DOCTORAL THESIS REVIEW

Ph.D. Candidate: Ing. Jaroslav Šnajberk
Thesis Title: Advanced Interactive Visualization Approach of Component-Based Software
Supervisor: Doc. Ing. Přemysl Brada

The work presented in this doctoral thesis involves three fields of Computer Science and Engineering, namely Component-Based Software Engineering (CBSE), Software Visualization (SV), and Human-Computer Interaction (HCI). The work can be framed within the broader field of Software Engineering (SE), whose contributions often combine multiple fields.

Complex and configurable software, for instance software product-lines, typically have to employ CBSE technologies to cope with complexity, reuse, and adaptability. A software product may be composed of hundreds of interacting components. Multiple technologies exist for aiding on tasks related to comprehension and reasoning about such complex component-based applications. SV is a field that greatly contributes with tool support for program comprehension, where different types of software artifacts can be visualized. This thesis addresses the visualization of component-based applications, namely in architectural terms. Finally, the HCI field comes into play in this work, given that a combination of visualization and interaction is proposed for achieving a better means for comprehension and reasoning about the structure of component-based applications.

The thesis work proposes a generic visualization approach for component-based applications, referred to as AIVA (Advanced Interactive Visualization Approach). By generic it is meant that the approach is not tied to any particular component-based technology. Therefore, the approach is adequate for visualizing components regardless of the implementation technology (e.g. OSGi, EJB). This achieved by capitalizing on earlier work on the ENT meta-model, an abstract model for defining the structure of component-based applications.

The ENT meta-model serves as the abstract syntax for describing components, whereas a UML-like concrete syntax for visualization was elaborated in the context of AIVA. The widespread UML component notation was extended/modified in order to address interactive features of diagram exploration and improve readability. The central enhancement of AIVA consists of enabling developers to filter/hide information, according to the desired level of abstraction when manipulating diagrams.

As a proof-of-concept of the AIVA approach, an extensible platform was developed as part of the thesis work. The platform is referred to as ComAV (Component Application Visualizer), and enables developers to extend it with support for component model types and visualization forms. There are two major roles of ComAV. On the one hand, the platform performs reverse engineering of ENT models from component model technologies (e.g. OSGi, EJB), while on the other hand, it offers visualization support for such models as proposed in the AIVA approach (or other visualization forms).

The AIVA approach and its realization in ComAV were evaluated by means of an empirical experiment for measuring the performance of users (developers) in answering questions regarding the structure of an OSGi component-based application. A comparison was made between UML 2.0 as embodied in IBM's Rational Software Architect (RSA), a widely adopted industrial-strength tool, and AIVA implemented in ComAV. The results revealed speed-up factors favoring AIVA in the order of 3-4 times with respect to the required time to answer the questions of the study.

The main contribution of the thesis work is centered on the integration of interactivity mechanisms in diagramming tools for component-based applications. This approach is used to cope with complexity, enabling developers to filter unnecessary information in order to get a better orientation when exploring component diagrams, as evidenced by the empirical experiment. I believe that mechanisms other than visual notations are necessary for program comprehension in general, CBSE in particular, and that the approach presented in this work follows a viable path towards that end.

The ComAV platform consists of an interesting deliverable of the thesis work. Besides embodying a proof-of-concept of the proposed approach, it may be used by other researchers to investigate about different components models and visualization forms, given that the platform is generic and extensible.

The empirical experiment that was carried out was not extensive and could have a deeper statistical analysis (namely, statistical significance). Nevertheless, I believe it stands as a perfectly valid first evaluation of the proposed approach, showing interesting results. The experiment could also have served the purpose of investigating in detail the difficulties that developers have when using the conventional diagrams (e.g. UML / RSA). Gathering information regarding the observation of user behavior in order to better characterize the problems with existing diagramming tools would have been an interesting issue to address in the thesis.

The thesis is in general well-written, both in terms of form and language. As an exception, I think that the presentation of Chapters 7 and 8 consist of a somewhat too technical description, close to what is normally found in the documentation of tools. Nevertheless, it is not always easy to expose the "real thing" without going into detailed technical issues.

The contributions of this thesis were published in adequate forums. Namely, in three conferences, being one of them sponsored by IEEE Computer Society, and in one journal (Elsevier's Electronic Notes in Theoretical Computer Science). In addition to these four publications stated in the thesis, the tool AIVA/ComAV was recently demonstrated at the European Conference on Software Maintenance and Reengineering (CSMR, March 2013), an important and recognized SE forum.

