The Three Dimensions of Requirements Engineering: 20 Years Later

Klaus Pohl and Nelufar Ulfat-Bunyadi

Abstract Requirements engineering is the process of eliciting stakeholder needs and desires and developing them into an agreed set of detailed requirements that can serve as a basis for all other subsequent development activities. In order to structure this field, we identified in 1993 three key dimensions which drive the requirements engineering (RE) process, namely, the specification, the representation, and the agreement dimension. In this chapter, we revisit the three dimensions of RE and sketch their evolution into our comprehensive RE framework in the past 20 years.

1 The Three Dimensions of Requirements Engineering (1993)

In the original CAiSE paper from 1993 [3], we identified the three dimensions of RE as depicted in Fig. 1.

The goal within the specification dimension is to arrive at a preferably complete requirements specification. At the beginning of the RE process, the understanding of the system and its requirements is typically opaque. At the end, the understanding about the requirements should be as complete as possible. In other words, all functional requirements, quality requirements, and constraints should be known at the required level of detail.

The goal within the representation dimension is to document all requirements as formally as possible to avoid misinterpretations. At the beginning of the RE process, mainly natural language (informal representations) is used to document the requirements for the system. At the end of the RE process, all requirements should be documented using a formal language. Key reason for the documentation using

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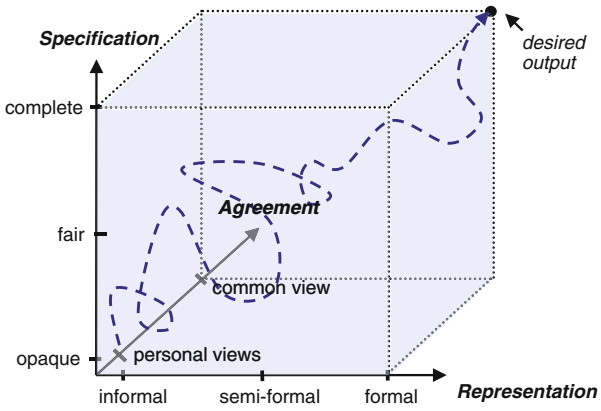

Fig. 1 The three dimensions of RE in 1993 [3]

a formal language is the precise semantics of formal languages which restricts the interpretation of the requirements and thus avoids some typical misinterpretations.

The goal within the agreement dimension is to reach an agreement on the requirements among all the stakeholders involved in the RE process. At the beginning of the RE process, the stakeholders typically have different views with regard to the goals and the requirements of the system. At the end, these different views should have converged. In other words, conflicts should have been detected and resolved and a common, integrated view about the goals and the requirements the system should fulfill should have been established.

Progress in one dimension can impact progress in the other two dimensions both, in a positive but also in a negative way. For example, the elicitation of new requirements may lead to new conflicts among stakeholders or may uncover existing conflicts. In this case, the progress in the specification dimension leads to a drawback in the agreement dimension. Or, the formalization of a requirement may reveal some gaps within the specification which leads to a drawback in the specification dimension.

2 The Three Dimensions and Their Application (1994)

In the 1994 Information Systems paper [4] (a selected best paper of CAiSE'93), we outlined various ways of applying the three dimensions including:

- The categorization of existing RE methods and tools by analyzing the support they provide with regard to the three dimensions and uncovering gaps in the support;
- The classification of RE problems (e.g. technical, social, and cognitive problems) by identifying the cause of the problem based on the three dimensions;

- The analysis of RE practice by identifying problems within industrial RE processes based on the three dimensions and solving them;
- The description of specific situations of an RE process within the three dimensions which are used as guidance for the engineers and for decisions to be made by the requirements engineer;
- The support for establishing pre-traceability of requirements by defining the information to be recorded during the RE process based on the three dimensions.

All these applications have been researched more deeply in the subsequent years and led to several publications. Our comprehensive textbook "Requirements Engineering: Fundamentals, Principles, and Techniques" [5] describes most of those findings and integrates most of these results into a holistic RE framework (see below).

