Dynamic Aspects of UML
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- Additional UML diagrams
  - Collaboration diagram
  - Sequence diagram
  - Activity diagram
  - State diagram

- One or more of these diagrams would be part of a design document which expresses behavior prior to writing code.
Review: Sequence Diagram

- In a sequence diagram the objects' behaviors are shown as *vertical lines* and messages cross between these lines.

- The time sequence is shown by vertical position, flowing down the diagram.

- Time is not generally to scale.

- Bars indicate periods of activity.
Sequence Diagram for Buying Insurance Policy

Jones : Buyer

→

1: buy(Apex, Thomas, 100k)

→

Smith : Broker

1.1: buy(Thomas, 100k)

1.2: issue(Thomas, 100k)

→

Apex : Company

1.3: payCommission()

[Thomas is the insured.]
Added Facets of Sequence and Collaboration Diagrams

- Objects can send messages to themselves (e.g. one method implemented using another, including recursion).
- **Pre-conditions** can exist on message arcs: [... pre-condition ...]
- Timing can be indicated on the diagram
- Object destruction indicated by large X
Timing Annotation

\[ b - a \leq 500 \text{ ms} \]
Message Types

- No specific detail of control passing

- Synchronous: Nested flow, as in typical method calls; caller waits for reply before resuming

- Asynchronous: No explicit reply before sender resumes.
Collaboration Diagrams

- Show objects, not classes, collaborating
- “Message” flows between objects, e.g. a method call:

```
buyer : Buyer

broker : Broker
```

sequence number (dewey decimal)  message

```
1.1: buy(Apex, Thomas, 100k)
```

note: Arrow does not connect boxes; it shows the direction of flow on an association.
Message Flow for Buying an Insurance Policy

1: buy(Apex, Thomas, 100k)

1.1: buy(Thomas, 100k, Jones)

1.2: issue(Thomas, 100k)

1.3: payComission()
Significance of Numbering

- Numbering shows the sequencing of messages.

- Dewey-Decimal: 1.1, 1.2 are messages introduced in handling of message 1, etc.
Activity Diagrams

- Activity diagrams are extensions of conventional flowcharts.
- Parallel execution is possible.
- Synchronization is representable.
Activity Diagram Example

- Print document
- Parallel Activities:
  - Create Postscript file
  - Send Postscript file
  - Receive Postscript file
  - Email confirmation
  - Print Postscript file

Printer1: Printer

“signal”
Synchronization of Activities
(fork-join subset of “Petri nets”)
"And" vs. "Or" Synchronization

Parallel Activities

{or} vs. {and}

Default
Branching of an Activity
(same as in traditional flowchart)
“Swimlanes” = Threads or Processes in Activity Diagram
State Diagrams

• Essentially Statecharts, as invented by David Harel (founder of I-logix).

• Statecharts are a structured form of finite-state machine.

• States can be decomposed into parallel or nested sub-systems.

• This is more economical than enumerating all states.
Every ordinary finite-state machine diagram is a statechart.

States are mutually exclusive.

States may involve program variables not represented by diagram structure.
Events vs. Condition/Action pairs

- Events designate some named event occurring, such as an external event.
- Condition/Action represents an event triggered by a condition on program variables and an action that may assign to those variables.
- The null condition is the same as “true”.
- The null action is that all variables are unchanged.
Nuance:
Hierarchy in StateCharts

Aggregate State

entry condition

exit condition

Phase I
Hierarchy

Aggregate States

Phase I

Phase II
Word descriptions signaling that an aggregate state might be appropriate:

- Phase
- Mode
- Region
- Interval
Statechart Example

- Combination FM/AM Radio and Cassette Tape Player (Auto-reverse)
  - Either the radio or the tape player is playing, but not both.
  - The unit can play only if power is on.
  - The tape plays iff a tape is inserted.
  - The radio can play in AM or FM.
Radio/Tape Player State Diagram

Top-Level View

toggle power switch

off ➔ on

toggle power switch
Radio/Tape Player State Diagram

First-Level Expansion

toggle power switch

off

on

radio mode

tape not inserted

insert tape

eject tape

tape inserted

toggle power switch

tape mode
Radio/Tape Player State Diagram

Second-Level Expansion

toggle power switch

off

on tape not inserted

radio mode

FM

AM

on tape is inserted

tape mode

forward

start reached

dead reached

eject tape

reverse

insert tape

toggle power switch

tape not inserted
Possible Design Flaws
Detected from Diagram
Redesign to Remedy Flaws