In accordance with the arguments expressed in this review, I recommend the thesis submitted by Ing. Jaroslav Šnajberk for Ph.D. defence.

Lisbon, 3rd of June, 2013

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Review of the Doctoral Thesis

Advanced Interactive Visualization Approach for Component-Based Software
Submitted by
Jaroslav Šnajberk

Content of the Dissertation

The dissertation is concerned with visualization approaches for understanding overall and detailed structure of a complex software system build from software components. The dissertation is written in English on 147 pages and structured in 10 chapters plus appendices. References include 13 reviewed bibliographic entries with candidate authorship or co-authorship. 1 paper was published in journal.

The introductory chapter provides a solid motivation for the work, state the goals to be achieved, and give an overview of the thesis structure. The following chapters address the problems of component-based (c-b) software development, a theoretical framework of the visualization principles and their role in understanding complex software issues. In Chapter 4, a previous work on c-b applications visualization approaches is reviewed.

In Chapter 5, the candidate proposes the meta-models based on UML 2 and ENT classification approach enhanced by the candidate. The main contribution is described in Chapter 6, where Advanced Interactive Visualization Approach (AIVA) is described. It is based on ENT classification but it can be also directly compared with widely used UML approach. Chapter 7 introduces Component Application Visualizer ComAV as a general platform for interactive analysis of component systems; implementation of AIVA is depicted in Chapter 8. The new visualization approach is evaluated and summarized in Chapter 9. Finally, Chapter 10 offers issues for future research.

Evaluation of the Dissertation

The dissertation presents the work on analysis of complex software systems using various visualization methods for information hiding and/or revealing internal structures of cb systems. It seeks the theoretically argued and practically verified solution that could be used to gain better understanding of software.

The work is well motivated and the candidate distinctly states the main objective of research. Although the various approaches to the software visualization have been the extensively researched areas, the candidate has identified a problem that is both interesting from theoretical point of view and relevant in practice. The approach to the problem is technically sound and theoretically well developed.

Overall assessment

The dissertation offers useful conclusions and accomplishes the main goals that the candidate has set:

- As the main contribution of the thesis, the theoretical model based on ENT classification was introduced. The technique is simple and easy to apply. The resulting solution with ENT meta-model captures the internal relationships of cb system in a unified way. It is comparable with UML approach however it is aiming at different aspects of a system to be visualized and analyzed.

- AIVA and ComAV tool provide new means to capture the characteristics of a system both in small and large scope. The introduced notation is simple and clearly understandable.
- The experiments carried out with different users have confirmed the correctness and the advantages of the proposed approach. The results were published in the prestigious publications.

Comments on the text

The thesis is well structured and easy to follow. Related work is sufficiently acknowledged and the author's contributions are clearly identified. To better motivate the work presented in this thesis, I think it would be good to provide a complete example of the overall process – starting with unclassified source code, adding the classification tags and then to proceed with visualization session aimed at understanding different features of a system.

Language and graphic level

Though the thesis reads well, it contains rather many grammatical errors and misspelling. On page 65, there are 8 errors at least. Although a sufficient number of figures are provided, but many of them are hardly recognizable even in its larger versions in appendices. A pity for a work that is called "Advanced ... Visualization ..."

Question for the defense

- The visualization process supported by a tool should improve the understanding of the systems' unknown features. How is this cognitive process supported? Specifically, is it possible to annotate the explored system on-the-fly, add ENT information to the software etc?
- Is it possible to "somehow pack" the parts of a system into user-defined simpler structures to support hiding of unnecessary details?
- Is it possible to apply/combine different visualization approaches on different parts of a system at the same time, on the same picture?
- The main goal of the AIVA is to help architects to understand and create mental models. How are these "mental" results captured and stored?

Conclusions

The Dissertation addresses an important and relevant problem in the areas of software engineering. The candidate has clearly formulated the problem and proposed original solutions. The dissertation offers useful approaches that are demonstrated on a nontrivial example of a c-b application. Thus I conclude that the author of the thesis *proved* to have an ability to perform research and to achieve scientific results. I recommend the thesis for presentation with the aim of receiving the Degree of PhD.

Brno, May 21, 2013

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