially different methods are needed to assess impact of
  – journals/conference
  – individual researchers/papers
Obstacles to impact

• The dominant reward/recognition system based on publication count does not favor impact
  – from D. Parnas, CACM 2007
    • "it encourages superficial research"
    • "it encourages small, insignificant results"
    • "it rewards publication of half-baked ideas"
    • "it slow scientific progress: to increase their score, researchers must avoid tackling the tough problems and problems that will require years of dedicated work and instead work on easier ones"
Obstacles to impact

• Building on top of others' work too often too difficult or impossible
  – TOSEM papers 2001-2006
    • 60% refer to a tool, only 20% installable
• ICSE'06 paper by Zannier, Melnik, Maurer evaluates ICSE empirical studies
  • complete absence of replicated studies
  • self-evaluations dominate empirical studies
Conclusions: on impact

• Research on impact of SE research must continue and should become a community effort
• As a community we need to get to a common understanding and articulate methods for definition and measurement of impact for
  – journals/conferences
  – individual research
    • define impactful research products beyond paper count
• We must be aware of risks
  – be rigorous, avoid being incestuous
Conclusions: on enhancing research flow

• Define community challenges and support repeated experiments
  – catalogs of case-studies on which competing approaches can be applied and compared
• Favor research products backed by tools, but verify that the claimed results of their use can be replicated
• Use Internet facilities for community support
  – research-as-service
• Reward successful reuse of one's research rather than paper citation
The end of the journey

In 40+ years we have gone far
Beginning of a new journey

We have been successful, but we can do more and better
Towards impact-aware research
Can the ICSE community take the lead of this?
Acknowledgements

• L. Osterweil, J. Kramer, A. Wolf and IMPACT project members for their insights into impact of research
• Andrea Mocci, Mattia Monga, for helping me in mining data
Thank you!!!