

Evolutionary Design of Complex Systems

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

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Technical Status Report

1. Ongoing Research and Development

1.1. Hyperware

Research on the Chimera hyperware project focused this quarter on understanding the requirements of our primary user, Northrop-Grumman Military Aircraft Systems Division, with respect to the domain of open hypermedia. In particular, Ken Anderson visited the Northrop-Grumman Pico Rivera facility on March 3, 1998. At that visit, Ken gave a talk about various aspects of Chimera, its support for heterogeneity, its integration with the WWW, and the techniques that can be used to integrate its services into applications. He then held in depth discussions with Garry Brannum with respect to Chimera's support for plug-ins that define new operations and link types, and how XML might be used to support this plug-in architecture. For instance, XML might be used to describe the relationships defined by a particular plug-in.

Yuzo Kanomata attended the EDCS Demo Days Dry Run Meeting held in El Segundo on March 16-19, 1998. At that meeting, he received further feedback from Garry Brannum with respect to new operations for the Chimera API and requests for new client integrations especially with respect to the Win32 platform.

In response to this feedback, work on the plug-in architecture, XML support, and the development of the Chimera API is continuing and will be phased into Chimera during its beta cycle. In response to the Win32 support request, work has begun on providing the Chimera API via a COM object. This will enable the integration of Win32 clients such as Microsoft Office, Internet Explorer, and the like.

The WebDAV working group, lead by Jim Whitehead, released the -06 and -07 versions of its distributed authoring protocol specification [GW+98], and held two 3+ week long working group last call for comments periods. These activities are the final steps taken by a working group before submitting their drafts to the IESG for approval as a proposed standard. The WebDAV working group also released a draft titled, "Requirements for Advanced Collections Functionality in WebDAV" [Sle98].

A preliminary version of WebDAV Explorer, a prototype WebDAV client application, was completed. This application is being used by several organizations to test the interoperability of their WebDAV server implementations. Work continues on this application as feedback is received from initial users.

Rohit Khare has been investigating issues related to next-generation hypermedia access protocols. In addition to tracking the development of HTTP-NG, he has been researching the potential for third-party extensibility using Web proxy servers, Extensible Markup Language, and the current generation of HTTP.

1.2. Software Architecture

Software architectures have the potential to substantially improve the development and evolution of large, complex, multi-lingual, multi-platform, long-running systems. However, in order to

achieve this potential, specific architecture-based modeling, analysis, and evolution techniques must be provided. One aspect of our current research in software architectures focuses on a type theory for software architectures, which allows flexible, controlled evolution of software components in a manner that preserves the desired architectural relationships and properties. Critical to the type theory is a taxonomy that divides the space of subtyping relationships into a small set of well defined categories. In the context of this work, we are investigating the effects of large-scale development and off-the-shelf reuse on establishing type conformance between interoperating components in an architecture.

Notable progress was made on understanding the how software architectures could be used as a basis for runtime software evolution. The contribution of architectural style and software connectors was explored and described in a paper slated for publication at the International Conference on Configurable Distributed Systems [OT98].

We have also begun to investigate different approaches for evolving software in-the-field (i.e., after it has been deployed). Many commercial systems employ such techniques as a means of providing end-user customizability and behavior extension by third-party developers. These techniques include application programming interfaces (APIs), scripting languages, software plug-ins, etc. Early results based on this work were submitted and accepted for publication at the International Workshop of the Principles of Software Evolution [Ore98].

We are investigating the use of UML (the Unified Modeling Language) to represent software architectures. UML is a object-oriented design notation that has recently be standardized by the Object Management Group. UML has wide-spread industry interest and growing tool support. Unlike previous object-oriented design notations, UML is formally defined and provides a constraint language and extension mechanisms. We have been able to use the UML constraint language to express most of the guidelines of the C2 style and some aspects of the Wright architecture description language [RRR97, RMRR97]. Expressing software architecture concepts in a standard design language is an important step toward wide-spread use of software architecture models.