3 Evolution of the Three Dimensions (2012)

From 1993 till today, various industrial cooperations as well as further research led to a deeper understanding of RE and in turn to an adaptation of the three dimensions. The key adaptations are:

- ***Content dimension*** (previously specification dimension): We renamed the specification dimension into content dimension. The reasons for this renaming are mainly twofold. First, the term 'specification dimension' led to various misunderstandings. Most notably, people mixed it up with the requirements specification itself. Second, as already described in 1993 [3], the goal of this dimension is to arrive at a "complete system specification" meaning that all relevant requirements are known and each requirement is understood at the required level of detail. Thus, this dimension actually deals with the knowledge gained during RE about the requirements and the constraints (independently of how this knowledge is represented). Therefore, 'content dimension' is a much better term for this dimension.
- ***Documentation dimension*** (previously representation dimension): We renamed the representation dimension into documentation dimension. This renaming reflects the need for documenting different types of information during the RE process including decisions, rationales, change requests, priorities, risks. Consequently, we refined and adjusted the goal to be achieved within this dimension. The goal is to document the content gained during RE using appropriate documentation languages (e.g. text-based use-case templates, decision tables, formal RE languages, structured text, graphical languages, pictures and the like) and to establish, at the end of the RE process, a requirements specification, which complies with the specification rules defined for the development project (see [5] for details). The final requirements specification does not necessarily have to be formal. In general, the choice of the language used to document particular

requirements information during the whole RE process depends on the usage of the information and the stakeholders using the documentation of the information. For example, the language used to document the requirements to support a proper validation could be totally different than, for example, the language used to document the same content to support design or test activities.

4 Comprehensive Framework for Requirements Engineering

The three dimensions served as a basis for developing our comprehensive RE framework, which comprises the following main building blocks (see Fig. 2):

- ***Three Core RE Activities***: There are three core RE activities, namely elicitation, documentation, and negotiation. The three core activities are directly derived from the three dimensions and are performed iteratively during the RE process depending on the progress made in each dimension.
- ***Four System Context Facets***: Each system is embedded into a context in which it is going to operate and for which it has to provide an added value. Among others, the context comprises the sources for requirements elicitation as well as the users of the system (people and other systems). The context does not only strongly influence the elicitation and definition of the requirements and the constraints about the system, but also the understanding and interpretation of this information. Since the system context is typically very complex, our framework structures the context into four facets: the subject, the usage, the IT system, and the development facet (cf. [1, 2]). Among others, the four facets support a systematic elicitation of information, stakeholder identification, and validation during requirements engineering (cf. [5]).
- ***Three Types of Requirements Artifacts***: The requirements artifacts are the main outcomes of the RE process and are used to drive the RE process itself, e.g. to decide what to do next. Over the years, the use of goals and scenarios has proven to be very beneficial for RE as well as subsequent system development. Thus, goals and scenarios should be used during RE in addition to the traditional solution-oriented requirements (see [5] for a detailed description). There are many key reasons for using goals and scenarios during RE. For example, conflicts among stakeholders can be identified and resolved more easily on a goal level than on the level of detailed solution-oriented requirements. Or, a scenario typically describes a concrete, envisioned system usage which provides a clear business or customer value. Therefore, our framework differentiates between three key requirements artifacts: goals, scenarios, and solution-oriented requirements. The latter comprise the traditional functional, data, and behavioral perspectives on requirements used in system development. In [5], we elaborate on the three key RE artifacts as well as their usage within the RE process.

