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Assessing the influence of import-coupling on OCL expression maintainability: A cognitive theory-based perspective

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ABSTRACT

The aim of this paper is to present the definition of the measures for the import-coupling of OCL expressions, along with the empirical validation of these as early indicators of the maintainability of OCL expressions. This empirical validation has been carried out by means of an experiment and its replica, conducted with undergraduate students of Spanish and Argentinean universities, respectively. To perform this experimental activity, we have followed a cognitive theory-based approach, since the understanding of the cognitive demands that OCL expressions place on software engineers will allow us to examine in greater depth the real influence of import-coupling on the maintainability of OCL expressions. The empirical results, obtained through the analysis of the data from the experiment and its replica, first of all separately and then together after a meta-analysis study, reveal evidence suggesting that import-coupling exerts a certain amount of influence on the comprehensibility and modifiability of OCL expressions. The measures that have most influence on OCL expression comprehensibility are those related to problem objects (Number of Navigated Relationships (NNR), Weighted Number of Navigations (WNN), Depth of Navigations (DN) and Number of Attributes referred through Navigations (NAN)), relationships between problem objects (Number of Navigated Classes (NNC) and Number of Explicit Iterator variables (NEI)), as well as reified objects (Weighted Number of Collections Operations (WNCO)). On the other hand, it is only measures related to relationships between problem objects that are the main influence on OCL expression modifiability. The influence of import-coupling on the comprehensibility and modifiability of OCL expressions was reaffirmed through the cognitive complexity (i.e. we show that import-coupling affects the cognitive complexity and that the latter influences the comprehension and modification of OCL expressions). These results may have educational implications, apart from what they might mean for practitioners in the industry, as is explained in the conclusions.

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1. Introduction

The growing attention given to using models in software development, such as in Model-Driven Development (MDD) [1], has brought model quality into the forefront as an area of research [63,52,57]. In particular, there is special interest in the quality of models specified with the Unified Modeling Language (UML) ,[67] since it is the current modeling standard for system development and it is being adopted increasingly throughout the world [41].

Although UML models provide a good view of software architecture, they are underspecified [36], due to the fact that not all the constraints and essential aspects of a system can be represented by using diagram-based UML notation [43]. UML models should be supplemented with the use of a textual add-on, the "Object Constraint Language" (OCL) [68], which provides the expressiveness and precision that diagram-based UML notation lacks [22,15,16]. Several authors recommended using OCL for expressing constraints in UML models, when designing object-oriented systems [27,90,87]. OCL is also recommended for specifying business rules in data base applications [28], and it has been extended to express security constraints in database models [32] and in datawarehouse models [70]. OCL was also used in a precise definition of software measures for statechart diagrams [76] and for business process models [81].

Most important software providers are recognizing the importance of OCL for developers and testers, promoting their use and incorporating OCL into their own tools [59,72].

All this serves to demonstrate that OCL is becoming an increasingly significant topic. In addition, it has been recognized that OCL could help to enhance the quality of the software produced [36,89,90,7,54], though measures which objectively quantify the quality of OCL expressions do not exist.

The gap in the field as just outlined was what triggered off the research we have been carrying out over the last 5 years. Its focus has been the definition and validation of measures with which to study the influence of import-coupling on two maintainability sub-characteristics of OCL expressions, namely comprehensibility and modifiability.

Our hypothesis is that the import-coupling of an OCL expression within a UML/OCL model may influence the cognitive complexity (i.e. the mental burden of individuals: modelers, developers, testers, etc.), and that high cognitive complexity leads to the situation where OCL expressions exhibit undesirable external qualities [48], such as lower levels of comprehensibility and modifiability. This hypothesis is based on the relationships presented in Fig. 1, which constitutes the theoretical basis for developing quantitative models [8–10].

Why are we interested in the influence of import-coupling on comprehensibility and modifiability? Our reasons are as follows: The extent to which an OCL expression depends on the rest of the UML model, i.e. the import-coupling [6] of an OCL expression, could influence its comprehensibility: The larger the UML context imported to the scenario of an OCL expression, the lower the comprehensibility of that OCL expression. Moreover, when a high number of references are used, implicit assumptions may become invalid over time, thus creating a situation where an OCL expression is more likely to have to be modified. The availability of import-coupling information of a model at early stages would be useful in deciding, for example, which classes should undergo more intensive verification or validation; design decisions can also be justified better.

- We focus on the comprehensibility of OCL expressions within a UML model, since these expressions should be comprehensible and flexible enough for any modification of their meaning to be easily incorporated into the model. Moreover, as comprehension is responsible for up to half the total cost of software maintenance [64], OCL expressions should be carefully considered, since they can be difficult to read and write [20,37,42] and OCL navigation can become complex or may be rather verbose to write [20].

We have specifically focused on OCL expressions specified on UML class diagrams, since the class diagram is one of the most commonly used diagrams in software modeling and is perceived by practitioners to be the most important diagram type [31,41].

Although the mechanism which causes the effect of measures on external quality attributes is assumed to be cognitive complexity [19] (i.e. the mental burden of individuals: modelers, developers, testers, etc.), the definition of measures and the findings of empirical studies are rarely explained using cognitive theories. Darcy and Slaughter [26] argue that the consideration of a theoretical perspective, such as human cognition, provides a solid foundation upon which to derive an integrative model relating internal and external attributes of software quality, and this is fundamental to the success of software measurement [33].

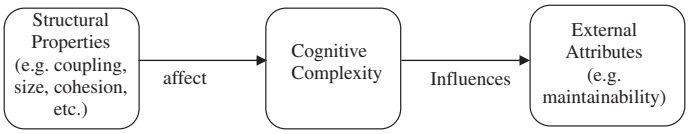

Fig. 1. Relationship between structural properties, cognitive complexity, and external quality attributes [8–10].