

# Evolutionary Design of Complex Systems

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

### Quarterly Report Volume 2, Number 3

Richard N. Taylor, David Redmiles  
Department of Information and Computer Science  
University of California  
Irvine, California 92697-3425

{taylor, redmiles}@ics.uci.edu  
<http://www.ics.uci.edu/pub/edcs/edcs.html>

Voice: 949-824-6429      FAX: 949-824-1715

For the period: 01 July 1998 through 30 September 1998  
Contract: F30602-97-2-0021

Prepared for:  
DARPA/ITO  
Air Force Research Laboratory, AFMC. USAF  
Office of Naval Research (ONRRO)

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# Technical Status Report

## 1. Ongoing Research and Development

### 1.1. Hyperware

This quarter, Chimera 2.0 development continued with two beta releases, extended alpha testing of the Win32 COM API, and work on further platform and client integration. Chimera 2 beta 6 was released to Northrop Grumman for the Third Annual EDCS Demo Days in July, and was later released to Raytheon in August to support the use of a Chimera infrastructure to access various artifacts used on the F-15 project. The beta 6 release featured the ability to filter links, thus allowing users to restrict links made visible on the Chimera Server's display to those of a specific type. A selectable traversal algorithm function was added which will allow client applications and users to select the traversal behaviors for Chimera. This allows the user to apply rules to traversals across the n-ary links Chimera supports, such as a rule to traverse to documents ordered with the newest linked document appearing first. These features improve usability of Chimera when scaled to hundreds of thousands of entities managed. Chimera 2 beta 7 was released on September 9th. This release includes refinements to functions and interfaces used in beta 6.

An alpha version of a Win32 COM API to Chimera was completed in early July. Based on feedback with its initial use, the alpha cycle was extended in order to ensure full compatibility with the Chimera API and to test various Microsoft DDE based client integrations. These integrations involve an application using a DDE interface to the COM API which then accesses Chimera. Memory allocation and deallocation between DDE and COM issues are the focus of efforts during this period. An integration of Adobe's Frame Maker on Windows NT was accomplished using the COM API this quarter. A port of the Chimera to the NT platform was also accomplished.

Roy Fielding is working with the Apache Group to assist with the transfer of HTTP/1.1 and WebDAV protocol enhancements to the Apache HTTP server technology, used by over 54% of all public Internet websites. The first-ever in-person Apache design meeting was held in San Francisco, July 2-3, to discuss what would be included in a major rewrite of the Apache server planned for Spring '99.

The Workshop on Internet-Scale Event Notification (WISSEN) was produced and hosted by UCI on July 13-14. Attendees included The Aerospace Corp, Microsoft, Tibco, BLIP, Lotus, Oracle, Sun Microsystems, Netscape, Activerse, Novel, and Hewlett Packard, Raytheon, GTE, Lucent, IBM Research, FileNet, and Tandem.

### 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 techniques for architecture-based modeling, analysis, and

evolution must be provided. Furthermore, one cannot fully benefit from such techniques unless support for mapping an architecture to an implementation also exists.

One aspect of the research conducted this quarter is the construction of an architecture-based modeling, development, and evolution toolsuite, called DRADEL. DRADEL is an outgrowth of our experience with systems developed and evolved according to the C2 architectural style. We formalized the syntax and semantics of an architecture description language (ADL) specifically designed to support architecture-based evolution and enumerated the kinds of evolution the language supports. We used the ADL as the basis of DRADEL, a component-based environment that enables modeling, analysis, and evolution of architectures expressed in the ADL, as well as mapping of architectural models to our implementation infrastructure (the C2 class framework). The architecture of the DRADEL environment itself can be evolved easily to support multiple ADLs, kinds of analyses, architectural styles, and implementation platforms. Our approach is fully reflexive: DRADEL can be used to describe, analyze, evolve, and (partially) implement itself, using the very ADL it supports.