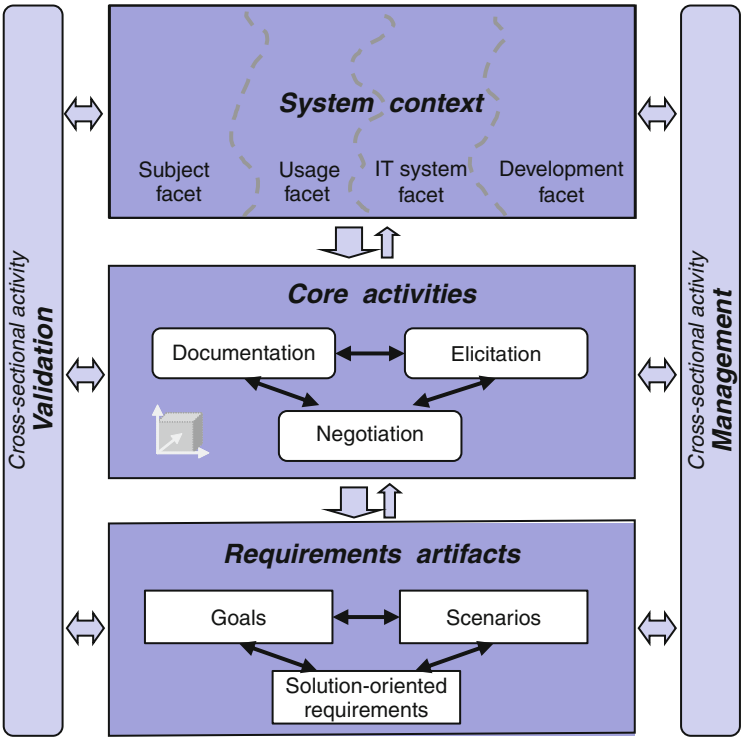

Fig. 2 Our comprehensive RE framework [5]

- ***Two Cross-sectional Activities***: Two cross-sectional activities, namely validation and management, complete our comprehensive RE framework:
  - ***Validation:*** Validation ensures proper quality assurance during the whole RE process. According to our framework, validation not only comprises the validation of the three key requirements artifacts but also the validation of the consideration of the four context facets as well as the validation of a proper execution of the three core activities (cf. [5]).
  - ***Management:*** Similar to validation, the cross-sectional management activity is not restricted to the management of the three key requirements artifacts but includes the management of the system context (e.g. to identify contextual changes) and the management of the execution and scheduling of the three core activities (cf. [5]).

Our comprehensive RE framework is widely used in industry and education. For example, the framework is used as reference model for structuring RE and RE processes within organizations, for determining weaknesses and improvement potentials of RE within the organizations, and as reference structure for trainings provided to managers, requirements engineers, developers, etc. Moreover it is the

backbone for our RE textbook [5] and used to structure RE lectures and courses at universities.

5 Our Comprehensive Textbook

Our RE textbook describes the framework in detail and elaborates on the related foundations, principles, and RE techniques [5]. Throughout the book, we describe the underlying fundamentals, techniques, and methods for the building blocks and illustrate key aspects with numerous examples. Moreover, we provide hints and guidelines for applying the various techniques and methods.

In addition to the elaboration of the building blocks of our framework, we present our goal- and scenario-based RE method called COSMOD-RE which supports the intertwined development of requirements and architectural artifacts for software-intensive (embedded) systems. We further sketch the interrelation between RE and testing and describe specifics of RE in the context of product line engineering.

6 RE Certification by IREB

IREB (the International Requirements Engineering Board) aims at providing a certification model and fostering further education in the field of RE. Members of the board are independent, internationally recognized experts from industry, research, consulting, and education. The 'Certified Professional for Requirements Engineering' (CPRE) certification model currently offers two qualification levels: foundation and advanced level.

Our comprehensive RE framework served as a basis for defining the syllabus and the exams for the foundation level. The foundation level requires being familiar with the terminology of RE, understanding the basic techniques and methods of RE and their application, and being familiar with well-known notations for requirements. To support people in preparing for the CPRE foundation level certificate, we have published the "Requirements Engineering Fundamentals" book [6]. This textbook is (will be) available in different languages including English, German, Portuguese, Spanish, and French. More than 10,000 requirements engineers world-wide have already passed successfully the certification of the IREB CPRE foundation level.

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