Towards Managing and Organizing Research Activities

Angelika Kaplan, Hamideh Hajiabadi, Manar Mazkatli, Larissa Schmid, Snigdha Singh
Karlsruhe Institute of Technology
Karlsruhe, Germany
firstname.lastname@kit.edu

Martina Rapp, Sofia Ananieva
FZI Research Center for Information Technology
Karlsruhe, Germany
lastname@fzi.de

Romina Kühn
Technische Universität Dresden
Dresden, Germany
romina.kuehn@tu-dresden.de

ABSTRACT

Science is a key pillar for human progress. Especially Software Engineering (SE) – as a research subdomain of Computer Science – is an intriguing field of research that has a high economic relevance nowadays and serves as a significant enabler for innovations in other research disciplines as well. However, conducting research in SE comes with several challenges that researchers face during different research activities: finding research gaps, choosing an appropriate research design for a relevant, scientific problem, understanding how to evaluate and assess work of other researchers, and communicating research results in an understandable, comparable, and trustable way. Currently, these activities are hampered by a lack of common terminology and missing understanding of dependencies between research artifacts (i.e., contributions, research questions, evaluation method) as well as different search restrictions and low information visualization and information overload in digital search engines. To support researchers during the aforementioned activities and to address the described challenges, we present a multidimensional classification scheme of SE research. We evaluate the approach regarding research planning activities and research paper classification based on a survey involving the research of five PhD students in SE and illustrate the applicability of this scheme. We argue that research results will be easier to understand, more comparable, and traceable over time by using the proposed classification scheme.

1 INTRODUCTION AND MOTIVATION

Software Engineering deals with the question how to systematically arrive from imprecise, incomplete and contradicting requirements to executable code. It is also a field of high economic relevance, which increases constantly (cf. "software is eating the world" [1]) and serves as an enabler for innovations in other research disciplines as well. On the one hand, software engineering picks up on research in the fields of sociology, cognitive science, and psychology (e.g., Belbin's team roles [6]). On the other hand, approaches developed in SE such as Scrum[1] are used and adapted by other (engineering) disciplines (e.g., [2]). From this point of view, it is important to assess how research of high scientific quality is planned and conducted in this area, evaluated according to scientific criteria, published in search engines and communicated in a transparent and understandable way for specific focus groups such as researchers and practitioners in industry. Thus, scientific SE papers have a major impact on an effective communication and knowledge transfer of research results in academia and practice. However, these aforementioned research activities are very challenging: First, researchers have to identify research gaps and related work for conducting scientific work. Today's search engines only support keyword-based searches mostly in title and abstract. Not much effort is done further: Papers are stored in monolithic PDFs lacking detailed documentation required for faster and more efficient knowledge transfer [3] considering the high number of publications. Second, researchers need to understand how to evaluate papers from digital sources regarding their relevance in order to relate or build own research upon. Third, planning and conducting research is also challenging regarding the selection of an adequate research design for a scientific problem to obtain insights and adequately communicate results (i.e., write and report research results in an understandable, trustable, and comparable way to impact ones own and related research communities). To support the aforementioned research activities which are moreover inherently interrelated, we present a classification scheme for the categorization of SE research with regard to derivable research artefacts (e.g., research question, research object, and method design). Thus, we aim to provide a common ground for planning, understanding and assessing scientific work, while supporting its traceability and comparison with related work. In addition, we report a quantitative and qualitative analysis of the classification scheme based on a survey via questionnaire and semi-structured interviews. Our results are published on GitHub[2].

2 CLASSIFICATION SCHEME

We first introduce the main concept of the classification scheme for managing and organizing research activities. The scheme classifies research work with regard to the research object, its related statements, and the underlying evidence. A *statement* is defined "as a fact, a hypothesis or conclusions out of data results of a research object with a given evidence" [3]. The construction of the scheme consists of three dimensions and further classes in each dimension:

(1) Research Object (i.e., object of research to be investigated) with classes *Problem (1.1)*, *Method (1.2)*, *Model (1.3)*, *Metamodel/Language (1.4)* , and *Automation (1.5)*.
(2) Kind of Statement (i.e., specific property of a research object) with classes *Property-as-such (2.1)*, *Property-in-relation (2.2)*, and *Relevance or Novelty (2.3)*.
(3) Evidence (i.e., research method and statement validity) with classes *Argumentation (3.1)*, *Motivating Example (3.2)*, *Case Study (3.3)*, *Survey (3.4)*, *Experiment (3.5)*, *Verification (3.6)*, and *Mining Software Repositories (3.7)*.

Figure 1 illustrates the classification scheme. Detailed specifications of the classes in each dimension are presented in [3].

[1]https://www.scrum.org/

[2]https://github.com/kaplannova/ACM-WomENcourage2021_artifacts_Classification-Scheme

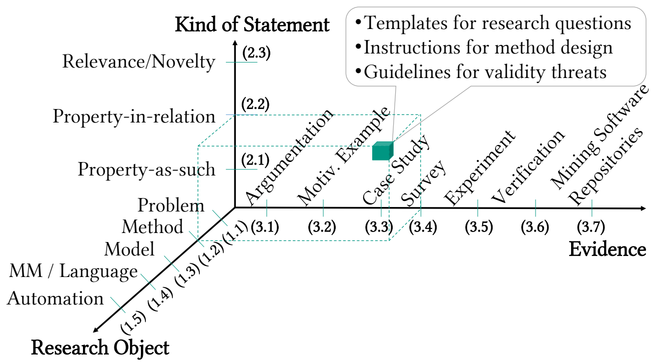

Figure 1: Classification of SE Research (adapted from [3])

3 RESULTS AND FINDINGS

We conducted a questionnaire-based survey with five PhD students and applied the classification scheme to their research (i.e., one selected working package (WP) per student). The goal was to evaluate the applicability of the *classification scheme construction method*, and to assess strongest and weakest aspects of the *classification process* of WPs in different WP phases.

