

Evolutionary Design of Complex Systems

Open Technology for Software Evolution: Hyperware, Architecture, and Process

First Annual Technical Report

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1. Progress and Accomplishments

We are working on several technologies to aid in the effective evolution of complex software. In particular our research foci are:

- open, broad-based hyperprogram and active rationale support
- component-based architecture evolution technology, and
- multi-stakeholder process support

Open hyperware, software architecture, and workflow/process technologies are key enablers for supporting evolution of complex software systems. We are developing techniques, standards, and tools in each these areas and are distributing the results via the World-Wide Web (WWW). The technologies are being developed cooperatively, so that results in one area leverage the other two. The hyperware focus is on developing infrastructure to integrate open link server hypermedia systems with the WWW, while adding support for hyperweb configuration management, semantically-rich link generation, cooperation agents, and automatic rationale capture. The architecture research is directed at reducing the cost of application development by providing domain-informed, style-based design guidance, architecture design environments with analysis capabilities, and implementation technologies. The process work is designed to improve coordination and managerial control of teams by allowing flexible definition, modeling, and execution of typical workflow and process applications over the Internet.

1.1. Hyperware

Our previous hypermedia work represents two different approaches to providing hyperware capabilities. Chimera embodies a link server approach while the WWW embodies a distributed link data approach. A link server provides greater control and coherency management of the hypermedia relationships and dependencies; distributed link data provides for better scalability and hyperweb robustness. We believe that the advantages of both approaches are necessary for a hyperware environment to support the complete evolution of complex software systems. A unique aspect of our work is that we are using our experience with both approaches to provide the best combination of capabilities. In addition, our leadership within the WWW standardization efforts (e.g. HTTP, URL, and WebDAV standards) provides us with the unique ability to transition this work into the next generation of World Wide Web technology.

The HTTP/1.1 protocol specification was officially published as an Internet Proposed Standard; Roy Fielding of UCI is the lead author [FG+97-2]. We have assisted in the implementation of HTTP/1.1 within the Apache server (Fielding is one of the original Apache developers). Apache remains the market-leading web server technology. Roy Fielding has also authored the revision of the Internet standard for Uniform Resource Identifiers [BFM97-2] and continues to guide it through the standard process with the expectation that it will be approved as an IETF Draft Standard in early 1998.

<<http://www.ics.uci.edu/pub/ietf/http/>>

<<http://www.apache.org/>>

<<http://www.ics.uci.edu/pub/ietf/uri/>>

The Internet Engineering Task Force (IETF) approved the charter of the WWW Distributed

Authoring and Versioning (WebDAV) working group, Jim Whitehead of UCI is the chair. The WebDAV working group has released the -05 version of its distributed authoring protocol specification draft [GW+97-2], and initial versions of its access control requirements document [Pal97], and access control protocol document [LG97]. The Internet Engineering Steering Group (IESG) approved the document "Requirements for a Distributed Authoring and Versioning Protocol for the World Wide Web" [SVW+98] for publication as an Informational RFC, completing this work item of the WebDAV working group.

<<http://www.ics.uci.edu/pub/ietf/webdav/>>

The first beta release of Chimera 2.0 is now available. This all-Java release is deeply integrated with the WWW and provides distributed access to hypermedia information. Chimera 2.0 clients can be either stand-alone applications or Java applets. URLs are used to reference Chimera hyperwebs and HTTP is used to establish connections between clients and servers. Java and C APIs are available for Chimera client integration. Integrated clients include Xemacs, Netscape 3.0, FrameMaker 5.0, JPEG and GIF viewers. The latest release includes the ability to import and export hyperwebs in XML (Extensible Markup Language) format, integration with the Rivendell Tool Server (from Columbia University) and the ability to select among a choice of user-interface look-and-feels.

<<http://www.ics.uci.edu/pub/chimera/>>

1.2. Software Architecture

Software architecture is a key enabler for evolutionary development of complex systems. Our approach to architecture is based on notions of style, composition, dynamic change, visualization, analysis, system generation, and active rationale support. Each of these elements has direct bearing on evolvability of a system. Architectural style is an abstraction of recurring composition and communication characteristics of a set of architectures. As such, styles are key design idioms that enable exploitation of suitable structural and evolution patterns and facilitate component and process reuse. Composition of pre-existing software components reduces time to market. Dynamic change supports in-field evolution of systems can cannot afford to be brought down. Visualization of system architectures facilitates understandability by all stakeholders in a software development process. Analysis at the architecture level makes predicting overall system behavior tenable. System generation facilities automate the task of building each system version and, thus reduce the cost of evolution. Finally, an architecture-based framework for design rationale not only facilitates rationale capture but also provides a framework for effective delivery and analysis of design rationale, so that designers get the information they need, when they need it.

