Industry-academia collaborations in Software Engineering: 20+ Years of Experience from 50+ international projects

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An invited talk for:
Feb 9, 2021
Outline

- **Background**
  - Background of the speaker… Principal Investigator (PI)
  - (Reminder) What is Software Engineering (SE) and SE research?
  - Our research philosophy and approach

- **Experience in industry-academia collaborations (IAC)**

- **Challenges, best practices, and collaboration models for IAC**
My background (international experience)

Work experience:

- Associate Professor, Queen’s University Belfast, UK, 2019-
- Associate Professor, Wageningen University, Netherlands, 2017-2019
- Associate Professor, Hacettepe University, Ankara, Turkey, 2015-2017
- Associate Professor, University of Calgary, Canada, 2006-2014
- CEO and Managing Consultant, Bahar Software Engineering Consulting, since 2001-
- Software Engineer, Offshore office of Corsha Software Inc., Quebec, Canada, based in: Tehran, Iran, 1998-2001

Education:

- PhD in Software Engineering, Carleton University, Ottawa, Canada, 2006
- MSc in Computer Engineering, University of Waterloo, Canada, 2003
- BSc in Software Engineering, Sharif University of Technology, Tehran, Iran, 2000
Acknowledgement

- I would like to thank all my collaborators since 2001 … (both in industry and academia) … and many others…
(Reminder) What is Software Engineering?

- Software engineering is the systematic application of engineering approaches to the development of software.

- Software Development Life Cycle (SDLC): Phases and knowledge areas:
  - Requirements engineering
  - Software design
  - Implementation (coding, programming)
  - Software testing and QA
  - Software maintenance and evolution
  - Software project management
  - Software process
  - …
Software Engineering (SE): Example Research Questions

- How can we manage **software requirements** in an **effective and efficient** manner?
- How can we **design software systems** in an **effective and efficient** manner?
- How can we **implement software** in an **effective and efficient** manner? (such as OO concepts)
- How can we **test** a given software system in an **effective and efficient** manner?
- How can we **maintain (evolve)** a given software system in an **effective and efficient** manner?
- How should we **manage a software project** in an **effective and efficient** manner?
(Many!) Motivations for applied SE research…

- Did you know that the **global cost** of detecting and fixing **software defects** has risen to **$312 billion annually**?

[Link to source](insight.jbs.cam.ac.uk/2013/financial-content-cambridge-university-study-states-software-bugs-cost-economy-312-billion-per-year)

- Thus, we really need effective and efficient **Software Engineering practices**…
Goal of software engineering (SE) research

- What we, SE researchers, do:

  1. Characterize / formalize software engineering practices, challenges, etc.
  2. Develop approaches to help engineers develop, and test software in an effective and efficient manner

Software companies and engineers

- Engineer and release software
- Software to be used by Clients (customers) using software systems
- Solicit requirements / needs

Software

SE researcher

- Train young researchers in SE
- Publish papers

- Founded and led by myself
- 3 faculty members
- 20+ graduate students
- 10+ industry partners
Research in University of Calgary, Canada (2006-2014)

- Established and led the Software Quality Engineering Research Group (SoftQual)
- [www.softqual.ucalgary.ca](http://www.softqual.ucalgary.ca)

- Research team:
  - 2 Post-doctoral fellows
  - 3 PhD students
  - 9 MSc students
  - 30+ undergraduate research students

- Almost all our projects were applied R&D projects in collaboration with the industry.

- More than 10 industrial partners such as IBM
- More than $1.3 Million CND in funding in 6 years

- Output:
  - More than 30 journal papers and 45 conference papers
  - Several software tools
  - One start-up firm and one commercialized software product
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Our research goal and philosophy

- Goal: To help software companies and engineers “engineer” (develop, test and maintain) large-scale software systems in an effective and efficient manner.

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Research Projects in the UK, EU and Turkey

  - Eight (8) partners from across Europe, including five industry and three academic partners – Project will start in November 2020
  - Budget: €5 million Euros

- **Research Project: TESTOMAT (The Next Level of Test Automation)**
  - Industry partners: Two large companies, project funded by the EU
  - Budget: €21 million Euros

  - Industry partner: An aviation contractor (anonymous)

- **Research Project: Improving test automation practices**

- **Research Project: Automated testing of law-management software suite**

  - Industry partner: Turkish Aerospace Industries, Inc. (TAI)
The TESTOMAT project: The Next Level of Test Automation

- **Topics:**
  - Model-based testing
  - Visualization of test results
  - Test prioritization and selection
  - Improving the quality of automated test-code

- **Project is funded by the ITEA3 program and the government of the six countries involved in the project**
  - “ITEA is a transnational and industry-driven R&D&I programme in the domain of software innovation [in Europe]”

