Use Cases

- Specify “actors” and how they interact with various component parts of a system
  - This is an external “black box” view of a system
- System is a collection of “use cases” (ie. Capabilities provided to users/actors)
- Represented using diagrams and schemas
  - Diagrams show flow of “uses” between actors and use cases
  - Schemas are more formal non-pictorial definitions
**Example Use Case diagram**

![Use Case diagram]

**Use Case schema**

**Use case:** Heat Cooking Tank  
**Description:** Heat a cooking tank to the temperature prescribed by the recipe of the juice to be mixed, and keep it at that temperature for the time prescribed by the recipe.  
**Reads:** Cooking tank, Batch, Recipe.  
**Changes:**  
**In:** Operator: Batch ID  
Thermometer: Current temperature.  
**Out:** Thermometer: Temperature request.  
Heater: switch on, switch off.  
Operator: heating finished.  
**Assumes:** Juice is present in tank.  
**Results:** Juice has been kept at desired temperature for the desired time.  
**Transactions:**  
- The system switched on the cooking tank heater.  
- The system checks the cooking tank thermometer every 10 seconds. When the desired temperature is reached, the heater is switched off, when the temperature is too low, the heater is switched on again.  
- When the end temperature is reached, the heater is switched off and a message is sent to the operator.
**Stakeholders and Questions**

- Users of the system
  - How do I want it to behave
- Developers of the system
  - What capabilities do I need to implement
- Customers
  - What are these capabilities and behaviors worth

**Message Sequence Diagrams**

- Sometimes called “ladder charts”
- Represent a particular sequence of messages exchanged between entities
- Popular in object-oriented methods to represent communications between objects
- Shows one particular communication sequence in one run of the system
  - Shows behavior as well as communication
- Can be extended with conventions to represent looping, casing, timeouts, synchronization, global conditions across different entities, delayed message reception, etc.
Stakeholders and Questions

- **Users**
  - What behaviors do I want/need

- **Developers**
  - What interactions need to be supported
  - What are the entities
  - What operations are to be supported

- **Inspectors?**
  - Are there safety issues

- **??**
Class Diagram

- In widespread use. Consists of
  - Name
  - Attributes
  - Operations/Methods
  - Associations
    - Cardinalities
    - Annotations
    - Qualifiers
    - Interfaces
    - More….. (much more)

Class diagram for juice plant

additional object class
• would be modeled by a control process in dataflow models.
Collaboration Diagrams

- Popular in object-oriented methods to represent message exchanges between objects
- Object specification augmented by annotations that represent dataflows between the communicating objects
- Differ from other notations
  - Nodes represent objects, not activities (as in DFDs, activity diagrams, activity charts, and block diagrams)
  - Nodes represent object instances, not object classes
- As in sequence diagrams, represent the sequence of messages in one particular scenario, not all possible communications scenarios.
Representing Other Types of Things

- Data, Objects, Artifacts
  - These are clearly secondary in all of the above diagrams
  - Often are more important than functional view
  - Harder to depict diagrammatically

- Process artifacts and views
  - Primary interest of management and customer stakeholders for much of the time
  - Typical questions:
    » What is the (development) plan? schedule?
    » Are we almost done?
    » What are we going to do next?
    » What if Joe quits?
  - Different representations are needed to reply effectively

Primitive Data Representations

- Record Structures
- Array Structures
- Linked List Structures
Representation of Data/Objects

• Complement to emphasis on representation of activities
  – Foregoing representations all focussed on activities
  – Weak capabilities for describing data and objects
  – Seen mostly as effects of activities
  – Numerous places where data descriptions were needed
    » eg. Request List in elevator example
      • Supposed to be sorted (which way?)
      • Elements had fields (what types?)

• Problems in doing this well
  – What information needed/what questions need answers?
    » Hierarchical decomposition of data
    » Legal actions on data
    » Typing information

• What forms of representation will be useful?
  » Natural language
  » Diagrammatic
  » Formal language

Much more will be said about this Later in the course
Primitive Process Representations

- PERT/CPM Charts
- Gantt Charts

Pert and CPM Charts

- Depict the process as a network of tasks
- Each step is a circle
- Incoming arrows are steps that must complete before this one
- Outgoing arrows are steps that might follow this one
- Each step has a time estimate
- No loops allowed
- So that maximum “flow time” can be computed
  - Along the “critical path”
- Early management tool
- Very naive and oversimplified view
  - no loops!!
  - Simplicity is its strength and weakness
Gantt Charts

- Familiar milestone charts, progress charts, ....
- Time represented along a horizontal axis
- Each task (person, ...) represented by a solid bar plotted against the time line
- Bar starts at “start time” and ends at “end time”
- Key Milestones represented by triangles placed along the bar
- Shows how tasks juxtapose
- Shows who should be doing what at all times
- Shows how product is supposed to evolve over time
- Effective for spotting schedule slippages

