

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 scalability. During this period, the beta cycle of Chimera 2.0 continued through beta 4 (released June 1st) and beta 5 (released to Northrop-Grumman for the Third Annual EDCS Demo Days). As a result of the demands of Northrop-Grumman Military Aircraft Systems Division's use of Chimera, support for operations which involved automated processing of large documents into the Chimera database was focused on. Northrop has taken advantage of the XML import features of Chimera (described in the previous Quarterly Report) to generate hyperwebs containing hundreds of thousands of hypermedia entities as opposed to the thousands of entities Northrop had previously used. In response, we have improved Chimera's support for scalability on all such data intensive operations by two orders of magnitude, from thousands to hundreds of thousands of entities handled. This was accomplished by adopting the use of a freeware relational database (MYSQL) and developing the capability to use filtering mechanisms over a large scale hyperweb. The use of MYSQL enabled us to respond to Northrop's demands in a rapid fashion (the increase of Chimera's scalability occurred in less than four weeks) however in order to further improve scalability, work has begun on evaluating COTS relational and object-oriented databases in order to meet Northrop's future demands.

Based on feedback and support for our own demo for the Third Annual EDCS Demo Days in July, Chimera 2.0 beta 6 has been developed and will be released publicly shortly after the July demos. Betas 5 and 6 include the scalability enhancements described above along with the improved XML support, selection of link traversal behaviors, and the new enhancement known as anchor and link filtering. Finally, beta 6 features the first alpha release of a Chimera API on the Win32 platform. Chimera's API is now available as a COM object that can be used to integrate Win32 applications.

The WebDAV Working Group, lead by Jim Whitehead, continued to work towards approval of the WebDAV Distributed Authoring Protocol by releasing version -08 of the IETF draft protocol [GW+98]. This document was sent to the Internet Engineering Steering Group (IESG) for approval. The draft successfully navigated the first part of the approval process, an Internet-community-wide last call for comments period.

In response to comments received during this period, concerns for WebDAV's use of the Extensible Markup Language's (XML) MIME media type "text/xml" were addressed. This has led to work on *XML Media Types* [WM98], a document which registers the "text/xml" and "application/xml" media types. During the reporting period, this document went through 6 major revisions, and received significant review from the World Wide Web Consortium's XML Special Interest Group and the IETF Media Types community. This document was submitted to the IESG and is currently awaiting approval.

The WebDAV working group began work on functionality enhancements in the areas of advanced collections, access control, and versioning. Advanced collections functionality encompasses ref-

erential members of collections, and ordering of collections, and is described by a requirements document and a protocol document. Requirements for access control were submitted during the reporting period, as was a versioning protocol draft. Work on these drafts will continue in the WebDAV working group.

Roy Fielding is working on a survey of software architectural styles that will characterize styles in terms of their impact on system communication across a network. The goal of this research is to provide a design framework to help software architects and application-level protocol designers choose an appropriate architectural style for the particular communications characteristics of their application.

1.2. Software Architecture

During this period, the C2 group, performed an initial integration of ArchStudio, a UCI architecture development environment, with the Armani constraint language from CMU (PI: David Garlan, contact: Robert Monroe). The integration enables architects to specify constraints on how a software architecture can evolve during runtime. As runtime software changes are requested, ArchStudio queries Armani to determine whether or not the change would leave the system in a consistent configuration. If the change violates a constraint, the change request is rejected; otherwise the change is applied to the running system by ArchStudio. This capability provides additional assurances that runtime software upgrades do not violate application integrity. This integration will be completed by the Third Annual EDCS Demo Days in July.

This quarter, the implementation of an initial prototype of an environment that supports architecture-based evolution on type-theoretic principles was completed. The environment supports architectural subtyping, type checking, and mapping of architectural descriptions to the C2 implementation infrastructure. The architecture of the environment itself can easily be evolved to support multiple architecture description languages (ADLs), types of analyses, architectural styles, and implementation platforms. The approach is fully reflexive: the environment can be used to describe, analyze, evolve, and (partially) implement itself, using the very ADL it supports.

A new design tool called Argo/UML was released this quarter. This tool includes cognitive support features found in the existing Argo tool for C2 software architectures, but these features are applied to the Unified Modeling Domain, a standard notation for object-oriented design. Like the previous Argo tool, Argo/UML has design critics and a dynamic “to do” list that together help designers resolve identified problems in a design. New features in Argo/UML include customizable navigational perspectives that structure the design around specific design tasks, checklists which save time in later design reviews, and some support for attaching problem-fixing wizards to critics.

Additionally, version 0.6 of GEF, the Java Graph Editing Framework was released. This version has many new editing features. GEF’s reusability has been enhanced by allowing existing objects to be used as the connected graph to be displayed. Now any existing graph-oriented data structure can be editing by GEF, so long as a mapping is defined between the graphical elements and the model elements. Other enhancements include better performance, simplified code organization, and better integration with standard java libraries.