Another aspect of our architectural research continued this quarter deals with implementing complex software connectors. Since architecture-level components often contain complex functionality, it is reasonable to expect that their interactions will also be complex. Modeling and implementing software connectors thus becomes a key aspect of architecture-based development. Software interconnection and middleware technologies such as RMI, CORBA, ILU, and ActiveX provide a valuable service in building applications from components. The relation of such services to software connectors in the context of software architectures, however, is not well understood. To understand the trade-offs among these technologies with respect to architectures, we have evaluated several off-the-shelf middleware technologies and identified key techniques for utilizing them in implementing software connectors. We have integrated four such technologies with the C2 implementation infrastructure: University of Colorado's Q system, Sun's Java RMI facility, University of Maryland's Polyolith software bus, and Xerox PARC's ILU distributed object system. Our platform for investigation was the C2 style. By encapsulating middleware functionality within software connectors, we have enabled the coupling of C2's existing benefits such as component interchangeability, substrate independence and structural guidance with new capabilities of multi-lingual, multi-process and distributed application development in a manner that is transparent to architects.

David Rosenblum and his students Rema Natarajan and Doris Tonne have been investigating techniques for supporting architectural concerns in the use of component interoperability standards. Rema Natarajan has enhanced Sun's Beans Development Kit to support composition of components or "beans" according to the rules of the C2 architectural style. The enhancements include (1) checking C2 design rules as beans are graphically composed; (2) encapsulating elements of the C2 class framework as beans, including explicit architectural connectors; and (3) providing interactive wrapping of off-the-shelf beans, whereby the architect provides a mapping from bean events to C2 request and notification messages. This work resulted in a publication for ISAW-3 [NR98] and a submission to ICSE'99 [NR99]. Doris Tonne has enhanced the Beans Development Kit and the definition of the JavaBeans "design pattern" to support evaluation of methods that incorporate bean invariants and bean method pre- and post-conditions.

David Rosenblum and Elisabetta Di Nitto (CEFRIEL/Politecnico di Milano) began investigating the problem of reconciling middleware constraints with architectural modeling, with a focus on middleware infrastructures for event-based architectures. Middleware infrastructures are becoming a significant component of large-scale software systems. Traditional software process models encourage postponement of implementation decisions as late in the lifecycle as possible, but this is no longer possible for middleware-based architectures and systems. Architectural models can severely restrict the choice of middleware infrastructures, and middleware infrastructures can impose strong constraints on architectural models. Therefore, languages and environments for architectural modeling must account for the constraints imposed by middleware infrastructures. As a first step in studying this issue, existing ADLs were evaluated as to their suitability for expressing and capturing constraints of event-based styles and event-based infrastructures. This work resulted in a publication for ISAW-3 [CDRW98] and a submission to ICSE'99 [CRW99].

We have released several beta versions of Argo/UML. The latest versions include substantially more functionality than was demonstrated at EDCS Demo Days. Specifically, more of the standard UML (Unified Modeling Language) diagram types are supported, more critics have been implemented, the critiquing system has been made more scalable, a new XML-based file format has been implemented, and new design visualization features have been added. Also, Jason Robbins has completed a survey of design critiquing systems.

### 1.3. Process

Endeavors has been connected to Oracle8 ORDBMS as a test-bed for transaction management within a database supported process environment. This will allow us to investigate the benefits of a transactional workflow system and to describe an optimal transaction manager model for the process environment.

## 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  
Nenad Medvidovic  
Peyman Oreizy

Jason Robbins  
Shilpa Shukla  
James Whitehead

*Research Programmers:*

Clay Cover  
Arthur Hitomi  
Yuzo Kanomata  
Edwin Kraemer  
Kari Nies

*Visiting Scholars:*

Elisabetta Di Nitto  
Alfonso Fuggetta

### **3. Notable Accomplishments and Technology Transition**

#### **3.1. Hyperware**

This quarter, we released Chimera 2.0 beta 6 and beta 7. An alpha version of the COM API was released with both betas. A client integration of Adobe's Frame Maker was accomplished using the COM API.

Chimera was demonstrated to numerous attendees at the 3rd Annual EDCS Meeting and Demo Fair in Baltimore, MD, July 18-23.

Yuzo Kanomata gave a talk on Chimera to two groups at Raytheon in August, the first group (team lead Diana Chu) was looking to integrate Chimera with the F-15 program while the second group (team lead Keith Grindstaff) was looking for possible hyperware integrations on Fire Finder Block 2, Sentinel, and the Standard Missile programs.

Roy Fielding's specification of Uniform Resource Identifiers (URI) [BFM98], the technology for identifying resources on the Internet, was accepted by the Internet Engineering Steering Group (IESG) for publication as Draft Standard RFC 2396. This publication does not cite the EDCS grant in accordance with IETF procedures.

