Modeling Legacy Architecture with UML

Jeroen van Tyn

Armstrong Consulting, Inc.
511 Second Street, Suite 100
Hudson, WI 54016
(800) 575-4160
www.armstrongconsulting.com
Goal of Today’s Presentation

To present and discuss the process of modeling non-OO software architecture using UML and Rose

- What our mission was
- What the presenting situation was
- What we tried
- What we settled on
Agenda

- Overview of legacy system
- Situation, management charter, stakeholder requests
- Challenges
- Existing source constructs
- Various modeling approaches
- Modified 4+1 View of Architecture
- Summary and questions
Context: Motorola’s OMC-R System

- Operations Management Center - Radio
- Manages and configures radio wave-based wireless communications networks
  - Cell sites, transmitters, etc. that carry radio transmissions to/from cell phones, 2-way pagers, wireless Internet devices
  - Largest customer is Nextel
- Major product releases twice per year
  - Fast pace of wireless technology development demands software support for new features
- 1 million+ lines of procedural (non-OO) code
  - C, stored procedures
Situation

- No big picture of the product’s software architecture
  - Existing documentation uneven and very low-level
- Lack of reliable brain-based system knowledge
  - Staff migration, staff turnover over software lifespan (1993 to the present)
- Distributed development team
  - Chicago, Texas, India
- No effective repository of project artifacts
  - Largely textual (Framemaker): very little visual modeling
  - No modeling tools other than sequence diagram drawing tool
  - Document management (CCM) ineffective
Management Charter

#1: Reduce defects in software development
- Many problems caught very late in the release development cycle

#2: Facilitate ability to enhance the product
- Cumbersome impact analysis for proposed features

#3: Enable componentization
- Network element configuration = most attractive feature set for componentization, incorporation into Motorola’s

Enable the above by modeling the software architecture using UML
Stakeholder Requests

- Management
  - Previous slide
  - Provide basis for establishing formal architectural analysis into the software development workflow

- Architects
  - Big picture of the system: major components & structures, relationships between them
  - Support impact analysis for adding new features
  - Context for documenting, developing and educating others about the system
  - Single-source repository for all architectural and design artifacts
Stakeholder Requests (cont’d)

- Subsystem Leads
  - Show how subsystems interact on a high level
  - Provide clear definition of subsystem boundaries (interfaces provided, interfaces required)
  - Support impact analysis for designing and implementing new features
  - Context for educating new developers about the system

- Developers
  - Roadmap for learning the design of the system
Challenges

- Non-OO source constructs
  - Implementation of functional decomposition (!)
  - Sparsely documented C programs, stored procedures
- Design artifacts largely out of date
  - Wide variety of detail, format, completeness
- No analysis artifacts
- Heterogeneous requirements artifacts
  - Combine high-level requirements with low-level design
- Many disparities and contradictions across artifacts
- Architects new to the system
  - No “gray-hairs” to rely on: everyone learning
Existing Source Constructs

- C programs
- Processes (EXE’s) communicating via modified IPC
  - Asynchronous messaging simulating synchronous behavior via coded “wait” loops
- Large numbers of complex stored procedures
- Several hundred business rules
  - No traceability to design, implementation: all done by hand analysis
Status: 4+1 View of Architecture

Logical View
Analysts/Designers
Structure

End-user
Functionality

Implementation View
Programmers
Software management

Process View
System integrators
Performance
Scalability
Throughput

Deployment View
System engineering
System topology
Delivery, installation
communication
Status: 4+1 View of Architecture (cont’d)

- **Use Case View**
  - System functionality poorly documented from an outside perspective
  - No visual modeling

- **Logical View**
  - No analysis model: everyone has their own concept of key abstractions
  - Design model spotty, mostly textual and very detailed
Status: 4+1 View of Architecture (cont’d)

- Implementation View
  - Software constructs already in place, so not a priority