- [www.testomatproject.eu](http://www.testomatproject.eu)
The TESTOMAT project

- **Benefit:**
  - Automating both the test-case design and test-case execution
  - Testing almost all possible paths (would be impossible to do in manual testing)

- **Let’s see the video below”:**
  - www.youtube.com/watch?v=RizUbMhBTho
The TESTOMAT project

Several papers are in the pipeline:

Model-based testing in practice: An experience report from the banking domain

Şerafettin Şentürk, Abdurrahman Akas, Ayşe Betül Karaöz
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Vali N Garousi
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Abstract — Model-driven software engineering has become more popular in recent years. Due to the high number and diversity of users, new testing approaches are necessary to reduce the occurrence of faults and ensure higher quality in industrial applications. The objective of this paper is to evaluate the use of Model Based Testing (MBT) practices in the development and execution of automated test suites to verify and validate internet-banking solutions in the context of a large banking institution in Turkey.

Keywords — Model-based testing, graphwalker, internet banking, expericence report, industrial case study

Pragmatic model-based testing: Experience from the web applications domain

Vahid Garousi
Queen’s University Belfast
Alper Buğra Keleş, Yusuf Balaman, Zeynep Özdemir Giller
Saha Information Technologies A.Ş.

Andrea Arcuri
Kristiania University College

Abstract: In the context of a large software testing company, we have deployed the model-based testing (MBT) approach to take the company’s test automation practices to the next level. We have chosen, from a set of MBT tools, an open-source tool named GraphWalker, and have pragmatically used MBT for end-to-end test automation of several systems. The MBT approach has provided various tangible and intangible benefits.
Projects in Canada

- Project 1: Decision-support for deciding “when to automate testing” and “what (test cases) to automate” **2010-2012**
  - Industry partner: Pason Systems Corporation, Calgary, Canada

- Project 2: Optimizing amount and level of software documentation **2009-2012**
  - Industry partner: NovAtel Inc., Calgary, Canada

- Project 3: Development and assessment of effective test automation infrastructure **2008-2011**
  - Industry partner: MR Control Systems International, Calgary, Canada

- Project 4: Development and assessment of effective automated “environment configuration” testing infrastructure **2007-2009**
  - Industry partner: Alberta Energy Resources Conservation Board (ERCB), Calgary, Canada
  - Challenge: The cost of manual “environment configuration” testing was very high. Need for test automation
Research project #2: Summary

- **Industry partner:**
  - NovAtel Inc., Calgary, Canada, a global leader in GPS and GNSS software and systems (embedded software with C/C++ code inside)
  - The company had CMMI Level-3 certification

- **Clients:**
  - Military, agriculture, ....

- **Challenge:**
  - Huge amounts of effort (cost $$$) were spent for developing and maintaining software documentation in the last several years

  Reminder: According to the literature and various empirical studies, software maintenance typically consumes 40 to 80% of software project costs.

- **Solution:**
  - A systematic approach for reducing cost of software documentation was developed and deployed in the industrial context
How did we systematically optimize cost of software documentation?

For requirements and design documents

- SW Architect (Requirements Engineer, Business analyst...)
- Approver (Team lead, etc.)

Diagram:
- Creating 1st Draft → First Draft → Reviews → Next Version Draft
- Working Draft → Approved Version → Change the doc and create the Next Version Draft

Legend:
- Doc-related Activity incurring costs
- Activity using documentation (benefits)

- E.g., fault localization, root-cause analysis, impact analysis
- E.g., do the actual changes to fix the bug at hand

Use doc to develop artifact/product at hand (e.g., design, code, etc.)
Cost Metrics

- Initial cost
- Number of minutes
- Number of words in the file
- Maintenance cost
- The above
- + Amount of change from each version to the next
- …

Benefit Metrics

- Benefit (usage) during development cycle
- Benefit (usage) after the development: during maintenance
- Which sections of a certain documentation are used?
- How much help a certain documentation artifact has made for a task at hand?
How can we systematically optimize cost of software documentation?

![Design Document Editing time vs. # of accesses](image-url)
Projects in Canada

- **Industry partner:**
  - NovAtel Inc., Calgary, Canada

- **Solution:**
  - A systematic approach for optimizing cost of software documentation was developed and released to the industrial context.