#### **3.2. Software Architecture**

The papers "Issues in Supporting Event-based Architectural Styles" [CDRW98] (by Antonio Carzaniga, Elisabetta Di Nitto, David Rosenblum and Alex Wolf) and "Merging Component Models and Architectural Styles" [NR98] (by Rema Natarajan and David Rosenblum) were accepted to the ACM SIGSOFT 3rd International Software Architecture Workshop (ISAW-3). The latter paper was one of only 8 papers invited for presentation to a plenary session of the workshop.

The papers "Design of a Scalable Event Notification Service: Interface and Architecture" [CRW99] (by Antonio Carzaniga, David Rosenblum and Alex Wolf) and "Extending Component Interoperability Standards to Support Architecture-Based Development" [NR99] (by Rema Natarajan and David Rosenblum) were submitted to the 1999 International Conference on Software Engineering.

Nenad Medvidovic, David S. Rosenblum, and Richard N. Taylor submitted a paper entitled "A Language and Environment for Architecture-Based Software Development and Evolution" to the 1999 International Conference on Software Engineering [MRT99].

Eric M. Dashofy, Nenad Medvidovic, and Richard N. Taylor submitted a paper entitled "Using Off-the-Shelf Middleware to Implement Connectors in Distributed Software Architectures" to the 1999 International Conference on Software Engineering [DMT99].

Dick Taylor, David Rosenblum, Gregory Alan Bolcer, Rohit Khare, James Whitehead co-organized the Workshop on Internet Scale Event Notification (WISEN'98), which was held at the University of California, Irvine, July 13-14, 1998. David Rosenblum gave the opening presentation on "Internet Scale Event Notification" and co-chaired a working group on "Requirements for Internet Scale Event Notification".

Peyman Oreizy and David Rosenblum were invited to attend the NSF/CNR Workshop on the Role of Software Architecture in Testing and Analysis (ROSATEA), held in Marsala, Sicily, Italy, June 30-July 3, 1998. Peyman Oreizy's presented a position paper entitled "Issues in Modeling and Analyzing Dynamic Software Architectures" [Ore98]. This paper describes the current state of dynamic software architecture research, and presents a number of open research problems in the area. David Rosenblum presented a position paper entitled "Challenges in Exploiting Architectural Models for Software Testing".

A journal paper entitled "On the Role of Software Architectures in Runtime System Reconfiguration" [OT98] by Peyman Oreizy and Richard N. Taylor was submitted to the IEE Software Engineering journal. It 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.

A survey of design critiquing systems was completed this quarter.

UCI's integrated software architectures tool suite (ArchStudio) was demonstrated at the 3rd Annual EDCS Meeting and Demo Fair in Baltimore, MD, July 18-23, to numerous attendees from industry.

Argo/UML has been downloaded and evaluated by employees of Lucent Technologies, Sun Microsystems, Alcatel, Lockheed Martin, Mitel, Nortel, Southwestern Bell, IBM, ISX Corporation, TRW, Siemens, Liberty Mutual Insurance, Hummingbird Communications, Fermi National Accelerator Laboratory, and dozens of other companies and universities around the world.

### 3.3. Process

Endeavors and Knowledge Depot were demonstrated to numerous attendees at the 3rd Annual EDCS Meeting and Demo Fair in Baltimore, MD, July 18-23.

Greg Bolcer presented his Ph.D. topic defense titled "Flexible and Customizable Workflow Execution on the WWW". He successfully argued to his committee that a workflow process support infrastructure can successfully provide and support: distribution of workflow processes and people, bi-directional integration with external tools, customization and reuse, dynamic change, and multiple stakeholders using a new set of implementation technologies and techniques using the WWW. These techniques include event-based integration, lightweight mobile components, support for inconsistent data, integration of multiple programming languages, a layered virtual machines architecture, and integration of coordinated end-user views through commonly used end-user Web technologies. Based on the experiences of prototypes built using the Endeavors system in the on-line training, document routing and approval, medical information systems, software process, and Web publishing. He was able to present a framework for validating his hypothesis that Endeavors supports an unprecedented level of flexibility, customization, and evolutionary capabilities lacking in any single system in the workflow, process, and groupware areas.

The paper "Supporting Dynamic and Adaptive Workflow on the WWW" [KBB98] by Peter Kammer, Greg Bolcer, and Mark Bergman was accepted for the Workshop on Adaptive Workflow Systems at Computer Supported Cooperative Work (CSCW)'98 in Seattle, WA.