1.3. Process

The Endeavors group's efforts focused on improving usability and interoperability. To this end, an installation manager called "Install Shield for Java" (ISJ) was used to facilitate installation of Endeavors. The installation management capabilities of ISJ include directory creation, file placement, configuration management, script creation, and environment modification. The incorporation of this system gives end-users "wizard" installation and de-installation facilities for Endeavors on Win95/NT and Solaris platforms.

Endeavors developers have completed a three tier database middle-ware module for the Endeavors system. This system consists of a programmer's interface for the client level (tier three), a middle tier web servlet module (tier two), and a RDBMS (tier one). The client connects to the middle tier using the provided API calls and utility functions from tier one. The middle tier module extends the Java HTTPServlet class and relies on a web server. The middle tier to tier one connection has currently been implemented using the JDBC which makes connections to the MYSQL RDBMS located at tier one. Communication between the tiers is via HTTP and will therefore be considered firewall friendly on many systems. The communication between the client and middle tier is based on ANSI SQL; this enables complex queries, joins, orderings and aggregations. The system supports prepared statements and multiple databases.

This new database middle-ware is compatible with the Endeavors user level Handler model. This feature provides a valuable tool for Endeavors users that require data storage into proprietary systems such as Oracle, MSSQL, and Sybase. In fact, handlers can be written to maintain user data into any DBMS that has an available JDBC driver. This model will enable Endeavors to interact with and maintain data and processes which rely on data from legacy data stores.

The new database middle-ware system has been incorporated with the Java Brain dynamic web content collection and presentation system, and is in the testing phase. The database system has enhanced Java Brain by providing optimized querying, data filtering, and relational data storage of the user data. This implementation is providing a test environment for the MYSQL RDBMS as a data storage facility for Endeavors user data.

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

Ken Anderson attended the Hypertext'98 conference held in Pittsburgh, Pennsylvania on June 20-24, 1998. There he participated in the 4th International Workshop on Open Hypermedia Systems and presented the paper *Client-Side Services for Open Hypermedia: Getting past the 'foo'...*[And98]. This paper represents work in the development of a standard protocol for client interoperability with open hypermedia systems. Chimera developers have been participating in this process for the past two years with the goal of producing a standard that can be taken to the IETF for wider distribution.

The WebDAV working group held two meetings, one at the Los Angeles IETF, on April 2, 1998, and a more substantial meeting June 15-17, 1998, hosted by Microsoft in Redmond, Washington. Requirements for advanced collections functionality were discussed at the Los Angeles IETF, and advanced collections, access control, and versioning were discussed during at the Redmond meeting.

Continuing its efforts to increase adoption of WebDAV by key Web technology companies, UCI conducted site visits to Microsoft, Adobe, IBM, and Kofax for consultations on the WebDAV Distributed Authoring Protocol. Additionally, introductory presentations on WebDAV were delivered during the HTTP Track at the 7th International World Wide Web Conference in Brisbane, Australia in April, and at the American Society of Information Science (ASIS) 1998 Mid-Year conference in Orlando, Florida, in May. A WebDAV tutorial was presented during the Hypertext'98 Conference in Pittsburgh, PA, in June. Articles on WebDAV appeared in the general press as well, with positive articles in InfoWorld [Wal98], Mac Week On-line [Dud98], and PC Week On-line [Han98].

This reporting period also saw reflection on the WebDAV protocol in the paper, *Lessons from WebDAV for the Next Generation Web Infrastructure* [Whi98], presented at the workshop, "Towards a New Generation of HTTP," held at the WWW7 conference, evaluates the extensibility of HTTP based on the experiences of the WebDAV working group, giving requirements for future Web infrastructure development efforts.

Rohit Khare and Jim Whitehead successfully co-chaired the workshop, "Towards a New Generation of HTTP", held with the 7th International World Wide Web Conference. Jim Whitehead was

also a panel member at WWW7 on the panel titled, “Missing the 404: Link Integrity on the World Wide Web.”

3.2. Software Architecture

A paper entitled *Architecture-Based Runtime Software Evolution* [OMT97] by Peyman Oreizy, Nenad Medvidovic, Richard N. Taylor was accepted and presented at the International Conference on Software Engineering 1998 (ICSE’98). The paper describes a software architecture-based approach to evolving mission critical software systems during runtime. The paper highlights the role of software connectors in facilitating runtime change.

A paper entitled *Decentralized Software Evolution* [Ore98] by Peyman Oreizy was accepted and presented at the International Conference on the Principles of Software Evolution (IWPSE 98), held in conjunction with ICSE’98. The paper describes the issues in supporting a decentralized model of software evolution, in which multiple, independent parties may evolve a software application.