We have designed and implemented a framework of abstract classes for modeling C2-style architectures [TMA+96] with concepts, such as components, connectors, communication ports, and so on. Among other things, the framework enables users to manually wrap OTS components. We have demonstrated this with two different implementations of the framework: one in C++ and the other in Java. Sources for both frameworks and demonstration applications are available on the WWW.

<<http://www.ics.uci.edu/pub/arch/c2.html>>

We have devised a comparison and classification framework for architecture description languages (ADLs) and performed an extensive survey based on that framework. This survey is meant to highlight existing ADL capabilities and shortcomings, and will help in our further investigation

of an ADL for C2-style architectures.

Argo, a Java-based interactive software architecture design environment, is in Beta release. Argo allows for graphical visualization and direct manipulation of architectural models. Architectural components and their relationships are modeled as connected graphs and presented via multiple, coordinated, customizable views. The architect can build, modify and analyze the architecture via Argo. The environment supports the design and dynamic manipulation of applications in the C2-style, "critic"-based analyses of architectural designs, and initial rationale capture agents. Graph editing support in Argo is provided by the Graph Editing Framework (GEF). GEF is a library of Java classes that make it easier to develop new applications that involve diagram editing and connected graph editing.

<<http://www.ics.uci.edu/pub/arch/argo/>>

<<http://www.ics.uci.edu/pub/arch/gef/>>

We are continuing research on techniques for supporting dynamic modification of software architectures to enable runtime evolution of mission- and safety-critical systems. We have used the C2 Java framework as a basis for a prototype tool, ArchShell, which enables users to interactively modify architectures after system generation. ArchShell can currently also perform some modifications of architectures at runtime. An initial version of this tool has been released. ArchShell was then integrated with the Argo architecture design environment using a tool integration strategy based on the C2-style. The integrated environment, called ArchStudio, enables architects to design a system's architecture using Argo's graphical user interface and analysis facilities, and subsequently execute the system using ArchShell. While the system is executing, the architect may continue to modify the system's architectural model. These modifications are instantly reflected in the running system using ArchShell. An external tool has been added to ArchStudio that enables new components to be downloaded from a Web browser and automatically installed into a running system.

<<http://www.ics.uci.edu/pub/arch/dynamic-arch.shtml>>

1.3. Process

The process work is directed at producing an open, distributed, extensible process execution environment which leverages WWW protocols and the platform portability afforded by Java. Additionally we are seeking to provide effective means of customizing and reusing process fragments, applying the lessons learned by the workflow and computer-supported cooperative work communities, and providing effective two-way integration with commonly used desktop applications using a variety of programming languages. A prototype system, called Endeavors, serves as an evolving platform for exploring these issues. The Endeavors process support system provides a web-based workflow for distributed team coordination, collaboration, and communication. The system supports lightweight, mobile, graphically specifiable, dynamic, reflexive, componentized, workflow processes that allow execution of workflows across multiple machines and devices by both technical and non-technical users. Partnerships with various commercial firms are providing feedback regarding how well our approach and techniques work in the field.

Major development milestones this year include the implementation of a distributed infrastructure. Severization of the Endeavors foundation layer now provides full distributed processing between remote Endeavors systems as well as support for file locking, remote handler invocation, and distributed process invocation. We have improved the Endeavors user interface by incorporat-

ing the JDK-1.1 new event model and have also added support for the automatic generation of web-based guidance pages. Finally, we have defined our own Endeavors development and release process and are using this process in our daily development efforts.

An alpha 3 release of the Endeavors process support system addresses issues of adoption, architecture, hyperlinked artifacts, and dynamic evolution of reusable workflow process fragments using existing network infrastructures; downloadable from:

<<http://www.ics.uci.edu/pub/endeavors/>>

A complete survey of Workflow, Process, and CSCW software and systems can be found at:

<<http://www.ics.uci.edu/pub/endeavors/docs/ComparisonMatrix.pdf>>

Expectation-Driven Event Monitoring EDEM provides developers with a platform for creating software agents to collect usability data and increase user involvement in the evolution of interactive systems. EDEM collects information that is currently lost regarding actual usage of applications to promote a more empirically grounded design process.

The Expectation-Driven Event Monitoring (EDEM) substrate is in alpha release. The substrate enables software engineers to define agents to monitor the usability of Java applications and evolve systems based on the resulting feedback.