We are continuing discussions with Sun Microsystems in an effort to transition the Endeavors/JavaBrain technology project in the web-based training domain.

The paper "Supporting Dynamic and Adaptive Workflow on the WWW" [KBB98] by Peter Kammer, Greg Bolcer, and Mark Bergman was accepted for the Workshop on Adaptive Workflow Systems at Computer Supported Cooperative Work (CSCW)'98 in Seattle, WA.

David Hilbert managed a development effort at Microsoft Corporation this summer in which an application (with over 1000 commands and 300 dialogs) was instrumented to collect usage data regarding the behavior of 500-1000 users using the application over a two month period. This industrial collaboration was initiated to allow the principles and techniques underlying UCI's EDEM research (in the area of large-scale collection of application usage data) to be evaluated within the context of a large-scale industrial project.

David Hilbert and David Redmiles submitted a paper entitled "Large-Scale Collection of Application Usage Data" to IEEE Transactions on Software Engineering for inclusion in a "Special Issue on Empirical Methods in Software Engineering". [HR98]

David Hilbert and David Redmiles submitted a paper entitled "Separating the Wheat from the Chaff in Internet-Mediated User Feedback" for inclusion in a "Workshop on Internet-based Groupware for User Participation in Product Development" to be held at CSCW'98. [HR98-2]

#### **4. Progress on Inter/Intra Cluster Collaborations**



## 4.1. Hyperware

Columbia University announced that Chimera will replace Xanth as the underlying hypermedia infrastructure on Oz web.

A Chimera installation was achieved at Raytheon for a EDCS2 grant proposal feasibility study.

## 4.2. Software Architecture.

We completed a proof-of-concept integration of our dynamic architecture technology (ArchStudio's ArchShell) with the Armani architectural constraint language from CMU (PI: David Garlan, contact: Robert Monroe). This capability helps provide assurances on runtime changes to software systems. This integration was demonstrated at the EDCS Demo Days in Baltimore, MD, July 18 - 23.

## 4.3. Process

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

We are continuing updating the Endeavors UI/System layer interface using the C2 architecture.

## 5. Publications

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

Tim Berners-Lee, Roy T. Fielding, and Larry Masinter. *Uniform Resource Identifiers (URI): Generic Syntax*. Internet RFC 2396, August 1998. [BFM98]

A. Carzaniga, E. Di Nitto, D.S. Rosenblum and A.L. Wolf, *Issues in Supporting Event-based Architectural Styles*, To appear in Proc. Third Int'l Software Architecture Workshop, Lake Buena Vista, FL, Nov. 1998. [CDRW98]

Antonio Carzaniga, David S Rosenblum, and Alexander L. Wolf. *Design of a Scalable Event Notification Service: Interface and Architecture*. Submitted to the 1999 International Conference on Software Engineering, Los Angeles, CA, May 16-22, 1999. [CRW99]

Eric M. Dashofy, Nenad Medvidovic, and Richard N. Taylor. *Using Off-the-Shelf Middleware to Implement Connectors in Distributed Software Architectures*. Submitted to the 1999 International Conference on Software Engineering (ICSE'99), Los Angeles, CA, May 16-22, 1999. [DMT99]

D.S. Rosenblum, *Challenges in Exploiting Architectural Models in Software Testing*, Proc. NSF/CNR Workshop on the Role of Software Architecture in Testing and Analysis, Marsala, Sicily, Jul. 1998, pp. 49-53. [DSR98]

David Hilbert, David Redmiles, *Large-Scale Collection of Application Usage Data*

Submitted to IEEE Transactions on Software Engineering for inclusion in a "Special Issue on Empirical Methods in Software Engineering". [HR98]

David Hilbert, David Redmiles, *Separating the Wheat from the Chaff in Internet-Mediated User Feedback*. Submitted to the Workshop on Internet-based Groupware for User Participation in Product Development to be held at CSCW'98. [HR98-2]

Peter Kammer, Greg Bolcer, and Mark Bergman. *Requirements for Supporting Dynamic and Adaptive Workflow on the WWW*. To appear in the Workshop on Adaptive Workflow Systems at Computer Supported Cooperative Work (CSCW) Workshop on Adaptive Workflow Systems in Seattle WA on November 14, 1998. [KBB98]

