State-of-the-Art Survey

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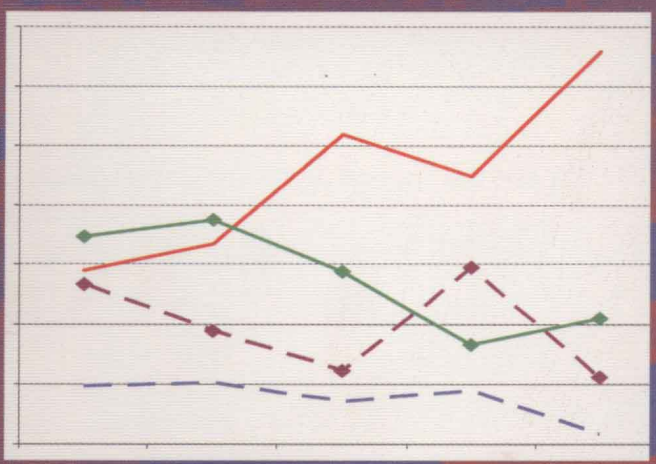
Victor R. Basili Dieter Rombach
Kurt Schneider Barbara Kitchenham
Dietmar Pfahl Richard W. Selby (Eds.)

Empirical Software Engineering Issues

Critical Assessment and Future Directions

International Workshop
Dagstuhl Castle, Germany, June 2006
Revised Papers



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Preface

Victor R. Basili, Dieter Rombach, and Kurt Schneider

Introduction

In 1992, a Dagstuhl seminar was held on "Experimental Software Engineering Issues" (seminar no. 9238). Its goal was to discuss the state of the art of empirical software engineering (ESE) by assessing past accomplishments, raising open questions, and proposing a future research agenda.

Since 1992, the topic of ESE has been adopted more widely by academia as an interesting and promising research topic, and in industrial practice as a necessary infrastructure technology for goal-oriented, sustained process improvement. At the same time, the spectrum of methods applied in ESE has broadened. For example, in 1992, the empirical methods applied in software engineering were basically restricted to quantitative studies (mostly controlled experiments), whereas since then, a range of qualitative methods have been introduced, from observational to ethnographical studies. Thus, the field can be said to have moved from experimental to empirical software engineering.

We believe that it is now time to again bring together practitioners and researchers to identify both the progress made since 1992 and the most important challenges for the next five to ten years.

Objectives

The purpose of this workshop was to gather those members of the software engineering community who support an engineering approach, based on empirical studies, to:

- Identify the progress of ESE since 1992 (Dagstuhl Seminar No. 9238*)
- Summarize the state of the art in ESE
- Summarize the state of the practice in ESE in industry
- Develop an ESE roadmap for research, practice, education and training

Three sessions were set up to discuss some of the most eminent challenges in ESE:

1 The Empirical Paradigm (Lead: Dieter Rombach)

The two topics addressed in this session were "Approaches for Empirical Validation" and "Exploration versus Confirmation." The session was complemented by a historical review.

Approaches for Empirical Validation
Numerous types of approaches are used for empirical validation. Questions relevant in this context include:

Which approaches are useful in what situation? How do we combine quantitative and qualitative studies? Which new and innovative approaches have surfaced lately?

Exploration versus Confirmation
Empirical studies range from exploring new, badly understood software engineering approaches for the purpose of incremental learning to confirming well-defined software engineering approaches. This raises a number of questions:
Which of these study forms is appropriate under what circumstances? How do we deal with validity threads (especially for exploratory studies)?

Historical Review
Guest Speaker: Mike Mahoney, a science historian from Princeton, provided a historical review on how other disciplines have dealt with the issue of "exploratory versus confirmatory studies." He then suggested some ideas for software engineering.

2 Measurement and Model Building (Lead: Victor Basili)

The two topics addressed in this session were "Data Sharing" and "Effective Data Interpretation."

Data Sharing
We have not yet established clear rules for handling ownership of empirical data – like those in other disciplines such as physics. This raises the following questions:
What is the value of empirical data, testbeds, and other study artifacts? How should they be shared for replication? What are the limits of sharing? How should ownership be recognized in publications? How can the probability of misuse be minimized?

Effective Data Interpretation
Proper interpretation of empirical data is a challenging task. The most obvious questions in this context include:
What are scientifically acceptable means of interpretation? What new approaches (e.g., visualization, simulation) can help? How do we combine evidence from individual studies into more abstract evidence?

3 Technology Transfer and Education (Lead: Kurt Schneider)

The two topics addressed in this session were "Technology Transfer" and "Education." They are two facets of making an impact with empirical work.

Technology Transfer
Empirical studies can be used to facilitate and speed up technology transfer into practice. Relevant questions in this context include:
How do we package results for different purposes and contexts? How can we use empirical software engineering to speed up technology transfer? What information do practitioners need from empirical studies? What is most convincing for practitioners?