We have been revising the design and implementation of the Argo software architecture design environment to make it more efficient and flexible, and to ease integration with design tools implemented in Java. Specifically, we have implemented initial versions of the UML meta-model and associated visualizations in GEF and critics in Argo. In addition, a survey of design critiquing systems is in progress.

1.3. Process

The Endeavors group continues to work on incorporation of the C2-style into the Endeavors architecture. The new design will allow for improved performance and dynamic configuration of distributed Endeavors components.

We are exploring the issues of distributed processes through the creation of prototype systems. In order to validate portions of the technology and as part of a senior level project course in software engineering, one team of students created an Endeavors process to manage an on-line, distributed, travel expense reimbursement system. The process combines the core Endeavors technology and other web based tools such as JavaScript to provide an easy to use, customizable interface to the

reimbursement process used in the ICS department. Another team of students began work on creating a process to provide control flow for the Endeavors bug tracking system. The process allows outside users to submit bug and suggestion reports through a web browser. The submission can then be verified, assigned to a developer, the bug fixed or suggestion implemented, and finally be approved for distribution.

EDEM is being redesigned for compliance with the Java 1.1 event model. New features will include more a flexible and efficient event dispatch mechanism, enhanced data collection and reporting options, an API to allow input and output of arbitrary events for monitoring, and default expectation agents with wizards to aid in expectation specification and agent parameterization. David Hilbert has been in contact with people at Sun Microsystems, Microsoft, and the University of Michigan in an attempt find suitable industrial (and/or non-UCI academic) partners to take part in an empirical evaluation of the EDEM technology.

Knowledge Depot is a tool for supporting Project Awareness. Originally it was a group memory used to store and automatically organize project related email and documents. It has evolved into a project awareness tool which allows geographically distributed project members to subscribe to specific categories of information in the group memory. These subscriptions cause the system to send users summaries of all new information to arrive in that subject, thus allowing people to remain aware of discussions and documents on project topics that affect them. A beta version of this tool is now being tested at UCI. This version is a redesign of the original Knowledge Depot to enhance speed, usability and accessibility.

2. Participants

Faculty:

David Redmiles
David S. Rosenblum
Richard N. Taylor

Research Specialist:

Kenneth 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

3. Notable Accomplishments and Technology Transition

3.1. Hyperware

The first beta release of Chimera 2.0 occurred on February 6, 1998. This release featured an improved user-interface to all Chimera servers, support for XML import and export of Chimera's hypermedia databases, and integration with Rivendell. The release was accompanied by a redesigned website (<http://www.ics.uci.edu/pub/chimera/>) that now includes better documentation and a Chimera tutorial.

The UCI/EDCS led WebDAV effort, building on its strong base of industrial support, visited the offices of NetObjects, Documentum, and FileNet, giving presentations educating their staff about WebDAV, and discussing potential strategies for integrating WebDAV technology into their product lines.

UCI/EDCS was instrumental in helping form a follow-on effort to WebDAV called DASL, DAV Searching and Locating. The DASL effort, currently in-process of becoming an IETF working group, will address issues of how to remotely search a repository which contains a set of WebDAV resources. Alex Hopmann, Microsoft, is chair of the DASL group. Jim Whitehead attended a Birds-of-a-Feather (BOF) meeting of the DASL group held at Xerox PARC on February 10, 1998.

Rohit Khare presented a plenary talk based on joint work with Adam Rifkin from Caltech at the DARPA/OMG Workshop on Compositional Software Architectures on "Composing Active Proxies to Extend the Web" [KR98]. He also presented "XML and WebDAV: a Tale of Two Standards" at XML'98 Developer's Day based on joint work with Jim Whitehead. He also began a bimonthly column series in IEEE Internet Computing which surveys application-layer information transfer protocols [Kha98].

3.2. Software Architecture

A paper by Nenad Medvidovic, Richard N. Taylor, and David S. Rosenblum entitled "An Architecture-Based Approach to Software Evolution" was submitted and accepted to the International Workshop on the Principles of Software Evolution [MTR98].

A paper by Nenad Medvidovic and Richard N. Taylor entitled "A Classification and Comparison Framework for Software Architecture Description Languages" was submitted for publication to IEEE Transactions on Software Engineering [MT98].