<<http://www.ics.uci.edu/~dhilbert/edem/>>

2. Professional Personnel

Faculty:

David Redmiles
David S. Rosenblum
Richard N. Taylor

Research Specialist:

Kenneth M. Anderson

Research Assistants:

Gregory Bolcer
Roy Fielding
David Hilbert
Peter Kammer
Michael Kantor
Rohit Khare
Neno Medvidovic
Peyman Oreizy
Jason Robbins
Shilpa Shukla
James Whitehead

Research Programmers:

Clay Cover
Arthur Hitomi
Yuzo Kanomata

Edwin Kraemer
Kari Nies

Degrees Awarded:

Kenneth M. Anderson, Ph.D.
Awarded June 1997
Dissertation: “*Pervasive Hypermedia*”

3. Publications in Technical Journals

E. James Whitehead. *World Wide Web Distributed Authoring and Versioning (WebDAV): An Introduction*. ACM StandardView, March, 1997. [Whi97]

Gail Kaiser, E. James Whitehead. *Collaborative Work: Distributed Authoring and Versioning*. IEEE Internet Computing, Vol. 1, No. 2, March/April, 1997, pp. 76-77. [KW97]

Nenad Medvidovic, Richard N. Taylor. *Exploiting Architectural Style to Develop a Family of Application*. Oct/Dec 1997 issue of the IEE Proceedings Software Engineering journal. [MT96-2]

Kenneth M. Anderson, Richard N. Taylor, and E. James Whitehead, Jr. *A Critique of the Open Hypermedia Protocol*. Journal of Digital Information, special issue on open hypermedia systems, vol. 1, issue 2. [ATW97]

Jason E. Robbins, David M. Hilbert, David F. Redmiles. *Extending design environments to software architecture design*. To appear in the International Journal of Automated Software Engineering. [RHR96-5]

4. Interactions (Related Activities)

4.1. Hyperware

Capturing momentum generated by front-page InfoWorld coverage in October [Rad97] the UCI/EDCS led WebDAV effort is now in the final stages of approval for its Web Distributed Authoring protocol document. Microsoft, Netscape, Xerox, Columbia University, and U.C. Irvine are currently developing WebDAV prototypes, indicating strong support for this emergent Internet standard. Once fielded, the major vendors will release compliant versions of their products and the WebDAV technology will enhance and simplify collaborative authoring of documents over the World Wide Web.

Kenneth M. Anderson presented a paper entitled “*Integrating Open Hypermedia Systems with the World Wide Web*” at the Eighth ACM Conference on Hypermedia Technology (Hypertext’97) [And97].

Kenneth M. Anderson presented a paper entitled “*Critique of the Open Hypermedia Protocol*” at the Third Workshop on Open Hypermedia Systems, held in conjunction with Hypertext’97 [And97-2].

Roy T. Fielding presented a paper entitled “*WebSoft: Building a Global Software Engineering*”

Environment” at the ICSE 97 Workshop on Software Engineering and the World Wide Web [Fie97].

E. James Whitehead, Jr. presented a paper entitled “*An Architectural Model for Application Integration in Open Hypermedia Environments*” at the Eighth ACM Conference on Hypermedia Technology (Hypertext’97) [Whi97-2].

E. James Whitehead, Jr. co-authored a paper entitled “Interoperability and Open Hypermedia Systems” that was presented at the Third Workshop on Open Hypermedia Systems, held in conjunction with Hypertext’97 [WW97].

4.2. Software Architecture

UCI’s Dynamic Architecture research has been evaluated and adopted by Northrop Grumman’s B-2 avionics simulation environment project (directed by Greg Johnson). The B-2 simulation environment consists of a large collection of complex tools, comprising approximately 1.7 million SLOC. Northrop Grumman is using UCI’s C2 architectural style to model the complex relationships between tools and UCI’s dynamic architecture technology (e.g., ArchStudio, ArchShell, Argo) to reconfiguring the B-2 avionics simulation environment during runtime.

Nenad Medvidovic presented a paper entitled “*A Framework for Classifying and Comparing Architecture Description Languages*” at the Sixth European Software Engineering Conference, held in conjunction with the Fifth ACM SIGSOFT Symposium on the Foundations of Software Engineering (ESEC/FSE) [MT97].

Nenad Medvidovic presented a paper entitled “*Reusing Off-the-shelf Components to Develop a Family of Applications in the C2 Architectural Style*” at the International Workshop on Development and Evolution of Software Architectures for Product Families. [MT96]

Nenad Medvidovic presented a paper entitled “*Reuse of Off-the-Shelf Components in C2-Style Architectures*” at the 1997 International Conference on Software Engineering in a joint session with the 1997 Symposium on Software Reusability (SSR’97). [MOT97]

Nenad Medvidovic presented a paper entitled “*Domains of Concern in Software Architectures and Architecture Description Languages*” at the 1997 USENIX Conference on Domain-Specific Languages [MR97].

Peyman Oreizy presented a paper entitled “*The WWW as an Enabling Technology for Software Engineering*” at the ICSE 97 Workshop on Software Engineering and the World Wide Web [Ore97].