- Process View
  - Processes in place
  - Communication between them documented, but not up to date
Status: 4+1 View of Architecture (cont’d)

- Deployment View
  - Very well understood
  - Fairly well documented

Deployment View

System engineering
- System topology
- Delivery, installation
- Communication
Approach

- Raise the level of abstraction
  - Focus on Use Case View and Logical View
- Gain agreement on basic functionality, key concepts
- Define modeling levels
  - What will be in the Logical View?
- Adapt and extend UML as needed
- Work top-down and bottom-up simultaneously
  - Top-down: create requirements artifacts, analyze from there
  - Bottom-up: start with existing code, abstract upward
Top-down Effort

- Existing system = implementation of functional decomposition (!)
- Use Case modeling
  - Looked to user interface for Use Cases
  - Actors fairly readily identified
  - Challenge: keep Use Cases at a high enough level, yet with enough detail to decide which are architecturally significant
- Analysis Modeling/Use Case Realizations
  - Big challenge: no agreement on key abstractions (big surprise to team members)
  - Very difficult to separate conceptual entities from implementation
Bottom-up Effort

- Goal: meet the top-down model somewhere in the middle
- Where to start? What equals a UML “splat” (classifier)?

Three major tries at this...
Try #1: C Program $\cong$ UML Class

- C program is a collection of (more or less) related functions
  - Corollary to class with operations

- State is an issue
  - State captured in files, tables, other data structures: requires further modeling conventions
Class Diagrams

- C function = operation on class
  - Parameters = function parameters
- No attributes: programs themselves are stateless
- Structural relationships
  - No instances, so association, aggregation, composition are irrelevant
  - Dependencies between caller & “callee” (next slides…)

<<C program>>
dist_mgr.c

<<C program>>
sys_dist.c

val_dist_acg(…)
abort_dist(…)

Interaction diagrams

Message = invocation of function in another C program

: dist_mgr.c

: sys_dist.c

val_dist_acg(…)

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Packages

- Package structure parallels UNIX directory structure
- Package dependencies required significant hand analysis of code
Rose Demo: C Programs as UML Classes
Evaluation of Try #1

Pro:

- “Classes” easy to identify
- Automatic reverse engineering
  - Custom program converts C headers to C++ format
  - Rose C++ reverse engineering capability
  - Interaction diagramming easily done in Rose
Evaluation of Try #1 (cont’d)

Con:

- Too many classes: not an effective big picture
- Not architectural in nature: too constrained by implementation
- Doesn’t effectively show communication between larger constructs
- Doesn’t yield new information
  - Code profiling tools, UNIX commands, MAKE files just as effective
Try #2: OMC-R Process \( \cong \) UML Subsystem

- OMC-R process = EXE “instance”
  - Process “contains” C programs
- Processes communicate via IPC
  - Motorola-extended version of standard IPC
  - Implemented as C functions making calls to common IPC library: parameters include receiving process ID, message ID and message parameters

Sender code fragment (inside LMUI process):

\[
\text{ipc_mq_send_msg ( \langle receiver ID\rangle, \text{LMGI\_I\_CMD\_MSG}, \ldots )}
\]

Receiver code fragment (inside LMGI process):

\[
\text{ipc_mq_receive_msg ( \langle my process ID\rangle, \text{LMGI\_I\_CMD\_MSG}, \ldots )}
\]
Subsystem encapsulation parallels implementation

- C programs make direct function calls only to other C programs within the same containing process
- Calls to other processes requires IPC call

Interface = functionally coupled set of IPC messages received by contained C programs

- Interfaces are purely conceptual: no direct physical

```
<<interface>> iLMGI_Download Manager

<<IPC>> LMGI_I_CMD_MSG ()
<<IPC>> LMGI_I_RMV_MSG ()
<<IPC>> LMGI_R_ISOCHK_MSG ()
```
Subsystem dependency: C program inside a subsystem sends IPC message to some other process