A paper entitled *On the Role of Software Architectures in Runtime System Reconfiguration* [OT98] by Peyman Oreizy, Richard N. Taylor was accepted and presented at the International Conference on Configurable Distributed Systems (ICCDs 4). The paper describes how architectural style, architectural connectors, and architecture-based analyses combine to provide a reliable and systematic approach to runtime reconfiguration of mission-critical software systems.

Neno Medvidovic presented a paper titled *An Architecture-Based Approach to Software Evolution* [MTR98], authored by Nenad Medvidovic, Richard N. Taylor, and David S. Rosenblum, at the International Workshop on the Principles of Software Evolution, held in conjunction with the International Conference on Software Engineering (ICSE’ 98).

Neno Medvidovic submitted a paper titled *Separating Fact from Fiction in Software Architecture* [MT98], authored by Nenad Medvidovic and Richard N. Taylor, to the 3rd International Software Architecture Workshop (ISAW3).

The paper *Software Architecture Critics in the Argo Design Environment* [RR98] by Jason Robbins and David Redmiles was accepted to Knowledge-Based Systems, an international journal.

The paper *Integrated Architecture Description Languages with a Standard Design Method* [RMRR97] was presented at the International Conference on Software Engineering (ICSE’ 98).

Eric Moyer of Air Force Institute of Technology Dept. Operational Sciences expressed interest in using GEF to develop a graphical front end to a set of operational science analysis tools. Ray Ferguson of Stanford Medical Informatics expressed interest in using GEF. Huon Butterworth of The Sonet Group (U.K.) expressed interest in using GEF for a network management application. Mathieu Padovani of Alcatel (France) expressed interest in using GEF for a telecommunications modeling application. Andrew Shewmaker of the Idaho National Engineering and Environmental Laboratory expressed interest in using GEF for network management application.

Our Argo/UML web site has had over 1300 visitors and the source code to Argo/UML has been downloaded over 100 times. Our Argo/UML mailing list currently has approximately 70 members, including employees of Aonix (a CASE tool vendor), ISX (a defense contractor), IBM, Oracle, Motorola, and nine universities. Also, E. William East of the US Army Corps of Engineers

Civil Engineering Research Laboratories expressed interest in our design critiquing infrastructure and provide detailed technical reports of the SEDAR critiquing system.

3.3. Process

Greg Bolcer completed a paper titled *Advanced Workflow Management Technologies* [Bol98] which was submitted for publication to the Journal of Software Process Improvement and Practice. The paper presents a survey of the available workflow technologies and outlines the requirements for an advanced workflow system.

Peter Kammer presented a paper titled *Supporting Distributed Workflow Using HTTP* [KBTH97] at the ISCP5.

David Redmiles presented a paper titled *An Approach to Large-Scale Collection of Application Usage Data Over the Internet* [HR97] at the 1998 International Conference on Software Engineering (ICSE'98).

David Hilbert presented an EDE paper titled *Agents for Collecting Application Usage Data Over the Internet* [HR98] at the 1998 Conference on Autonomous Agents (Agents'98).

4. Progress on Inter/Intra Cluster Collaborations

4.1. Hyperware

Our work this quarter focused on supporting Northrop-Grumman's use of Chimera as described above. Our primary goal in this effort is to achieve the insertion of Chimera into Northrop's production software environments.

Further refinement of the integration with Columbia University's Rivendell Tool Server with Chimera was achieved with feedback provided for future versions of Rivendell. Feedback was given to Columbia University as they began replacing Xanth with Chimera for their hyper-media infrastructure technology.

4.2. Software Architecture

Our integration of ArchStudio with the Armani architectural constraint language was a result of collaboration with Robert Monroe at CMU (PI: David Garlan). The integration also enables ArchStudio to generate ACME architectural descriptions.

4.3. Process

EDEM was successfully integrated by Lockheed Martin C2 Integration Systems into the Global Transportation Network (GTN) demonstration scenario to be shown at the Third Annual EDCS Demo Days in Baltimore in July 98.