Example Gantt Chart

<table>
<thead>
<tr>
<th>Field Support</th>
<th>Test</th>
<th>Builder #1</th>
<th>Builder #2</th>
<th>Customer Liaison</th>
<th>Design</th>
<th>Get money</th>
<th>Document</th>
<th>Plan</th>
</tr>
</thead>
</table>

2005 2006 2007 2008 2009
Multirepresentation Systems

• Have seen that different representations are of different uses
• One diagram may be useful in different ways to different stakeholders
• But most stakeholders require a variety of diagrams
• Several different diagrams can be expected to be needed to satisfy the different stakeholders
• Problems with different views/diagrams
  – Are they all representing the same software product?
  – How to assure that they are all consistent with each other?
  – If the product changes, then ALL views must change correspondingly

Multiple Views
Plato’s Cave

STATEMATE

- Focus on Statecharts—an enhancement of FSM's
  - Augmented by other views (e.g. activity Diagrams)
- Key feature is maintenance of consistency among views
- Rigorously defined semantics
  - Including specification of needed consistency
- References
- Commercially available software system
Multiple Views in Statemate

- Rationale for multiple views: Too much information in a single diagram creates clutter, confusion, defeats clarity

- Advantage of multiple views: Each represents a different viewpoint, different model, with a different diagram

- Disadvantage: Reader needs to synthesize views, assure that they are really consistent with each other

- Multiple views in Statemate:
  --Module Charts (a hierarchy representing capabilities)
  --Activity Charts (hierarchical dataflow charts)
  --Statecharts (hierarchical finite state machines)
  --Sequence Charts

- All facilitated by a slick user interface

- Statemate views depict some different views, but also overlap with each other: facilitates cross-checking for consistency and easier comprehension
Multiple Views in Statemate

Activity view

Module view

Message
Sequence view

Statechart view

Textual view

The Importance of Redundancy

Redundancy

• Specifying or doing the same thing more than once
• Usually considered undesirable in computing
• Typically regarded as desirable in engineering
• Particularly useful in safety engineering
  – NASA 5-way redundancy
• Can help assure that multiple views are not inconsistent
  – Different views should not be inconsistent about things in their intersection
Module Charts

- Hierarchy shown by
  --Indentation
  --Nesting module-charts inside each other

- How many levels of nesting without losing clarity?
Activity Chart

- A Data Flow Diagram
  --Hierarchical
  --focus (depicted by solid boxes) on functions
  --Arrows depict data flows

- All of this helps user/reader to associate features of one with features of the other

- New dataflow diagram feature:
  --Control box (rounded): at most one per activity
  --Suggests need to depict how and when data will flow among functions—not just what
  **Example: How to represent an activity consisting of a set of cases with DFD's?**
  --Dashed arrows represent flow of control information (eg. signals, commands, status reporting/changing)
  >>This is redundant with arrows in Module Charts

- This, in turn, anticipates new view represented using the third type of chart
Statecharts

• Extension of basic notion of FSM

• FSM’s are effective in modeling systems that are
  --clearly and accurately modelled as being in only one of a
  finite number of states at a time
  --considered to move from state to state driven by events
    drawn from a finite set of possibilities

• Statecharts add some features to what basic FSM’s can represent
  --Hierarchy:
    >> Keeps charts from getting too big, hard to understand
  --ANDing and ORing of states:
    >> to model simultaneously being in >1 state
    >> example: elevator in moving/not or doors_open/not
  --Elaborate specification of transition conditions

• Correlation with Activity Charts helps comprehensibility
Add Activities and Actions

- **Activities**
  - Associated with a state
  - Start when the state is entered
  - Take time to complete
  - Interruptible
- **Actions**
  - Associated with a transition
  - Take an insignificant amount of time to complete
  - Non-interruptible

Activities and Guards in Statecharts

- **Activities**
  - An activity can also send an event
- **Transitions**
  - A transition may have a guard conditions as well as an event specified
  - Transitions can also specify an action that happens in response to the receipt of an event
Statechart