Sender and receiver both dependent on IPC subsystem
Interaction Diagrams

- Message = name of incoming IPC message
  - Remember: IPC messages are on interfaces ( ! )

But how useful is this? ...all interaction diagrams would show just one “step”
  - We’re interested in showing a conversation between a set of subsystems...
Subsystem Interaction Diagrams

- Rose can’t show subsystem directly on an interaction diagram
- “Subsystem stand-ins” solve the problem
  - Subsystem stand-in = class the realizes same set of interfaces that the subsystem realizes

Additional Class Diagram:

```
iLMGI_Download Manager
LMGI
<<subsystem>
LMGI stand-in
<<subsystem stand-in>>
```
Subsystem Interaction Diagrams

Interaction diagram using subsystem stand-ins:

: LMUI stand-in

LMGI_I_CMD_MSG(

: LMGI stand-in

DL_I_DLSTRQ_MSG(

: DL stand-in

This is a non-standard (non-RUP) interaction diagram

- Combines external view of subsystems receiving messages with internal view of interface message realizations!
- **But it models what we wanted to show!!**
Rose Demo: Processes as UML Subsystems
Evaluation of Try #2

Pro:
- Larger-grained picture = helpful
- Grouping IPC messages into interfaces = helpful
- Can flesh out subsystem realizations as needed for understanding
- Interaction diagrams (using subsystem stand-ins) = useful

Con:
- Processes still too fine-grained and implementation-constrained
- Stakeholders want info on incoming AND outgoing messages
- Architecture should show “externally visible properties”
  - Received messages are only part of the story
OMC-R “subsystems”: larger conceptual chunks

- “Subsystem” (“TNM functional area”) = a collection of C programs
- Run in (perhaps) several processes
- Are functionally distinct
- Conceptually layered
  - Application (CM, FM, PM)
  - Infrastructure (IPC, SNMP, event handling) = collections of implemented architectural mechanisms

- Communicate strictly via IPC messages
- Arguably “own” important data structures/stores (state)
Notation

Blend of two sources:

- *Applied Software Architecture* by Hofmeister, Nord & Soni
- Rational’s UML Profile for Real-time Modeling

Concepts:

- component
- port
- connector
- protocol
- binding
Conceptual Component

- UML definition: “a physical, replaceable part of a system that packages implementation and conforms to and provides the realizations of a set of interfaces”

- Conceptual component:
  - is conceptual, not (necessarily) physical
  - decomposable into other components

Elided notation

\[
\text{Load Mgmt}
\]

Canonic notation

\[
\text{<<ccomponent>>}
\]

\[
\text{Load Mgmt}
\]
Port

- An interaction point for a conceptual component
  - In context of a particular collaboration with another component

- Is different from a UML interface in that it:
  - defines both incoming and outgoing messages
  - may have its own implementation
  - is associated with a protocol that mandates how the incoming and outgoing messages can be ordered
Port (cont’d)

Elided notation

LMGI

Download Control

Canonic notation

<<ccomponent>>
LMGI

<<cport>>
Download Control
Connector

- Represents a communication channel between two ports that play complementary roles in a protocol.
- Is different from a UML association in that it:
  - connects ports instead of classes.
  - places the protocol restriction on the ports that it connects.
Class Diagram: Components, Ports, Connectors

Elided notation:

LMGI

Download Control

LMUI

Download Ack

Canonic notation:

<<ccomponent>>
LMGI

<<cport>>
Download Control

<<cconnector>>

<<ccomponent>>
LMUI

<<cport>>
Download Ack
Protocol

- A specification of desired behavior that can take place over a connector
  - Explicit specification of contractual agreement between participants in the protocol
  - Each participant plays a specific protocol role
  - May specify valid communication sequences, documented by state machines and/or sequence diagrams

- Binary protocol
  - Involves just two participants: base and conjugate roles
  - Conjugate role transposes incoming and outgoing message sets of the base role
Protocol (cont’d)

Extended UML:

```
<<binary protocol>>
Download Commands

incoming
LMGI_I_CMD_MSG ( )

outgoing
LMGI_R_UPDLMUI_MSG ( )
```

UML with stereotypes:

```
<<binary protocol>>
Download Commands

<<incoming>> LMGI_I_CMD_MSG ( )
<<outgoing>> LMGI_R_UPDLMUI_MSG ( )
```
We use stereotyped “realizes” relationships so that ports “inherit” the operations from the protocol.

