Object-Oriented Modeling for Planning and Analysis

Pilot Study
Applying Object-Oriented Analysis Methods and Visual Modeling Tools to Predict Urban Water Demand
Questions to Answer

- Are object-oriented analysis and design methods useful to select and improve analytical tools for future CWP Updates?

- Are visual modeling environments such as Extend effective to use in a shared vision planning approach related to the CWP?
Objectives for Meeting

- **Morning** – Introduce:
  - Pilot study
  - Object-oriented analysis and design methods
  - Visual modeling tools

- **Afternoon** – Review recent application of these methods and tools related to predicting urban water demand
What We Would Like from You

- Your thoughts about whether object-oriented modeling techniques and visual modeling environments can be useful to help select and improve analytical tools.

- Your opinion as to whether what we present this afternoon improves your understanding of what CWP has done to predict urban water demand.
Presentation Content

- Description and Context of Pilot Study
- Intro to Object-Oriented Modeling
- Intro to Unified Modeling Language
- Intro to Visual Modeling Environments & Extend
- Present Object-Oriented Analysis of Reporting Recent Urban Water Use
- Present Extend Model for Predicting Urban Water Demand
- Discussion
Description and Context

Pilot Study
Applying Object-Oriented Methods and Visual Modeling Environments to Predict Urban Water Demand
Motivation

- Would like more clarity around analytical methods
- Experiment with methods to improve development, communication, testing, and refining of analytical tools to produce quantitative deliverables
Objectives for Pilot

- Experiment with different methods to improve understanding about how to produce *Future Scenarios* and *Alternative Response Packages*

- Determine if tested methods and tools help us interact more effectively with experts and other stakeholders
Focus for Experiments

- Chose one area of interest: predicting urban water demand
- Test the usefulness of:
  - Object-oriented modeling techniques
  - Graphical modeling notation (UML)
  - Extend – a visual modeling environment
Context for Pilot Study

- California Water Plan Update 2005
  - Volume 1: Chapter 5 Implementation Plan
  - Recommendation 11 – Improve Water Data Management and Scientific Understanding
- In response to the CWP recommended Action Plan and Intended Outcomes
- 1 of 3 pilot studies recommended by SWAN
CWP Recommended Actions

- Develop a general checklist of issues, resources, data, and analytical tools as well as guidelines to aid regional integrated resource planning
- Select and/or develop analytical tools and data in support of next California Water Plan Update
CWP Recommended Actions

- Participate in efforts by the CWEMF to develop and carry out a plan for long-term improvement of analytical tools and data for statewide planning
CWP Quantitative Activities

- **Collaboration** – How can we work together effectively for long-term quantitative development?
- **Information exchange** – What role can state serve in sharing useful information for regional and statewide planning?
- **Numbers for the Water Plan** – How to produce Quantitative Deliverables?
Other Related Projects

- Delta Vision
- Common Assumptions
- Water PIE
- Water Use Efficiency Comprehensive Evaluation – CALFED
Other Related Pilots

- Southern California Water Demand Study – RAND (Complete)
- Inland Empire Utilities Agency Pilot – RAND (Dec. 2006)
- Integrating UWMP’s with Water Plan (Possible)
- Common Schematic – UC Davis (Sept. 2008)
Putting the Pieces Together

● CWP Team will review findings from pilots and propose methods in early 2007 to develop *Future Scenarios* and *Alternative Response Packages* for next Update.

● Proposal will describe coordination with regional planning efforts.