A paper by Peyman Oreizy and Richard N. Taylor entitled "On the Role of Software Architectures in Runtime System Reconfiguration" was accepted at the International Conference on Configurable Distributed Systems (ICCDs) [OT98]. The paper describes the role that dynamic

architectures, specifically architectural style and software connectors, play in evolving software during runtime.

A paper by Peyman Oreizy, David S. Rosenblum, and Richard N. Taylor entitled “On the Role of Connectors in Modeling and Implementing Software Architectures” was published as a UC Irvine Technical Report [ORT98]. The paper describes the role of connectors in supporting the modeling, analysis, and execution of software systems. In particular, the beneficial role of connectors in flexibility, heterogeneity, code mobility, and distribution.

A paper by Peyman Oreizy entitled “Decentralized Software Evolution” was submitted and accepted to the International Workshop on the Principles of Software Evolution [Ore98]. The paper compares and contrasts different strategies for evolving a software system in-the-field (i.e., after it has been deployed).

A paper by Peyman Oreizy, Michael M. Gorlick, Richard N. Taylor, Dennis Heimbigner, Gregory Johnson, Nenad Medvidovic, Alex Quilici, David S. Rosenblum, and Alexander L. Wolf entitled “Self-Adaptive Software” was submitted for publication [OGT+98]. The paper describes the dynamic software architectures can be used as a basis for designing, analyzing, and deploying self-adaptive software (i.e., software that modifies its own behavior in response to environmental changes).

At the EDCS Demo Days Dry-Run meeting held in Los Angeles, CA, Peyman Oreizy and Rick Brenner (PI from Draper Labs) organized a special interest group on dynamism. In attendance were: Peyman Oreizy, Rick Brenner, Paul Robertson, John Salasin, Bob Balzer, Jim Veitch, Greg Sullivan, Carolyn Talcot, Andre van der Hoeck, David Wile, and Michael Young. The group discussed issues pertaining to dynamism, specifically as dynamism is supported by different EDCS technologies. Topics included granularity of dynamism, the effects of open versus closed systems on dynamism, and separation of concerns in systems supporting dynamism.

Richard N. Taylor presented a paper entitled “Architectural Implications of Common Operator Interfaces” 1998 Ground System Architectures Workshop [TMO97]. He also participated in a panel of the same name.

Jason Robbins presented a paper entitled “Software Architecture Critics in Argo” at the 1998 Conference on Intelligent User Interfaces [RHR97-2]. The paper was selected as one of the best of conference, and the authors were invited to submit an expanded version to Knowledge-Based Systems, an international journal.

Jason Robbins and David Redmiles submitted a paper entitled “Software Architecture Critics in the Argo Design Environment” [RR98] to Knowledge-Based Systems, an international journal. This paper is based on the IUI’98 paper [RHR97-2], but is expanded to include a detailed comparison of the critic-based approach to other intelligent user interface approaches.

Nathan Sharp of Phoenix Integration expressed interest in using GEF as part of a commercial product. Jean-Michel Roque of Soft-Mountain (France) expressed interest in using GEF in a commercial product. Sathish Hariharan of Corel Corporation expressed interest in using GEF to develop a modeling tool. Carlos Apodaca of Booz, Allen & Hamilton expressed interest in using GEF to develop a network configuration tool.

3.3. Process

A paper entitled “Supporting Distributed Workflow Using HTTP” was accepted for presentation at ICSP5: Computer Supported Organizational Work [KBTH98].

In January, the Endeavors group met with Dan Matheson, Rich Wildman and Anthony Earl, research engineers from CoCreate’s workflow team, to discuss use of Endeavors in CoCreate’s workflow product. Subsequently, Mark Allen from CoCreate visited Irvine to view demos of Endeavors and further discuss integration of Endeavors into their product.

An EDEM paper and demonstration was presented at the 1998 Conference on Intelligent User Interfaces (IUI98) by David Redmiles [HRR97-2].

A survey of automated techniques for extracting usage/usability information from automatically captured user interaction events was completed this quarter [Hil98].