Education
Empirical methods have to be taught, on the one hand; on the other hand, empirical studies can be used to teach other computer science and software engineering topics better. This raises a number of questions:
What are the experiences for effectively teaching empirical study competence? What are the experiences and approaches for integrating empirical studies into computer science or software engineering curricula? What educational methods are suitable for teaching empirical or evidence-based software engineering? How can education be improved?

Workshop Organization

To address the aforementioned challenges, an international workshop on the topic of "Empirical Software Engineering" was organized and held at the International Conference and Research Center for Computer Science (IBFI) at Dagstuhl Castle in Germany. The motivation for this workshop was to provide a forum for a relatively small but representative group of leading experts in software engineering with an emphasis on empirical studies from both universities and industry to meet and reflect on past successes and failures, assess the current state of the practice and research, identify challenges, and define future directions. An Organizing Committee identified key topics and key people who should participate in the workshop. The topics were chosen for discussion along with the session chairs and the people who were to present introductory talks. A final session was aimed at devising a roadmap for future work.

After the selection of discussion topics, introductory talks, and session chairs, approximately 30 more participants were invited to submit position statements on the selected topics. The participants came from Europe, the USA and Canada, Asia, and Australia.

The workshop was scheduled to run from Tuesday, June 26, 2006, through noon on Friday, June 30, 2006. Three full-day sessions were devoted to the topics listed. A half-day session was devoted to the development of a roadmap.

Session Organization

During each session, the Chair set the stage, by summarizing the state of 1992 and introducing the two selected topics. Two introductory presentations per topic set the tone and raised issues for discussion by identifying the progress made since the 1992 Dagstuhl Workshop, raising issues and challenges for the next five to ten years, and providing a list of provocative statements. Based on the issues raised by the introductory presentations and additional issues raised by other seminar participants, lively discussions took place. The discussions were deepened in up to four parallel working groups. Each working group was asked to provide a summary of their discussion. The session was concluded with the presentations of the working groups and final discussions. The material contained in this volume includes, for each session, the keynote address, introductory talks, position papers, summaries of the working groups, and a discussion summary.

Results

In session 1, on the empirical paradigm, the topics of approaches for empirical validation and of exploration versus confirmation were discussed. Workshop participants agreed that the community has matured since 1992 but is still in a very early phase compared to other disciplines. Improvements were suggested, among others, with regard to types of studies (e.g., longitudinal case studies), complementary usage of quantitative and qualitative studies, and theories for aggregating results across studies.

In session 2, the topics of data sharing and effective data interpretation were discussed in the context of measurement and model building. Clearly, as a community we need to build on each other's work in order to build models that represent the knowledge of the discipline better. We need effective approaches to interpret these models across multiple domains, environments, contexts, etc. Workshop participants agreed on these goals but did not always agree on how to achieve them. Discussions ran from debates on the necessity of protocols, to the use of open source data as opportunities of study, to ways of combining the results from individual studies, to building theories based on multiple studies.

In session 3, technology transfer and education were discussed. These issues are tightly interwoven. Good empirical education will lead to competent graduates. In their industrial careers, they are more likely to use and adopt empirical results than others. However, this will be a long-term effect. Workshop participants agreed there need to be explicit, short-term technology transfer mechanisms. Discussions and working groups discussed achievements and pointed to future research agendas.

Past Achievements

Since 1992, the community's understanding of how to perform empirical studies in the area of SE has improved. Consequently, the amount of empirical study activity has grown dramatically and there are many more sources of data and results from studies than there were then. Furthermore, the community was able to provide a body of knowledge from empirical studies in a few software engineering areas (e.g., inspections).

There have been a fair number of collaborations, some sharing of data, attempts at combining evidence from various studies and even the beginnings of the development of theories. Some of these results come from the enlargement of the community of researchers and some come from the availability of vehicles for publication and sharing of knowledge, e.g., ISERN: the International Software Engineering Research Network (started in 1993), the *Journal of Empirical Software Engineering* (started in 1996), and the International Symposium on Empirical Software Engineering (started in 2001). Some of the data have begun to be shared by different research groups, often involving some form of collaboration. But there are problems associated with successful sharing, e.g., regarding the overhead. Open source has become a major source of new data and opportunity for study. Various mechanisms are being studied for combining results of individual studies using experience bases and evidence-based approaches. Very little has been done in building theories from multiple studies but the problem has been identified as an area for further research.

Since 1992, empirical methods have been taught at many universities today. All courses discussed were created and designed after the 1992 workshop. The necessity to study empirical work in software engineering was seen on different levels of education, from Bachelor to graduate levels. Today, there is a clear shift to expecting empirical validation of results in software engineering publications. Papers are less likely to be accepted without them. PhD students, the potential next generation of researchers, are exposed to ESE techniques in a growing number of institutions.