● Work with technical advisory groups such as SWAN.
Timeline

- Develop approach and perform quantitative analysis for next CWP 2006 – 2008
  - SWAN Pilot Studies Q1 2006 – Q4 2007
  - Develop proposal for next CWP through SWAN Q1, Q2 2007
  - Final proposal for next CWP Q2 2007
  - Public Review Draft of CWP Q4 2008
CWP Quantitative Deliverables

A Review
Big Picture for Numbers

- Enhance shared understanding of California water management system
- Illustrate recent conditions
- Describe a range of changes likely between now and 2030
- Identify and test promising responses to expected changes
Quantitative Deliverables

- **Water Portfolios**
  - Describe where water originates, where it flows, and what it is used for based on recent data

- **Future Scenarios**
  - Describe expected changes by 2030 if water managers do not take additional action

- **Alternative Response Packages**
  - Describe packages of promising actions, predict expected outcomes, and compare performance under each scenario
Water Portfolios Underway

Service Area

TER DEPOSITS:
SURFACE WATER: 27.6
GROUNDWATER: 17.0
CYL & DESAL: 0.0
TRANSFERS: Not applicable

RETURN FLOW:
EVAPOTRANSPIRATION OF APPLIED WATER:
AG: 21.8
WETLANDS: 0.6
URBAN: 2.6

TOTAL INCIDENTAL E & ET AG RETURN FLOWS: 0.3

WATER USE (APPLIED):
AGRICULTURAL: 31.5
WETLANDS: 1.3
URBAN: 39 to 43
TOTAL: 41.1

Return Flow within Service Area

Evaporation and Evapotranspiration of Applied Water, Precipitation and Conveyance Losses:
Insufficient Data
How to Produce Other Deliverables?

- We have agreed on a what we want
- Getting specific about how to produce them
- Consider near-term and long-term

Task: Select or develop analytical tools
Before Selecting Tools

- We want to take a fresh look at collective understanding of how the water management system works.
- We want to interact with subject matter experts to make sure we capture the latest thinking.
- Document our collective understanding of important elements of water management system.
Current Approach

- Focus on one quantitative topic at a time (e.g., predicting urban water demand)
- Improve understanding & document requirements necessary to compute satisfactorily
- Interact with subject matter experts to refine
- Select potential implementation techniques and test along the way
Possible Method to Select and Improve Analytical Tools

- Apply an iterative development process (IDP) widely used to create commercial software
  - Use exercises to define actors, their responsibilities, and their interactions
  - Keep it simple, do only what is required to reach understanding
  - Leads to system requirements
  - Supports creation of adaptive software
Basic Steps in IDP

- **Define Use Cases** – write stories or scenarios of how people will use the analytical tool
- **Define Conceptual Model** – create a description of the important concepts, attributes, and associations using objects
- **Define Interaction Diagrams** – define responsibilities and interactions between software objects
- **Define Design Class Diagrams** – define software classes and their attributes and operations
Potential Artifacts

- **Vision** – a short executive overview of big ideas
- **Use-Case Model** – a set of typical scenarios of how analytical tool will be used
- **Glossary** – defines noteworthy terms and can include data dictionary
- **Business Rules** – describe requirements or policies relevant beyond this project
Potential Artifacts (2)

- Conceptual Model – a visual representation of important things in a real system of interest
- Interaction Diagrams – a visual representation of dynamic interaction between objects
- Design Models – describes object responsibilities and how to fulfill requirements with software
Object-Oriented Modeling
An Introduction
**mo • del – n.**

- a simplified representation of a system or phenomenon
- a schematic description of a system, theory, or phenomenon that accounts for its known or inferred properties and may be used for further study of its characteristics
Object-Oriented Modeling

- Use a familiar way of human thinking and abstraction
- Describe system in terms of entities, interactions, and responsibilities

**object** *n.*
1. something perceivable by one or more of the senses, especially by vision or touch
2. something intelligible or perceptible by the mind
Example of an Object Model

Sailboat

Mast

1..3

Hull

1..2

1

1
Object-Oriented Practices

- Object-oriented **analysis** emphasizes finding and describing the objects or concepts in the system of interest.
- Object-oriented **design** emphasizes defining software objects and how they collaborate to fulfill requirements.
- Object-oriented **programming** emphasizes building software to fulfill requirements.
Model vs. Analytical Tool

- **Model** is used in this context to mean a simplified representation of a complex system developed to improve understanding of a problem or solutions.