5. Publications

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

Kenneth M. Anderson. *Client-Side Services for Open Hypermedia: Getting past the 'foo' ...*. In Proceedings of the 4th International Workshop on Open Hypermedia Systems held at Hypertext'98. [And98]

David M. Hilbert, David F. Redmiles. *Agents for Collecting Application Usage Data Over the Internet*. In Proceedings of the 1998 Autonomous Agents Conference (Agents'98). [HR98]

David M. Hilbert, David F. Redmiles. *An Approach to Large-Scale Collection of Application Usage Data Over the Internet*. In Proceedings of the 1998 International Conference on Software Engineering. Kyoto, Japan, April 19-25, 1998. [HR97]

Peter J. Kammer, Gregory Alan Bolcer, Richard N. Taylor, Arthur S. Hitomi. *Supporting Distributed Workflow Using HTTP*. In Proceedings of ICSP5: Computer Supported Organizational Work. [KBTH97]

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

Peyman Oreizy. *Decentralized Software Evolution*. In Proceedings of the International Workshop on the Principles of Software Evolution (IWPSE 98). Baltimore, MD. [Ore98]

Peyman Oreizy, Nenad Medvidovic, Richard N. Taylor. *Architecture-based Runtime Software Evolution*. In Proceedings of the 1998 International Conference on Software Engineering. [OMT97]

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

Jason Robbins and David Redmiles. *Software Architecture Critics in the Argo Design Environment*. Accepted by the Journal of Knowledge-Based Systems. [RR98]

Jason E. Robbins, Nenad Medvidovic, David F. Redmiles, David S. Rosenblum. *Integrating Architecture Description Languages with a Standard Design Method* In Proceedings of the 1998 International Conference on Software Engineering. [RMRR97]

6. Travel

Table 1: Project Meetings/Conferences and Attendance

Meeting	Location	Dates	Attendees
IETF	Los Angeles, CA	Apr 2	RF, RK, JW
WWW7	Brisbane, Australia	Apr 14-18	RK, JW
International Conference on Software Engineering (ICSE)	Kyoto, Japan	Apr 19-24	RNT, DR, DSR, PO, DH, NM, AH
ACM SIGCHI (CHI'98)	Los Angeles, CA	Apr 18-23	RF, JR, MK, KA
International Conference on Configurable Distributed Systems (ICCDs'98)	Annapolis, MA	May 4-7	PO
WebDAV Working Group Meeting	Redmond, WA	June 15-17	RK, JW
International Conference on Software Process (ICSP5)	Chicago, IL	June 14-17	PK
Hypertext' 98	Pittsburg, PA	June 20-24	JW, KA

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

7. Near Term Plans

7.1. Hyperware

Chimera will complete the evaluation of COTS relational and object-oriented databases and adopt a technology that will enable Chimera to scale up an additional level of magnitude to support hyperwebs containing millions of hypermedia entities. The plug-in architecture for Chimera, a feature that was delayed this past quarter as a result of responding to Northrop's scalability demands, will be released. The new Win32 API for Chimera will move from alpha to beta status and will feature additional integrations with Win32 applications such as Microsoft Word and Excel. Finally, a Chimera API for the Open Hypermedia Protocol will be developed to help move the Open Hypermedia standards effort forward.

The WebDAV project will be working to get the Distributed Authoring Protocol accepted by the IETF, and widely adopted by Web technology vendors. Work will continue on refining advanced collections, access control, and versioning capability. The WebDAV working group will hold a meeting at the Chicago IETF, in August. Approval of the XML Media Type registration draft by the IESG is expected during the next three months. A paper titled *Control Choices and Network Effects in Hypertext Systems* [Whi98-2] will be submitted to the Hypertext 1999 Conference.

UCI plans to hold a workshop on internet scale event notifications (titled WISEN), on July 13-14.

Roy Fielding will be continuing work on his survey of software architecture styles for network-based applications that will incorporate and describe our methods for classifying architectural styles according to the nature of their component interactions and its impact on the network performance of such applications.

7.2. Software Architecture

We plan to complete the integration of our dynamic architecture technology (ArchShell) with the Armani architectural constraint language from CMU (PI: David Garlan). We plan to demonstrate this new capability at the EDCS Demo in Baltimore, MD, July 18 - 23.

Jason Robbins will continue development of Argo/UML, attend EDCS Demo Days, and finish a survey of critiquing systems. He will also continue development of GEF and support of GEF users. Near term plans for Argo/UML include enhanced support for UML standard diagram types, visual indications of feedback from critics, and full support for wizards which fix identified design problems.

7.3. Process

Future directions of this research are to resolve an overall transaction model for the Endeavors system. We will also be combining two undergraduate project-course bug tracking system products together into one system. The final bug tracking system will incorporate the data management capabilities of one with the process management capabilities of the other into one system. We hope to include a notion of distributed transaction processing management into the final bug track product.

David Hilbert will work at Microsoft this summer to evaluate the principles and techniques underlying EDEM within a large-scale industrial application instrumentation project. This application features over 1000 commands accessible through user interface menus and toolbars and over 300 user interface dialogs.

David Hilbert and David Redmiles will submit an EDEM paper to an upcoming special issue of IEEE Transactions on Software Engineering focused on Empirical Methods in Software Engineering.

David Hilbert and David Redmiles will submit a revised version of UCI's *Survey of Computer-Aided Techniques for Extracting Usability Information from User Interface Events* [Hil98] to ACM Computing Survey.

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