4. Progress on Inter/Intra Cluster Collaborations

4.1. Hyperware

The integration of Chimera with Rivendell, announced in the 4th Quarterly Report of 1997, was successfully completed. The Rivendell Tool Server is technology produced by Gail Kaiser’s group at Columbia University.

Students at UCI have maintained the Columbia WebDAV server, keeping it compliant with the latest revisions of the WebDAV distributed authoring protocol specification. This server was instrumental for testing the WebDAV Explorer client.

4.2. Software Architecture

We are continuing our collaboration with Stephen Dai at Northrop Grumman (PI: Greg Johnson) on the use of a C2-style architecture in modeling and implementing the B-2 avionics simulation environment.

This quarter we released the ArchStudio architecture tool suite for designing, analyzing, and implementing runtime reconfigurable software architectures to SEI’s EDCS software repository at <http://jf.sei.cmu.edu/SRM/jump.html>. The package includes the Argo design environment, the ArchShell dynamic architecture modification tool, the Java/C2 class framework, and several example C2-style architectures.

4.3. Process

EDEM will be demonstrated as part of the Lockheed Evolver GTN Scenario at the July 1998 2nd Annual EDCS Demo Days.

Members of the Knowledge Depot group met with Barry Boehm’s group at USC on April 1 to present Knowledge Depot and discuss differences between it and Win-Win.

5. Publications

Papers that have been published or accepted for publication this quarter.

David M. Hilbert, Jason E. Robbins, David F. Redmiles. *EDEM: Intelligent Agents for Collecting Usage Data and Increasing User Involvement in Development*. Proceedings of the 1998 Conference on Intelligent User Interfaces. [HRR97-2]

David M. Hilbert, *A Survey of Computer-Aided Techniques for Extracting Usability Information from User Interface Events*. Technical Report UCI-ICS-98-13, Department of Information and Computer Science, University of California, Irvine. [Hil98]

Peter J. Kammer, Gregory Alan Bolcer, Richard N. Taylor, Arthur S. Hitomi. *Supporting Distributed Workflow Using HTTP*. To appear in Proceedings ICSP5: Computer Supported Organizational Work. [KBTH98]

Rohit Khare and Adam Rifkin. *Composing Active Proxies to Extend the Web*. Proceedings of the OMG-DARPA-MCC Workshop on Compositional Software Architectures. [KR98]

Rohit Khare. *Life in a TP*. IEEE Internet Computing, March/April 1998. [Kha98]

Nenad Medvidovic, Richard N. Taylor, and David S. Rosenblum. *An Architecture-Based Approach to Software Evolution*. To appear in Proceedings of the International Workshop on the Principles of Software Evolution (IWPSE 98). [MTR98]

Peyman Oreizy, Nenad Medvidovic, Richard N. Taylor and David S. Rosenblum. *Software Architecture and Component Technologies: Bridging the Gap*. Proceedings of the OMG-DARPA-MCC Workshop on Compositional Software Architectures. [OMTR97]

Peyman Oreizy, David S. Rosenblum, Richard N. Taylor, *On the Role of Connectors in Modeling and Implementing Software Architectures*. Technical Report UCI-ICS-98-04, Department of Information and Computer Science, University of California, Irvine. [ORT98]

Peyman Oreizy. *Decentralized Software Evolution*. To appear in Proceedings of the International Workshop on the Principles of Software Evolution (IWPSE 98). [Ore98]

Peyman Oreizy, Richard N. Taylor. *On the Role of Software Architectures in Runtime System Reconfiguration*. To appear in the Proceedings of the International Conference on Configurable Distributed Systems (ICCDs 4). [OT98]

Jason E. Robbins, David M. Hilbert, David F. Redmiles. *Software Architecture Critics in Argo*. In Proceedings of the 1998 Conference on Intelligent User Interfaces. [RHR97-2]

Richard N. Taylor, Nenad Medvidovic, Peyman Oreizy. *Architectural Implications of Common Operator Interfaces*. Proceedings of the 1998 Ground System Architectures Workshop (GSAW'98). [TMO97]