- **Analytical tool** is used in this context to mean a computational aid created to produce quantitative deliverables.
Parts of an Analytical Tool

- Conceptual model
- Theoretical model
- Numerical model
- Data
- Data management
- Software
- Hardware
- Administrative aspects
Analytical Tool Life Cycle

- **Analysis** – emphasizes an investigation of the problem and requirements (Do the right thing)
- **Design** – emphasizes a conceptual solution that fulfills the requirements (Do the thing right)
- **Implementation** – the design is used to build functioning software
- **Application** – apply tool to conduct studies
- **Maintenance** – preserve, administer and refine
- **Retire** – replace or discontinue use
Unified Modeling Language (UML)
One Tool for Object-Oriented Analysis and Design
What is UML?

- The Unified Modeling Language is a visual language for specifying, constructing and documenting artifacts of systems.
- It is the de facto standard diagramming notation for drawing or presenting pictures related to object-oriented software.
- Can be complicated but we are keeping it simple.
No Silver Bullet

- UML is simply a standard diagramming notation – boxes, lines, etc.
- Visual modeling with common notation can be helpful
- Does not replace the need for system knowledge and sound design skills
- Just as a word processor does not write, UML does not design
Ways to Apply UML

- **UML as Sketch** – informal and incomplete diagrams to explore difficult parts of problem or solution

- **UML as blueprint** – relatively detailed design diagrams used either for
  - Reverse engineering to visualize and better understand existing code
  - Code generation
Perspectives to Apply UML

- **Conceptual** – the diagrams are interpreted as describing things in a real system of interest
- **Specification** (software) – the diagrams describe software abstractions (technology independent)
- **Implementation** (software) – the diagrams describe software implementations in a particular technology (such as Java)
How Have We Used UML?

- As a sketch tool during interactive conceptual modeling of real system of interest (e.g. predicting urban water demand)
- To illustrate how existing analytical tools work (e.g. Urban Water Use Model)
- To help create new software implementations in Extend
An Example

- Demonstrate methods with simple predator-prey model
- Based on tutorial distributed with Extend software
Iterative Development Process

- **Analyze** – what are the questions we want to answer and what are the key components needed to answer it?
- **Design** – how might we represent our conceptual model of the real system using math and software constructs?
- **Implement** – “code” design in a software development environment
Vision

- Allow user to study dynamic interaction of hare and lynx populations in a fixed geographic area
- Allow user to vary key assumptions to determine change in populations over time
Use Case

- Main actor: ecologist / analyst
- Main Success Scenario:
  - Analyst specifies area of habitat.
  - Analyst specifies starting populations.
  - Analyst specifies rate of hare kills per lynx.
  - Analyst specifies birth rates.
  - Analyst specifies lynx mortality rates.
  - Plot change in populations over time.
Create Conceptual Model

- Possible Objects:
  - Habitat
  - Hare
  - Lynx
  - Hares or Hare Population
  - Lynxes or Lynx Population
Function of Conceptual Class Diagram

- Identifies **key objects** in real system of interest
- Shows **important relationships** between objects
- Identifies **key attributes**
- Identifies **key operations**
- Represents a **static view**
Conceptual Class Diagram

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Hares</th>
<th>Lynxes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>Population</td>
<td>Population</td>
</tr>
<tr>
<td>Hare Density</td>
<td>Birth rate</td>
<td>Birth rate</td>
</tr>
<tr>
<td></td>
<td>Mortality rate</td>
<td>Mortality rate</td>
</tr>
<tr>
<td></td>
<td>Give birth</td>
<td>Give birth</td>
</tr>
<tr>
<td></td>
<td>Die</td>
<td>Eat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Die</td>
</tr>
</tbody>
</table>
Function of Sequence Diagram

- Demonstrate designed interaction of objects in software
- Illustrate sequence of events
- Shows communication between objects
- Represents a dynamic view
Sequence Diagram

- Habitat
  - Set Area
  - Hare Population
  - Calculate Hare Density
  - Hare Density
  - Calculate Hare Kills per Lynx