Peyman Oreizy presented a paper entitled “*Software Architecture and Component Technologies: Bridging the Gap*.” at the OMG-DARPA-MCC Workshop on Compositional Software Architectures [OMT97-2].

Peyman Oreizy will present a paper entitled “*Architecture-Based Runtime Software Evolution*” at the 1998 International Conference on Software Engineering. [OMT97]

Jason E. Robbins presented a demonstration and paper entitled “*Argo: A Design Environment for Evolving Software Architectures*” at the 1997 International Conference on Software Engineering [RHR97].

Jason E. Robbins presented a paper entitled “*Integrating C2 with the Unified Modeling Language*” at the 1997 California Software Symposium [RRR97].

Jason E. Robbins will present a paper entitled “*Software Architecture Critics in Argo*” at the 1998 Conference on Intelligent User Interfaces [RHR97-2].

Jason E. Robbins will present a paper entitled “*Integrating Architecture Description Languages with a Standard Design Method*” at the 1998 International Conference on Software Engineering [RMRR97].

A paper entitled “*Architectural Implications of Common Operator Interfaces*” will be presented at the 1998 Ground System Architectures Workshop [TMO97].

4.3. Process

The Endeavors process support system has generated a great deal of interest in the corporate community. The project is currently involved in several technology transition efforts:

Users/Companies who have evaluated Endeavors for commercial and other uses:

- Netscape Communication Corporation, Jim Cunningham
- Sony Pictures Imageworks, Jim Berney
- Oracle Corporation, Bahram Saghari
- FileNet Corporation, Bruce Waddington
- MCC, Nancy Perry
- ISI, David Benjamin

Users/Companies who have deployed, plan to, or are currently using Endeavors to deploy workflow processes include:

- Sun Microsystems, Tom Arkwright
- PacBell, Ray Licon
- CoCreate/HP, Mark H. Allen
- Personal Software Process, A. Winsor Brown
- TACOM, Mike Saboe

As part of our technology transition efforts the Endeavors team has taken an active role in developing processes for both PacBell and Sun Microsystems.

Under the direction of Ray Licon, a systems analyst at Pacific Bell, we have developed a process for the PacBell Applications Development Group (ADG). Licon presented the ADG process using Endeavors in an executive meeting where he demonstrated how Endeavors creates, executes, and maintains workflow processes. The results of this meeting has initiated Endeavors to be used as the solution technology for the ADG organization, which authorizes all of Pacific Bell internal software development projects.

Sun Microsystems is using Endeavors as a process execution environment for their internal Java education program. An Endeavors process was created for Tom Awkwright to drive Sun’s web-based instruction delivery system. A series of collection forms were then designed and implemented sufficiently to allow a user with little training to develop a complete training course. Java

Train can include visual aids such as gif graphics or Java Applets and can create True false, Multiple Choice, and Match Word type “questions”. Courses are easily created and presented over the WWW through Endeavors. The Endeavors process provides Sun with an easily extensible means to coordinate multiple courses and collect metrics on the course takers. The system will be used on Sun’s new Java Stations.

Engineers at Lockheed-Martin successfully downloaded and tested EDEM 1.0. UCI made some modifications to accommodate a non-standard, third-party Java library used at Lockheed-Martin. With these modifications, the Lockheed-Martin personnel were able to use EDEM to monitor end users in their Global Transportation Network scenario. This transfer to Lockheed-Martin demonstrated the ease with which the EDEM software could be used: only minimal assistance was required from UCI and that was for a non-standard environment at Lockheed-Martin. Plans are currently underway with Lockheed Martin C2 Integration Systems to enhance EDEM to provide more advanced support for the GTN scenario. Contacts are Teri Paton and Lyn Uzzle (EDCS Integrators).

Gregory Alan Bolcer presented a paper entitled “*Endeavors: A Process System Integration Infrastructure*” at the 1996 International Conference on Software Process [Bol96].

David F. Redmiles will present a paper entitled “*EDEM: Intelligent Agents for Collecting Usage Data and Increasing User Involvement in Development*” at the 1998 conference on Intelligent User Interfaces [HRR97-2].

David M. Hilbert will present a paper entitled “*An Approach to Large-Scale Collection of Application Usage Data Over the Internet*” at the 1998 International Conference on Software Engineering [HR97].

David M. Hilbert will present a paper entitled “*Agents for Collecting Application Usage Data Over the Internet*” at the 1998 Autonomous Agents Conference [HR97-2].

Gregory Alan Bolcer presented a demonstration and paper entitled “*Endeavors: A process Sytem Infrastructure*” at the 1997 International Conference on Software Engineering [HBT97].

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