**More details in the following articles:**

Usage and usefulness of technical software documentation: An industrial case study

Golara Garousi a,b, Vahid Garousi-Yusifoğlu c,d,e, Guenther Ruhe b,d, Junji Zhi e, Mahmoud Moussavi b, Brian Smith f

a, b, e geoLEGIC Systems Ltd., Calgary, Alberta, Canada
b, c, e Department of Electrical and Computer Engineering, Schulich School of Engineering, University of Calgary, Alberta, Canada
c, d System and Software Quality Engineering Research Group (SySoQual), Department of Software Engineering, Atilim University, Incek, Ankara, Turkey
d Department of Computer Science, University of Calgary, Calgary, Alberta, Canada
e Department of Computer Science, University of Toronto, Toronto, Ontario, Canada
f, e NovAtel Inc., Calgary, Alberta, Canada

Cost, benefits and quality of software development documentation: A systematic mapping

Junji Zhi a, Vahid Garousi-Yusifoğlu b,c,e, Bo Sun d,e, Golara Garousi c,f, Shawn Shahnewaz c, Guenther Ruhe c,d

a Department of Computer Science, University of Toronto, Ontario, Canada
b System and Software Quality Engineering Research Group (SySoQual), Department of Software Engineering, Atilim University, Incek, Ankara, Turkey
c, d Department of Electrical and Computer Engineering, University of Calgary, Alberta, Canada
d Department of Computer Science, University of Calgary, Alberta, Canada
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f geoLEGIC Systems Ltd., Calgary, Alberta, Canada
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Challenges and best practices

- Synthesized the findings of 33 primary studies

Data from: 33 “primary” studies… Three of them:
A typical simplified process for industry-academia collaborations

Industry–academia collaborations in software testing: experience and success stories from Canada and Turkey

Vahid Garousi1,2 · Matt M. Eskandar3 · Kadir Herkioloğlu4
# Challenges and best practices

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Best practices (success patterns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lack of research relevance</td>
<td>1. Knowledge management (communication, terminology, transfer, training and skills)</td>
</tr>
<tr>
<td>2. Research method related</td>
<td>2. Ensure engagement and manage commitment</td>
</tr>
<tr>
<td>3. Lack of training, experience,</td>
<td>3. Consider and understand industry's needs, challenges, goals and problems</td>
</tr>
<tr>
<td>and skills</td>
<td>4. Ensure giving explicit industry benefits and solve the right problem</td>
</tr>
<tr>
<td>4. Lack or drop of interest /</td>
<td>5. Have mutual respect, understanding and appreciation</td>
</tr>
<tr>
<td>commitment</td>
<td>6. Be Agile</td>
</tr>
<tr>
<td>5. Mismatch between industry and</td>
<td>7. Work in (as) a team and involving the &quot;right&quot; practitioners</td>
</tr>
<tr>
<td>academia</td>
<td>8. Consider and manage risks and limitations</td>
</tr>
<tr>
<td>6. Communication-related issues</td>
<td>9. Researcher's on-site presence and access</td>
</tr>
<tr>
<td>7. Human and organizational factors</td>
<td>10. Follow a proper research/data collection method</td>
</tr>
<tr>
<td>8. Management-related issues</td>
<td>11. Manage funding/recruiting/partnerships and contracting privacy</td>
</tr>
<tr>
<td>9. Resource-related issues</td>
<td>12. Understand the context, constraints and language</td>
</tr>
<tr>
<td>10. Contractual, and privacy</td>
<td>13. Efficient research project management</td>
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<tr>
<td>concerns</td>
<td>14. Conduct measurement/ assessment</td>
</tr>
<tr>
<td></td>
<td>15. Test pilot solutions before using them in industry</td>
</tr>
<tr>
<td></td>
<td>16. Provide tool support for solutions</td>
</tr>
</tbody>
</table>
Another work

Selecting the right topics for industry-academia collaborations in software testing: an experience report

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PDF in: www.researchgate.net/profile/Vahid_Garousi2

Table 4: Ranking of the topics in our case based on the criteria defined by Misirli et al. [1]

<table>
<thead>
<tr>
<th>Topics</th>
<th>Fitness criteria for topics (1: Low, 2: Medium, 3: High)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need for more test automation for test group X</td>
<td>Concreteness 3</td>
</tr>
<tr>
<td>Need for more test automation for test group Y</td>
<td>Concreteness 3</td>
</tr>
<tr>
<td>Need for more test automation for test group Z</td>
<td>Concreteness 3</td>
</tr>
<tr>
<td>Assessing and improving an in-house test automation framework for test group Q</td>
<td>Concreteness 3</td>
</tr>
<tr>
<td>Establishing a systematic, effective and efficient GQM-based measurement program for the testing department</td>
<td>Concreteness 2</td>
</tr>
<tr>
<td>Assessment and improvement of test process maturity using TMMI and TPI-Next</td>
<td>Concreteness 3</td>
</tr>
<tr>
<td>Bi-directional knowledge transfer (in software testing) from/to international organizations in the aviation industry</td>
<td>Concreteness 2</td>
</tr>
</tbody>
</table>
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  - Of the speaker, and his research teams in the past
  - Our research philosophy and approach
- **Success stories of industry-academia collaborations**
  - Projects in Canada
  - Projects in Turkey
  - Challenges, best practices, and collaboration models

Questions and answers