- Lynxes
  - Set Birthrate
  - Set Initial Population

- Hares
  - Set Birthrate
  - Set Initial Population
Summary

● So far, illustrated process to complete first two stages of Analytical Tool Life Cycle
  - Analysis
  - Design

● Next, illustrate stages 3 and 4
  - Implementation
  - Application
Parts of an Analytical Tool

- Conceptual model
- Theoretical model
  - Numerical model
  - Data
  - Data management
- Software
- Hardware
- Administrative aspects
Visual Modeling Environments

An Introduction to Extend
Features and Utility of Visual Modeling Environments

- Graphical display of system with on-the-fly simulation results
- Approximation of more complex models (e.g. look up tables)
- Quick run time (a few minutes)
- Perform screening or gaming type analysis for strategic or policy decisions
- Facilitates object-oriented modeling
Previous Applications

- Visual modeling tools have been used successfully for years in water planning.
- Some applications include:
  - Alabama-Coosa-Tallapoosa/Apalachicola-Chattahoochee-Flint River
  - Missouri River
  - Bill Williams River in Arizona
  - Washington State
  - Central and South Florida
Tools Evaluated by DPLA

- Extend
- Analytica
- Stella
- Vensim
- WEAP
- PowerSim
- Simile
- Model Maker
Desired Features

- Extensive pre-defined functions
- User defined functions and sub routines
- Ability to link to Excel and Access for input and output
- Built-in sensitivity and alternatives analysis
- Ability to organize model into sub-systems
- Free reader
Extend is a visual modeling environment that allows users to combine predefined "blocks" to build a simulation model of a system. The Extend blocks are essentially software objects that a user can easily manipulate and combine. Users can create their own custom blocks.
Extend Demo

Predator-Prey Example
Summary

● Demonstrated first four stages in Analytical Tool Life Cycle
  - Analysis
  - Design
  - Implementation
  - Application

● Represents one of countless ways to meet requirements of simple example
Parts of an Analytical Tool

- Conceptual model
- Theoretical model
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- Software
- Hardware
  - Administrative aspects
After Lunch

- We will present
  - Object-oriented modeling materials created to describe how DWR currently quantifies recent urban water use
  - An Extend model for how future urban water demands were calculated for the CWP Update 2005
  - What we have learned from this pilot so far
Questions and Comments
Lunch Break
A Reminder

Questions to Answer
and What We Would Like from You
Questions to Answer

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What We Would Like from You

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Motivation

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Urban Water Use

Testing Object-Oriented Modeling Techniques and UML to Describe DWR Process
Example Artifacts

- This information is contained in paper sent with agenda
- Completed in June 2006
- Artifacts describe how we
  - Estimate water use in a study area
  - Calculate water use by customer classes in a DAU
Multiple Perspectives

Actual Water Management System

- People
- Physical structures
  - Natural
  - Constructed
- Water
- Nature

Interested Public
Informed Public
Statewide Water Planning Efforts
Conceptual Model of Water Management System

Laws and regulations
Institutions
Markets
View Artifacts

Use Cases, Class Diagrams, and Sequence Diagrams
What We Have Learned

- Object-oriented techniques seem promising for us
- There are start-up costs
- We learned by doing
- Can be helpful to improve understanding of and document existing analytical tools
- Keep it simple
Questions and Comments
Extend Demo

Predicting Urban Water Demand
What We Have Learned

- Extend has a lot of capability
- There are start-up costs
- We learned by doing
- Can be helpful to improve understanding of and document existing analytical tools
- Clearly shows data flows
- Allows for rapid testing of conceptual, theoretical, and numerical approaches
Questions and Comments
Your Turn

- We would like to hear your reactions to our two questions:
  - Are these techniques and tools useful for selecting and improving analytical tools?
  - Did they contribute anything to your understanding about how we quantify urban water use and predict urban water demand?
- Anything else?
Next Steps

- We plan to apply the object-oriented modeling techniques to explore methods for predicting urban water demand (treating demand as a behavior rather than a use)
- We would like to present results of this pilot study to SWAN in December 2006
- Based on your input we will host at least one more workshop before December