6. Travel

Table 1: Project Meetings/Conferences and Attendance

Meeting	Location	Dates	Attendees
Composable Software Architectures Workshop	Monterey, CA	Jan 4-7	RK, PO
1998 Conference on Intelligent User Interfaces	San Francisco, CA	Jan 6-9	DR, JR
DASL BOF Meeting	Xerox PARC Palo Alto, CA	Feb 10	JW
1998 Ground System Architectures Workshop	El Segundo, CA	Feb 25-27	RT
EDCS Demo Days Dry-Run Meeting	Los Angeles, CA	Mar 16-19	DR, DSR, RT, DH, PK, PO, JW, CC, YK, KN
XML Conference	Seattle, WA	Mar 25-27	RK

**Initials for attendees are based on the list of participants given on page 5.*

7. Near Term Plans

7.1. Hyperware

The Chimera project will advance in several aspects next quarter. The first release of the plug-in architecture will occur. The XML support in the first beta release will increase with XML being used to specify configuration information for the Chimera servers. An alpha version of the COM API to Chimera will be released. In addition, more information in terms of documentation and tutorials for Chimera will appear on the Chimera website.

WebDAV plans on submitting its Distributed Authoring Protocol specification to the IESG for approval as a proposed standard in April. Roy Fielding, Rohit Khare, and Jim Whitehead plan on attending the Los Angeles IETF meeting the first week of April. A three-day meeting of the WebDAV working group is planned for June 15-17, 1998, in Redmond, CA.

Next quarter Rohit Khare and Jim Whitehead will co-convene a workshop on the future of HTTP at WWW7. Rohit Khare will also be presenting a short paper (on XML history) and poster (on security) at this conference. In addition, he will be presenting the pro-Web protocols stance in a panel at COOTS'98 in Santa Fe.

7.2. Software Architecture

The current work on type-theoretic aspects of software architectures will be continued. We have already put many of these ideas into practice in the context of the C2 architectural style and its

accompanying ADL. During the next quarter, we will continue with the development of a set of tools to support architectural subtyping, type checking, and mapping of architectural descriptions to the C2 implementation infrastructure. We also intend to evaluate several existing theorem provers and model checkers to aid us in establishing behavior conformance between two components.

Next quarter we plan to pick-up the ArmaniLib library from Robert Monroe at CMU (PI:David Garlan) and utilize its constraint system for governing the evolution of dynamic architectures.

Work on software architecture environments will focus on applying the Argo infrastructure to the domain of object-oriented software architecture using the UML notation. In the next quarter the UML version of Argo will be made more complete and robust and will be evaluated in a user study. Jason Robbins will continue a survey of design critiquing systems. Critiquing systems are knowledge-based software tools that support designers by giving advice about potential errors, incomplete parts of the design, the implications of design decisions, and possible design alternatives. The Argo design environment has a critiquing system as one of its major features.

7.3. Process

The Endeavors group will continue to develop a C2-style architecture for the Endeavors system. We will experiment with creating different types of connectors for distributed Endeavors components. We will also add Endeavors process technology to the JavaBrain program. JavaBrain is a project sponsored by the University of California MICRO program and Sun Microsystems which enables users of the system to create and view web based training courses. The first process will provide content creation control and guidance. Next quarter, members of the Endeavors group will travel to Detroit to install Endeavors at the USA TACOM for use in their software development process.

Over the next quarter, we plan to complete our redesign of EDEM for Java 1.1 with a number of added and enhanced features. David Hilbert and David Redmiles will also work to convert UCI's "Survey of Computer-Aided Techniques for Extracting Usability Information from User Interface Events" [Hil98] into a journal publication. David Hilbert will continue to seek out industrial (and/or non-UCI academic) partners to take part in an empirical evaluation of the EDEM technology.

During this next quarter, Knowledge Depot will be released to users at the University of California, Irvine and prepared for release to users at Bell Atlantic Science and Technology. User surveys will be sent out to users of the Lotus Notes versions of this tool. Implementation-wise, we will be refining the system to be easily installed on all standard platforms, refining the usability, adding more support for annotation of information, and integrating the system more closely with other EDCS funded technologies (Endeavors and Chimera).

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