- **Download Control**
  - <<cport>>
  - <<obeys>>
  - LMGI_I_CMD_MSG ( )

- **Download Ack**
  - <<cport>>
  - <<obeys conjugate>>
  - LMGI_R_UPDLMUI_MSG ( )

**Binary Protocol**

Download Commands

- <<binary protocol>>
- <<incoming>> LMGI_I_CMD_MSG ( )
- <<outgoing>> LMGI_R_UPDLMUI_MSG ( )
Extra “realizes” relationship required: allows us to draw interaction diagrams where components send messages to one another.

**Class Diagram: Rose Support**

Class Diagram: Rose Support

**<<ccomponent>>**

LMGI

**<<cport>>**

Download Control

**<<obeys>>** Extra “realizes” relationship required: allows us to draw interaction diagrams where components send messages to one another

**<<Rose support>>**

**<<binary protocol>>**

Download Commands

**<<incoming>>** LMGI_I_CMD_MSG()

**<<outgoing>>** LMGI_R_UPDLMUI_MSG()
Interaction Diagrams (new slide!!)

- I’ll show an example in Rose here…
Elided notation:

Canonical notation (component containment excerpt):

- Load Management
  - LMGI
  - LMUI
  - NE Status
Notation: Port Binding

- Port of enclosed component may be bound to port of enclosing component
  - Enclosing component’s port may or may not obey the exact same protocol as enclosed component’s port obeys
  - Multiple ports from enclosed components may bind to a single port of an enclosing component

Elided notation:
Notation: Port Binding (cont’d)

Canonic notation:

<<component>>
Load Management

<<component>>
LMGI

<<cport>>
NE Status
(from LMGI)

<<cport>>
NE Status
(from Load Management)

<<cbinding>>
Rose Demo: Conceptual Components
Evaluation of Try #3

Pro:
- Notation is conceptually scaleable
- Captures constraints on interactions between components
- Fits with the real-time, asynchronous nature of OMC-R system
- Provides big-picture view of system

Con:
- Difficult to model in Rose: Rose Realtime is better, but UML stereotypes mean somewhat different things
- Interaction diagrams difficult, error-prone
- Modeling state is still a big issue
Modified 4+1 View of Architecture

- **Use Case View**
  - Captured functional requirements separate from solutions

- **Logical View**
  - Analysis model
    - Crucial element for gaining understanding, agreement on the fundamental system concepts
  - Architectural model
    - High-level functional abstractions in the solution space
  - Design model
    - Combination of abstract elements and concrete elements directly traceable to code

- **Process, Implementation, Deployment Views**
Summary Reflections

- Architectural modeling is an immature art
  - Many different approaches, all have strengths and weaknesses
- Modeling non-OO constructs with UML presents special challenges
  - We couldn’t find anyone else who was doing this…
  - How to capture state?
- Visual modeling with Rose
  - Complicated diagrams
  - Model organization is crucial (deep package structure)
Summary Reflections (cont’d)

- Extended UML notation for architectural modeling
  - Conceptual modeling was very useful, scaleable
  - Lower-level modeling (Hofmeister/Nord/Soni’s Module and Execution views) was confusing, so we omitted it
  - The notational conventions we ultimately adopted served main purpose of showing big picture of legacy architecture
  - Ongoing refinement of notational conventions
- In short: if it promotes clarity, use it; else leave it out
Thank you for your attention and participation!