**Initialize**
do: Initialize course object

cancelCourse

**Unassigned**
do: Assign professor to course

cancelCourse

**Open**
entry: Register a student

cancelCourse

**RegisterComplete**
do: Generate class roster

cancelCourse

**Unassigned**
do: Assign professor to course

**Canceled**
do: Send cancellation notices

**Registered**
do: Report course is full

**Closed**
do: Report course is closed

addStudent

numStudents = 0

registration closed
numStudents < 3

numStudents = 10

registration closed
numStudents > 3

numStudents > 3

registration closed
numStudents < 3

Statechart with Nested States

**Initialize**

**RegisterComplete**
do: Generate class roster

registration closed
numStudents > 3

numStudents = 0

Add student
numStudents = 10

**Open**
entry: Register a student

**Closed**
do: Report course is closed

addStudent
Message Sequence Chart View

- Very much like what we have seen before
- Vertical red lines augment diagram with timing information
  - Simultaneous activities
  - Specification of time lag between messages
1. Charging subsystem indicates electrical system load.
2. Customer requests the rear defog system to turn on.
3. The rear defog led is illuminated.
4. The rear defog relay is enabled.
5. Vehicle speed increases past the high speed threshold - the relay can be enabled indefinitely.
6. Load condition one exists, the system starts modulation of the rear defog relay.
7. Modulation starts at the calibrated duty cycle the relay is enabled
8. Modulation continues, the relay is enabled.
9. Modulation continues, the relay is disabled.

Time: 0.000000
[DEFOG_DRIVE_OFF--0x1]
[DEFOG_DRIVE_OFF--0x0]
[DEFOG_DRIVE_OFF--0x1]
[LOAD_RHS_FWD--LR_LEVEL]

Time: 10.000000
[DEFOG_DRIVE_OFF--0x1]
[DEFOG_DRIVE_OFF--0x0]
[LOAD_RHS_FWD--LR_LEVEL]

Time: 14.000000
[DEFOG_DRIVE_OFF--0x1]
Statemate Support Environment

- Tools to support drawing/changing diagrams
- Tools to support input of textual information through forms/templates
- Diagrams enhanced by use of color (?)
- Tools to generate simulations automatically -- support "stepping through" the system
- System assures consistency among the diagrams -- changes automatically depicted consistently in all diagrams
- Tools to automatically generate Ada code that emulate Statechart behavior

Template Input
Cross-Checking/Redundancy Checking
Discrete Event Simulation Too

Simulation Monitor

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Value</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEFaulT_DRIVE_SIG</td>
<td>CL</td>
<td>FALSE</td>
<td></td>
</tr>
<tr>
<td>DEFaulT_CYCLE</td>
<td>CL</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>K_PERIOD</td>
<td>K</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>LOAD,SHAPE_IN</td>
<td>H</td>
<td>UMLLEVEL0</td>
<td></td>
</tr>
<tr>
<td>OFF_TIME</td>
<td>H</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>ON_TIME</td>
<td>H</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>REMOTE_INIT</td>
<td>CL</td>
<td>TRUE</td>
<td>FCL</td>
</tr>
</tbody>
</table>
Statemate Weaknesses

- Does not seem to scale all that well
  -- Hierarchy depicted by nesting all on one 2-dimensional surface
- Data still treated as secondary
- Focus still on functionality
  -- Other characteristics and views are worth thinking about too:
    >> Speed
    >> Implementation approaches and issues
    >> ...

UML (Unified Modeling Language): The Latest (?)

- Merger of Booch, Rumbaugh, Jacobsen work
  -- “The three amigos”
  -- All worked for Rational (now IBM)
- Comprehensive suite of diagrams
- Some semantics in place
  -- But not all
  -- International task forces (!) working on this
- Process for using them was developed too
  -- Rational Unified Process (RUP)
- UML blew away the opposition
  -- Not clear this was good
(Some) UML representations

- Class Diagrams
- Use Cases
- Sequence Diagrams
- Package Diagrams
- State Diagrams
- Activity Diagrams
- Collaboration Diagrams
- Deployment Diagrams

Different combinations used by
Different users for different projects

Major UML Problems/Objections

- What are semantics of all of these features of all of these diagrams?
  - Task forces working on them
  - Maybe there is just too much there (?)
- Diagram semantics overlap
  - Which diagram to use when
  - How to tell when they are inconsistent
- Extensibility
  - Use of “stereotype” feature
  - How to reconcile semantics of new features with existing ones
UML Tries to cover everything

• A diagram type for everything
• But they are not well connected to each other
• Few rules on what to use when
• Long reach with uncertain grasp

Evaluation of Diagrammatic Approach

• Pictures considerably aid clarity
• Significantly reduce possible ambiguity
• Increasingly strong semantics of increasingly intricate pictures yield increasing completeness and increasing assurance of consistency
• Increasingly intricate pictures are decreasingly clear, decreasingly modifiable
  --Modern approach is to provide tools to help
• In place of one intricate and complex diagram, many systems substitute a set of coordinated diagrams, each of which is relatively simple (eg. Statemate)
  --leads to problems in assuring consistency of diagrams, but tools can help here too

BUT ALSO:
• Most diagrams help depict functionality, but not other characteristics, (eg., data, process, etc.)