Nenad Medvidovic, Eric M. Dashofy, and Richard N. Taylor. *Employing Off-the-Shelf Connector Technologies in C2-Style Architectures*. To appear in the Proceedings of the California Software Symposium (CSS'98), pages 21-30, Irvine, CA, October 23, 1998. [MDT98]

Nenad Medvidovic and David S. Rosenblum. *Assessing the Suitability of a Standard Design Method for Modeling Software Architectures*. To appear in Proceedings of the First Working IFIP Conference on Software Architecture (WICSA1), San Antonio, TX, February 22-24, 1999. [MR99]

Nenad Medvidovic, David S. Rosenblum, and Richard N. Taylor. *A Language and Environment for Architecture-Based Software Development and Evolution*. Submitted to the 1999 International Conference on Software Engineering (ICSE'99), Los Angeles, CA, May 16-22, 1999. [MRT99]

Nenad Medvidovic and Richard N. Taylor. *Separating Fact from Fiction in Software Architecture*. To appear in Proceedings of the Third International Software Architecture Workshop (ISAW-3), pages 105-108, Orlando, FL, November 1-2, 1998. [MT98]

Rema Natarajan and David S. Rosenblum, *Merging Component Models and Architectural Styles*, To appear in Proc. Third Int'l Software Architecture Workshop, Lake Buena Vista, FL, Nov. 1998. [NR98]

Rema Natarajan and David S Rosenblum, *Extending Component Interoperability Standards to Support Architecture-Based Development*. Submitted to the 1999 International Conference on Software Engineering, Los Angeles, CA, May 16-22, 1999. [NR99]

Elisabetta Di Nitto and David Rosenblum. *Exploiting ADLs to Specify Architectural Styles Induced by Middleware Infrastructures*. Submitted to the 1999 International Conference on Software Engineering, Los Angeles, CA, May 16-22, 1999. [NR99-2]

Peyman Oreizy. *Issues in Modeling and Analyzing Dynamic Software Architectures*. Proceedings of the ROSATEA Workshop. June 30th - July 3, 1998, Marsala, Sicily, Italy. <<http://www.ics.uci.edu/djr/rosatea/>> [Ore98]

## 6. Travel

**Table 1: Project Meetings/Conferences and Attendance**

Meeting	Location	Dates	Attendees
EDCS Demo Days	Baltimore, MD	July 18 - 23	RNT, DSR, DR, KA, JF, JR, PO, MK, CC, AH, YK
Internet Engineering Taskforce (IETF)	Chicago, Il	August 24 - 27	RF, JW, RK
Lucent Technology's Bell Labs	Naperville, IL	August 28	RF, JW, RK
ROSATEA Workshop	Marsala, Sicily, Italy	June 30 - July 3	PO
WISEN	Irvine, CA	July 18 - 23	PO

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

## 7. Near Term Plans

### 7.1. Hyperware

The Chimera COM API will be released next quarter. A Chimera port to Linux will be complete. A Chimera Adobe Acrobat client integration will begin.

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

In the short term, Nenad Medvidovic will be working on integrating the ideas on architecture-based evolution that have emerged over C2's life span:

- component evolution via heterogeneous subtyping,
- connector evolution via context-reflective interfaces and flexible information filtering, and
- configuration evolution via heterogeneous connectors and minimized component interdependencies.

Another set of issues deals with the proposed community-wide effort on developing the architecture-based development toolkit.

We plan to complete a survey of decentralized software evolution approaches, which simply stated, enable third-parties to evolve a software application independent of the organization that originally developed it.

Near-term efforts on the Argo/UML tool will focus on providing new cognitive support features and visualization features. Also, we will begin evaluation of the impact of Argo/UML's cognitive features in a user study.

We will complete prototypes of the experimental JavaBeans environments and anticipate demonstrating them at EDCS Demo Days in Baltimore in June 1999. We will also enhance the DRADEL environment to generate JavaBeans skeletons from C2SADEL models and to derive interface checking methods from the interface specifications that appear in the C2SADEL models.

### 7.3. Process

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" to ACM Computing Surveys.

EDEM will be updated to support the latest Java GUI toolkit and will be enhanced to provide more flexible data abstraction, selection, context-capture, and reduction.

## References

- [BFM98] Tim Berners-Lee, Roy T. Fielding, and Larry Masinter. *Uniform Resource Identifiers (URI): Generic Syntax*. Internet RFC 2396, August 1998.
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- [Rob98] Jason Robbins. *Design Critiquing Systems*. Tech Report UCI-ICS-98-41.