Example. For illustrating purpose regarding the classification process, we give an example from the survey WP-ID-5. First, we give a short summary of the WP that is published in [4]: Architecture-based performance prediction allows cheap evaluation of the performances, if they parameterized over the influencing factors (e.g., input data, used hardware, the applied workload). Modeling and calibrating the architectural Performance Model (PM) is too costly, where existing approaches have to re-extract and re-estimate the whole parametrized Performance Model Parameters (PMP)s by measuring the complete system after each code change. The approach *Continuous Integration of Performance Models* (CIPM) addresses this issue by updating and estimating PMs with parametric dependencies. We can identify four *Research Objects*: (i) The incremental calibration process is a Method (1.2) to estimate processes of PMPs. It provides (ii) prediction models for PMPs (Model (1.3)) considering the parametric dependencies. For estimating PMPs (iii) two Metamodels (1.4) are proposed and used. This (iv) solution approach is automated (Automation (1.5)). Every research object can relate to at least one statement with different kind of evidences (cf. Table 1). For instance, the automation of the incremental-calibration (1.5) was evaluated by investigating the scalability (2.2) by measuring the execution time for different input parameter with Experiments.

Table 1: Classification Results of Conducted WP-ID-5

Research Object	Statement	Evidence
(1.2) Incremental calibration process	(2.1)	(3.2) (3.3) (3.5)
(1.3) Prediction models	(2.2)	(3.3) (3.5)
(1.4) Meta-Model for estimating PMPs	(2.2)	(3.1)
(1.5) Automation of incremental-calibration	(2.2)	(3.5)

Construction Method. We evaluated selected properties of the proposed construction method, i.e., *understandability* of concept, *orthogonality* of dimensions and underlying classes, *usefulness* of classification process [5], and *visualization technique* (cf. Figure 1). For the properties, we used a quantitative rating scale (1 (weak) - 5 (strong)) in addition to qualitative arguments to the rating. Table 2 summarizes survey results. Strongest properties were rated to understandability (av.: 4.4), orthogonality (av.: 5/4.8), and the visualization technique (av.: 4.6), while the weakest rating concerned usefulness (av.: 4.3).

Table 2: Results of Classification Construction

WP-ID	Understandability	Orthogonality (dimensions/classes)	Usefulness	Visualization Technique
1	3	5/4	5	3
2	4	5/5	4	5
3	5	5/5	NN	5
4	5	5/5	4	5
5	5	5/5	NN	5
Average	4.4	5/4.8	4.3	4.6

Classification Process. In the following, we present insights for WPs in phases (i) planned and in conduction and (ii) conducted regarding the classification process itself. Regarding (i), the strongest aspects lie in showing the variability of research strategies and supporting the refinement of contributions; the weakest aspects are given in an unclear granularity of classifying and statement definitions in early planning phases. For the (ii) conducted WPs, we primarily showed the applicability of the approach. It also helped to clarify the research artifacts retrospectively with organizing and orchestrating the final dissertation and to find research gaps.

Conclusion and Ongoing Work. In this work, we presented a classification scheme for SE research to support researchers in organizing and managing their research activities (i.e., planning, conducting, communicating, assessing research, and identifying related work), and evaluated the scheme using a questionnaire-based survey. As long-term goal, we plan to evaluate ongoing research of the PhD proposals according to the proposed classification scheme (1) in order to refine and consolidate its construction, and (2) to monitor and evaluate the quality of the working packages in the planning phase, while actually conducting the research. Additionally, we are working on the extension of the classification scheme on a conceptional level: each coordinate in the three-dimensional classification scheme should be assigned to corresponding templates for research questions, instructions for method design (e.g., choosing appropriate metrics according to statement and underlying evidence), and validity threats, which need to be discussed according to the research object, kind of statement, and underlying evidence. Such refinements may also help to support more detailed scientific search options and visualization techniques than currently available.

REFERENCES

[1] Marc Andreessen. 2011. Why software is eating the world. *WSJ* 20 (2011).
[2] Mitch Bott and Bryan Mesmer. 2020. An Analysis of Theories Supporting Agile Scrum and the Use of Scrum in Systems Engineering. *EMJ* 32, 2 (2020), 76–85.
[3] Angelika Kaplan, Maximilian Walter, and Robert Heinrich. 2021. A Classification for Managing Software Engineering Knowledge. In *EASE '21*. Association for Computing Machinery, New York, NY, USA.
[4] Manar Mazkatli, David Monschein, Johannes Grohmann, and Anne Koziolek. 2020. Incremental Calibration of Architectural Performance Models with Parametric Dependencies. In *ICSA '20*. IEEE.
[5] Muhammad Usman, Ricardo Britto, Jürgen Börstler, and Emilia Mendes. 2017. Taxonomies in software engineering: A systematic mapping study and a revised taxonomy development method. *IST* 85 (2017), 43–59.
[6] Patrick Wagstrom. 2011. Engineering Software Engineering Teams *(SSE '11)*. Association for Computing Machinery, New York, NY, USA, 31–34.