Empirical validations do not necessarily require controlled experiments. During the last few years, well-prepared case studies in a realistic environment added an important facet. In a real industry project, a technique can prove its scalability and its fit to a specific industry context. Therefore, collaborations between academia and industry have been widely acknowledged in the meantime. They are a key to making an impact with empirical results. This awareness has grown significantly since 1992.

Key Points of Dissent

Probably the biggest source of dissent was the need for protocols in the sharing of data. Some felt that there should be some organized set of protocols for sharing data that would promote the sharing activity and protect the integrity of the data, while others felt a more free form of exchange was more appropriate. The concept of whether the experimenter owned the data was hotly debated and the view that programs are often considered the intellectual property of the developer was considered a detriment to data sharing.

Much empirical work is based on identifying problems, goals, or hypotheses, and then identifying the kind of design that should be applied and data that should be collected. There was some concern that studying open source was more of a bottom-up approach and that the data needed might not always be available, leading to a poor study or a change of focus for the study to satisfy the data that are there.

Although there is a general trend towards offering courses on empirical techniques, there is no consent on their contents or structure. Depending on the teachers' attitude, courses either tend to be focused on statistical methods or on conveying a more general view of research and evidence. Different books on empirical results emphasize different styles. Stimulating reflection in students is the common driver of both attitudes.

Collaboration with industry is seen as an important prerequisite. Researchers want to transfer their results to industrial use. Often, this is associated with funding through a company. Many see consulting and industry validation almost as synonyms. However, some participants stressed the two-way character of such a collaboration. Not only will practitioners learn from researchers, but researchers will also need to learn from practice: What are relevant research questions? What are valid arguments to sell a result? Researchers and industry experts need to meet on middle ground.

Important Topics for Future Work

A historian's perspective yielded the insight that ESE should not feel that it is behind, but there is a normal progress in the maturing of science that, as history shows, takes some time; ESE still needs to probe / explore what the important factors are in

software engineering. Much of science rests on engineering experience and ESE needs to accept that wrong models can be useful to advance science.

Generalization remains a major issue for controlled experiments performed under laboratory conditions. Generalization can be approached by building (logical) models. Extend the body of knowledge from empirical studies by incorporating the whole range of empirical evidence, ranging from controlled experiments to longitudinal case studies, by also integrating quantitative and qualitative research methods.

To better support reuse of empirical knowledge (combination of results), standardized ways, not only for performing empirical studies but also for reporting the results, have to be agreed upon.

Combining the results of various studies is necessary to evolve our understanding of the software engineering discipline. There is a need to share data and artifacts across research groups so that results of varying studies can be analyzed, models built and evolved, and influencing variables identified. An article offering various protocols for the sharing of data and artifacts has been published in the *Journal of Empirical Software Engineering* (2007). The future work involved here is to test out the protocols and evolve them based on experience.

In many ways, empirical study in software engineering is opportunistic, and we need to find those opportunities for data and artifacts. Open source is one such opportunity. We need to experiment with mechanisms that allow us to use open source projects in more effective ways, e.g., by letting an empiricist be part of the study from the beginning.

Identifying and experimenting with ways to combine data from multiple studies are one of the most important areas of research if we are to be successful in building effective models in the software engineering discipline. We still struggle with how to do it effectively.

Abstracting from models to theories is a natural progression for most disciplines. Research is needed in approaches to building theories, representing them, documenting them, schematizing them, and evaluating them.

Teaching empirical techniques requires good teaching material, such as textbooks. Sample documents and free data would be of great help to try established empirical techniques. Participants suggested exchanging study material on specific Web sites. These could be shared among the empirical research community.

Establishing and maintaining collaborations between industry and academia will be even more important in the future. Many (junior) researchers find it challenging to approach a company successfully. Even senior researchers admit there can be many failures and disappointments before a fruitful collaboration emerges. More guidance and more examples in the area of collaborations would lower the threshold.

How to select rewarding topics for ESE research was discussed several times. While research had important successes in fields such as reviews and inspections in the past, many believe the agenda needs to be broadened. Different schemes were proposed to visualize current areas of work. Industry will have a say in defining future research roadmaps.

Established, well-understood areas of empirical work, such as inspections, make good candidates for a common repository of education material. Every student who wants to become a mature empirical researcher should replicate some of the classical inspection studies!

Acknowledgements

It would have been difficult to organize a workshop like this without help from the community. First, we would like to thank all the workshop participants for their effort in submitting position papers and participating in the discussions. Next, the presenters of the introductory talks and the session chairs as well as the chairs of the working groups deserve a special thank you for their contributions to the success of the workshop.

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September 2006

Victor R. Basili
Dieter Rombach
Kurt Schneider

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