Fifth ICSE Workshop on Component-Based Software Engineering
White paper

Anatomy of a Research Project in Predictable Assembly

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Introduction

Predictable assembly is the activity of predicting properties of assemblies of components prior to actually acquiring the components. Developing and using theories of composition is a core problem area for research in component-based software. A key objective of the *Fifth ICSE Workshop on Component-Based Software Engineering* is the identification and development of composition theories. We will discuss the general structure of composition theories, assess where progress is being made, and identify areas where more needs to be accomplished. To make this discussion efficient, it is essential that we obtain a clear understanding of what constitutes a problem of predictable assembly, and what qualities attend to their solution. Given the diversity of problem domains, component technologies and theoretical approaches to predictable assembly, establishing such a clear understanding is no trivial matter. Yet, the effort is worthwhile because it will prove useful not just to the workshop, but will be conducive to more productive discussions in the research community in the future as well.

In this white paper, the authors propose a structure and vocabulary to serve as a basis for this clear understanding. This structure takes the form of a model research outline that describes topics that should be covered in a hypothetical research paper in predictable assembly. We will refer to the content of this hypothetical report as a model problem and its model solution. The vocabulary of predictable assembly is introduced in the description of elements of this outline. As a test of the generality of the proposed structure and terminology, we illustrate its use to evaluate the classification of an actual research project as being one that addressed a problem in predictable assembly.

A problem in predictable assembly is characterized as a software engineering problem that can be reduced to the form: “Given a set of components C, predict property P of an assembly A of these components” At the core, a solution to such a problem will involve a prediction theory. The prediction theory will be based on certain assumptions about the environment in which the assembly will run and will require information about the components that make up the assembly, thus there are many peripheral issues that reside within the bounds of research in predictable assembly. Whether a paper describes a project that is devoted to developing an assembly-level prediction theory or one of the peripheral issues, a paper describing the work should include all elements of the model described in the following section.

Vocabulary

The following definitions apply to the model problem definition that is provided below and will be assumed during the workshop.

An ***assembly*** is a set of components and their interconnections.

An ***assembly environment*** provides services for component deployment, and application creation. The assembly environment may also provide assembly-time enforcement of the component model.

A ***component*** is an implementation of functionality that can be distributed in binary form and composed without modification according to a composition theory.

A ***component framework*** provides runtime enforcement of the component model. The framework plays a role analogous to that of an operating system[1] but at a higher level of abstraction, one that is usually tailored to an application domain or required assembly properties (e.g., performance or security).

A ***component model*** defines one or more required component interfaces, allowable patterns of interactions among components, communication behaviors among components and between components and the component runtime system, and, possibly, a programming model for component developers.

A ***component technology*** is an assembly environment together with a component model and a component framework.

The Research Model

For any project in this research area, the elements of the research model will be visible; they should be identified and made explicit in a research paper.

To elaborate, the elements of the research model are:

1. A problem statement in the form: "Given a set of components C, predict property P of an assembly A of these components, denoted A.P." In addition to this statement the problem description should include a high-level description of the application area in terms of the types of systems that might be built and the types of components that would be used as well as a description of quality attributes that are likely to be of concern with respect to the development and use of systems in the domain.
2. A description of an assembly-level property prediction theory that is parameterized by C, and perhaps others such as topological constraints. While the project might not

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[1] In fact, the various COM-based Microsoft component models are an integral part of the Microsoft operating systems.

be the development of a property theory, it should involve one in some way. It might be that the project is focused on measuring a component-level property, in which case there should be a statement of what assembly-level property theories depend on the component-level property. The assembly-level prediction theory description should include a discussion of the assumptions the theory is based on including assumptions about the components to which it is applied and the environment in which the components are deployed.

3. A definition of a component property c.p, where c is an element of C, and where c.p might not be of the same type as A.P, note that there may be more than one type of component property that must be known to determine the value of A.P. That is, it might be true that the prediction theory applied at the assembly level depends on component properties of other types or that are determined by different means than the assembly-level property. Again, it might be that the focus of the project is not the component-level property but component-level properties should come into play in any problem in predictable assembly and a description of such properties should be included in the report. Depending on the focus of the project, there might also be discussion of how a value associated with the property comes to be known, how it is communicated, the degree of certainty with which the value is known, and environmental conditions that may affect the value.

4. A plausible description of how the property theory could be validated, that is, the authors should at least give some evidence that it is possible to demonstrate the validity of the theory. Ideally, a description how the theory was experimentally tested will be included in the paper. If the property theory is wholly logical rather than empirical, some proof or other formal argument should be given to demonstrate its validity.

5. A plausible description of how the component properties can be established, through measurement or logical means. Again, even if component properties are not the focus of the project the fact that the problem solution depends on them in some way requires that there be some evidence given that the property values are knowable to some degree of certainty. It might be that the property is discovered through measurement or it might be that it is discovered through evaluation of the source-code. Whatever the case, some argument that the property is knowable should be included in the paper.

6. An illustration of the application of the property theory to a particular assembly. This discussion should include a description of the component technology in which the assembly was built, and a description of the assembly itself including descriptions of the components and the framework into which they were deployed. It should also include a description of the how the experiment was conducted and results. Some of this material will generally be included in the problem description, if so it can be referred back to.

Example Use of the Research Model

At the Software Engineering Institute we developed a prediction-enabled component technology (PECT), COMTEK, that supports prediction of latency of assemblies of components based on measures of component latency.

1. The problem statement for our project is:

   "Given a set of COMTEK wave application components, predict the latency of an assembly of these components deployed in the COMTEK runtime environment."

   In a paper reporting on the development of a latency prediction enabled variant of COMTEK we included a detailed description of the COMTEK development environment, including the interaction mechanisms provided in the framework, component specifications, and a description of how assemblies of COMTEK components are created. The COMTEK development environment supports building applications in several domains. We chose to use the family of components provided for building audio applications.

2. Although the report was generally concerned with the development of a PECT, we illustrated our approach by developing a PECT that supported assembly-level latency prediction. The report contains a detailed description of the type of latency predicted, the component-level property required for making assembly-level latency prediction, the limitations of the topology of assemblies to which the theory applies. In our case the latency prediction theory is applicable in the case when components are activated in series using a cyclic scheduler. We defined assembly latency as the elapsed time between two consecutive invocations of the `execute()` method of some component.

3. Latency for an individual component is defined as the duration of time starting from the invocation of its `execute()` method to its return from that method. The report includes a discussion of how COMTEK components are defined and why this definition is appropriate for them.

4. The report contains a discussion of how the assembly-level latency prediction theory was developed and how it was validated through logical argument as well as through experiment that involved measurement of latency of several assemblies and comparison of the results with the predicted latency for each assembly.

5. Component latency was measured in the deployment environment. A discussion of the test harness used for measuring component latency is included in the report.

6. The report contains a description of the COMTEK environment, a set of audio assemblies that were used to validate the prediction theory and a description of how the latency was measured for the example assemblies, results captured, and the prediction validated.

The complete report can be obtained from the Software Engineering Institute [1].

Summary

To summarize, the objective of this paper is to provide a means for determining whether a project is relevant to CBSE5, which is narrowly focused on research and practice in the area of predictable assembly of component-based systems. The paper describes a model for research papers reporting on projects in predictable assembly, and gives an example of its use to demonstrate that a particular paper is a report on such a project. This model will be used as criteria for evaluation of position papers submitted to CBSE5.

References

[1] S.A. Hissam, G.A. Moreno, J.A. Stafford, K.C. Wallnau, "Packaging Predictable Assembly with Prediction-Enabled Component Technology," CMU/SEI-2001-TR-024, November 2001.