

# A Pattern-based Approach to Requirements Formalization and Its Supporting Tool

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博士学位論文  
論文内容の要旨および審査結果の要旨

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A Pattern-based Approach to Requirements Formalization and Its Supporting Tool

1. 論文内容の要旨

① Aim of the Study

Formalization of user's requirements has been recognized as an effective approach to achieving precise, accurate, and complete requirements for software systems and many examples of applying formal specification techniques to realistic software projects have been reported in the literature. However, it is also the fact that most practitioners find formal specification techniques challenging in use. The problem is that they lack sufficient ability and skill to use the formal notation properly. How to effectively help practitioners construct formal specifications to deepen their understanding of the user's requirements still remains a barrier for transferring formal methods to industry.

This doctoral research aims to tackle this problem by developing a specification pattern-based approach and its supporting tool to facilitate the formalization of requirements. Several challenging issues are studied, which include the structure of a specification pattern, the organization of patterns, the representation of patterns knowledge for generating guidance to the developer, and the techniques for building a supporting tool.

② Summary of the Contents

The doctoral thesis is mainly composed of eleven chapters: (1) Introduction, (2) Related Work, (3) An overview on the pattern-based approach to requirements formalization, (4) Specification pattern system, (5) Requirements formalization based on the specification pattern system, (6) Representation of the pattern knowledge, (7) Prototype tool for supporting the pattern-based

approach, (8) Experiment, (9) Conclusion and future work.

After introducing the background and motivation of the research in Chapter 1 and related work in Chapter 2, an overview of the proposed approach is described in Chapter 3, including an introduction to the background of the pattern-based software development paradigm, the underlying principle of the proposed pattern-based approach to requirements formalization, and a simple example to explain the principle. From Chapter 4 to Chapter 6, each of the specific techniques used in the pattern-based approach is discussed comprehensively with examples. Chapter 4 focuses on the discussion of specification pattern definition and the structure of a pattern system. Chapter 5 concentrates on the discussions of how to refine informal specifications to formal ones with the help of specification patterns and various specific techniques for data type declaration. Chapter 6 presents an attribute tree and a specialized finite state machine called Hierarchical Finite State Machine (HFSM) to represent pattern knowledge for generating guidance for the developer to take the next appropriate step. Chapter 7 describes a prototype software tool for supporting the proposed pattern-based approach. The design of the tool and the implementation details are discussed. In Chapter 8, two experiments on the tool supported approach are presented, with the aim of exploring the domain to which the tool and the approach can be applied, evaluating their performance, and finding the weakness for future improvement. Finally, Chapter 9 concludes the thesis and points out future researches.

### ③ Contributions and Originality

The thesis includes the following three major contributions made by the doctoral candidate.

- (1) A specification pattern system is proposed and well defined. The novelty of the system is the use of specification patterns that can be applied by machines to produce effective guidance for the user of the supporting tool to gradually achieve a formal specification from informal requirements. The unique characteristic of the system is that the specification patterns are only used by machines while the user is effectively guided to focus on clarifying requirements without being aware of the existence of the patterns.
- (2) Attribute tree and HFSM techniques for representing pattern knowledge are established. Based on the formal definition of the specification pattern system, an attribute tree notation and a specialized finite state machine called HFSM are

proposed as techniques for representing pattern knowledge. Techniques for searching and applying patterns based on the two representations to produce guidance for the user are established and their usefulness is elaborated.

(3) A prototype tool for supporting the pattern-based approach is constructed. By building the prototype tool, the feasibility and usability of the proposed pattern-based approach is validated. The tool also enables the developer to efficiently use the approach for formalizing requirements in realistic software projects.

## 2. 審査結果の要旨

The significance of the doctoral research mainly lies in the establishment of the specification pattern-based approach to guiding software developers to gradually clarify informal requirements into formal specifications without requiring the developer to have necessary skills for manipulating formal notation. Several challenging issues, such as specification pattern definition, pattern system structure, pattern knowledge representation, and effective software tool support, have been addressed successfully. This novel contribution opens up a new research direction for the formal methods and software engineering communities in developing more effective and highly automated techniques for requirements engineering and specification construction in the future. The whole thesis is well organized and the content of each chapter is well presented. The techniques are described logically and comprehensibly, and the English presentation is clear, accurate, and easy to understand.

以上のことより、本審査小委員会は全会一致をもって提出論文が博士（理学）の学位に値するという結論に達した。