Concern-Sensitive Heuristic Assessment of Aspect-Oriented Design

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Abstract. Recent empirical studies of aspect-oriented design have stressed that the inaccurate modularisation of some concerns potentially leads to a plethora of non-obvious modularity flaws. Nowadays, modularity assessment is mostly supported by design heuristics rooted at conventional attributes such as module coupling, module cohesion, and interface complexity. However, such traditional module-driven assessments cannot be tailored to the driving design concerns, thereby leading to recurring false positives and false negatives in design evaluation processes. Our goal is to promote concerns as explicit abstraction in the design assessment process. We propose an assessment technique composed of (i) a concern-oriented measurement framework to support the instantiation and comparison of concern metrics, (ii) a set of concern metrics instantiated and formalised according to our measurement framework, and (iii) a representative suite of concern-sensitive heuristic rules for detection of design flaws. To evaluate our concern-oriented assessment technique, we are conducting a number of empirical studies which encompass a plethora of crosscutting and non-crosscutting concerns.

1 Problem Description

With the emergence of Aspect-Oriented Software Development (AOSD) [9], there is an increasing awareness that some system concerns might be the key factors to the deterioration of system modularity and the main cause of faults [2, 6]. A concern is any consideration that can impact the implementation of a program [11]. AOSD aims to enhance design modularisation through new composition mechanisms, such as pointcut-advice and inter-type declarations [9]. Aspects are new units of modularity for encapsulating crosscutting concerns, i.e. system properties that naturally affect many system modules.

However, the achievement of modular aspectual designs is far from being trivial. Recent studies have shown that inaccurate separation of certain concerns with aspects leads to multiple concern-specific flaws [3, 8]. Even the "aspectisation" of conventional crosscutting concerns, such as exception handling [1, 6], concurrency control [8], and the Observer design pattern [8], might impose negative effects on the system modularity, including (i) increase on the number of undesirable concern couplings [3], and (ii) decrease on the cohesion of modules realising a certain concern

[8, 12]. These concern modularity flaws make the change and removal of the target concerns error prone [1, 6] and lead to the manifestation of ripple effects [3, 8].

The recognition that concern identification and analysis are important through software design activities is not new. In fact, there is a growing body of relevant work in the software engineering literature focusing either on concern representation and identification techniques [2, 11, 12] or on concern analysis tools [5, 11]. However, there is not much knowledge on the efficacy of concern-driven assessment mechanisms for design modularity and error proneness. Even though some works have started to define concern metrics [2, 4, 11, 12], there is a lack of design heuristics to support concern-sensitive assessment.

Design heuristics are metrics-based rules that capture deviations from good design principles [10]. Concern heuristics would lead to a shift in the assessment process: instead of quantifying properties of a particular module, they would quantify properties of one or multiple concerns with respect to the underlying modular structure. To the best of our knowledge, there is no systematic study that investigates whether this category of heuristic rules enhances the process of (i) evaluating design modularity attributes, (ii) identifying error-prone realisations of design concerns, and (iii) detecting design anomalies, such as bad smells [7]. A bad smell is any symptom that indicates something may be wrong and it generally indicates that overall design should be re-examined [7].

In fact, the area of concern-oriented evaluation is still in its infancy and it also suffers from not subsuming to a unified terminology and formalisation of concern measurement. Even the terminology used in existing definitions of concern metrics is diverse and ambiguous by nature [4]. Hence, it is not straightforward the elaboration of concern heuristics relying on those poorly defined metrics. For instance, it is not clear in definitions of concern metrics the granularity of artefacts, ranging from architecture [12] to implementation-specific artefacts [2, 4], and the target concern modularity property (e.g., coupling, cohesion, or tangling). The terminology of concern relies on the jargon of specific research groups, thereby hampering: (i) the process of instantiating, comparing, and theoretically validating concern metrics, (ii) their adoption in academic and industry settings, (iii) independent interpretation of the measurement results, (iv) ways of composing concern metrics to systematically boost heuristic rules, and (v) replication of empirical studies using concern metrics.

2 Goal Statement and Expected Contributions

Our main goals are *(i) to promote concerns as explicit abstraction in the heuristic design assessment*, *(ii) to provide formal definitions and automated support for concern-based heuristic rules and their composing metrics*, and (iii) *to empirically assess the efficacy of the concern-sensitive heuristics when compared with conventional ones*. In the context of the previously described problems, the expected contributions of our PhD research are summarised as follows.

1. A survey and critical review of (i) existing measurement frameworks, (ii) existing concern-oriented metrics, and (iii) metric-based heuristics rooted at conventional modularity attributes, such as coupling and cohesion.

2. A concern-oriented measurement framework [4] to support the instantiation and comparison of concern metrics.
3. A set of concern metrics formalized according to our measurement framework and empirically evaluated whether they are useful to detect design flaws (and error-prone code).
4. A representative suite of concern-sensitive heuristic rules for (i) assessing the overall modularity of design-driven concerns and (ii) detection of specific design flaws including well known bad smells [7].
5. A fully implemented and documented tool for concern-oriented design assessment to support all elements of our heuristic assessment technique.
6. A complementary set of empirical studies to evaluate different usefulness and usability facets of our concern-oriented heuristic technique for assessment of design modularity and error proneness, including:
   a. Evaluation of the measurement framework's generality through the instantiation of concern metrics and their application in empirical studies.
   b. Systematic investigation on the accuracy of the concern-sensitive heuristics in statistically relevant studies encompassing heterogeneous forms of crosscutting and non-crosscutting concerns.
   c. Quantitative and qualitative assessment of the positive and negative impact of aspect-oriented composition mechanisms and crosscutting concerns on evolving applications.

3 The Proposed Solution

Concern-oriented measurement framework. In order to address the formalisation of concern metrics, our PhD research proposes a concern-oriented measurement framework that supports the instantiation and comparison of concern metrics. The proposed framework [4] subsumes a unified concern terminology and criteria in order to lay down a rigorous framework to foster the definition of meaningful and well-founded concern metrics. In the definition of the measurement framework, we undertook an extensive survey of the state-of-the-art on concern measurement [4].

Concern-oriented metrics and heurists. In addition to a concern measurement framework, we are revisiting existing metrics-based heuristic rules and proposing innovative concern-sensitive design heuristics based on a suite of concern metrics. The proposed design metrics and heuristics have the distinguishing characteristic of exploiting concerns as explicit abstractions in the design assessment process. The goal of concern metrics is the association of quantification with concern properties. Besides, concern-sensitive heuristics targeted at enhancing the modularity assessment process by detecting two overlapping categories of modularity flaws, namely crosscutting concerns and classical bad smells [7]. Furthermore, we are investigating concern-sensitive heuristics as mechanisms to support the detection of (i) faults related to crosscutting concerns [1] and (ii) refactoring opportunities [13].

Automated support. To effectively employ our concern measurement approach, it is imperative to provide automated support to reduce the burden on identifying and representing design concerns as well as applying concern metrics and heuristic rules.

An initial architecture model and a prototype tool [5] to support the proposed assessment technique have already been defined. The final implementation of our tool might provide the following functionality: (i) concern representation in a hierarchical model (*Concern Model*), (ii) means to project concerns onto artefacts of detailed design and implementation (*Concern Manager*), (iii) a reasonable set of concern metrics instantiated by our framework (*Metric Collector*), and (iv) an extensible set of concern-sensitive heuristics (*Rule Analyser*).

Empirical evaluation. To evaluate the generality of the proposed concern measurement framework, in the first year of our research we demonstrated the framework instantiation and extension of a number of concern metrics [4]. We also discussed how the proposed measurement framework can help to point out limitations on the used metrics, and assist the planning of new experimental replications. Now (second year), this Doctoral research is focusing on a statistically relevant evaluation on the accuracy of concern-sensitive heuristics in a number of empirical studies. We have already selected eight representative applications [3, 6, 8] which encompass heterogeneous forms of crosscutting and non-crosscutting concerns. For example, in one application [3] we target at systematically verifying the suitability of aspect-oriented composition mechanisms for designing stable and modular software product-line designs. Software product lines [3] represent a common and important technology to support the derivation of a wide range of applications. In the last year of our research, we expected that the collected data might be relevant to draw conclusions regarding the usefulness of concern-sensitive heuristic assessment to detect design anomalies.

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