Radio Mode
- Band: FM
- Band: AM
- Band toggled
- Band not toggled

Tape Mode
- Insert Tape
- Eject Tape
- Forward
- Reverse
- Direction: Forward
- Direction: Reverse

Switch Between Radio and Tape Modes
Another Nuance: Concurrency in StateCharts

Dashed line indicates concurrent subsystems

Subsystem I

Subsystem II
Augment the Radio/Tape Design to Permit Recording from Radio

- The Radio and Tape can now operate concurrently.
- The tape may record in either direction.
- We can no longer let the presence of the tape dictate the mode; must use buttons.
Partially-Developed Radio/Tape Player/Record

- **Radio Mode**: 
  - On/Off
  - AM/FM
  - Band Toggled

- **Tape Mode**: 
  - Tape Inserted
  - Tape Not Inserted
  - Insert Tape
  - Eject Tape
  - Play
  - Stop
  - Record
  - Forward
  - Reverse

- **Mode Selection**: 
  - Per Buttons

- **Buttons**: 
  - Play
  - Stop
  - Record
  - Forward
  - Reverse

- **States and Transitions**: 
  - Off
  - On
  - Pressed
  - Not Inserted

- **Actions**: 
  - Insert Tape
  - Eject Tape
Concurrency in StateCharts provide representational economy

- A statechart with concurrency provides for the representation of $M \times N$ states with only $M + N$ bubbles.

- The combinatorial explosion of states is thereby reduced.
Data Flow Diagrams (DFDs)

- Classical software engineering tool
- Not part of UML (yet!)
- Data flow can be loosely handled as objects, but object diagrams are ambiguous as to whether they are representing true data flow.
Data Flow Diagrams

- The main idea:
  - Represent system as a directed graph of software modules (nodes)
  - Arcs between nodes represent the “flow” of data from one module to another
Data Flow Diagrams

Applications that lend themselves to this model:

- “Pipe” composition, as in Unix pipes
- Problems treatable as functional decompositions on streams of data
- File- and document-processing problems: The “flow” is represented by intermediate immediate files that are written by one module and read by another.
Advantage of DFDs

- DFDs have an intuitive feel that is easily understood by the customer (vs. Objects, which might be less intuitive), so could be used as a sort of specification language.
- Good for “assembly-line” processing of commodities or documents.
- Data flow makes programming into plumbing.
DFD for Order Processing

Order details + blank order form

Complete order form

Validated order

Record order

Signed order form

Send to supplier

Adjusted available budget

Order details

Order amount + account details

Orders file

Budget file

Checked and signed order + order notification

source: Ian Sommerville, Software Engineering, 5th Ed.
More DFD points

- DFD capable of showing various levels of abstraction.
- A processing box can be expanded into its own DFD, etc., enabling "zooming" into the structure of the system.
- Does not particularly lend itself to showing interactive behavior, since output is separated from input.
DFD Example with Databases

source: Ian Sommerville, Software Engineering, 5th Ed.
Data Dictionaries
Data Dictionaries

- Glossary or “database” of names and associated descriptions of entities, associations, attributes used in the system.
- Represents a project-wide shared repository of system information
- Provides:
  - A mechanism for name management. As a system model may be developed by different people, there is potential for name clashes
  - A link from analysis to design and implementation
## Data Dictionary Example

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Type</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>has_labels</td>
<td>1:N relation between entities of type Node or Link and entities of type Label.</td>
<td>Relation</td>
<td>5.10.93</td>
</tr>
<tr>
<td>Label</td>
<td>Holds structured or unstructured information about nodes or links. Labels can be text or can be an icon.</td>
<td>Entity</td>
<td>8.12.93</td>
</tr>
<tr>
<td>Link</td>
<td>Represents a relation between design entities represented as nodes. Links are typed and may be named.</td>
<td>Relation</td>
<td>8.12.93</td>
</tr>
<tr>
<td>name (label)</td>
<td>Each label has a name which identifies the type of label. The name must be unique within the set of label types used in a design.</td>
<td>Attribute</td>
<td>8.12.93</td>
</tr>
<tr>
<td>name (node)</td>
<td>Each node has a name which must be unique within a design. The name maybe up to 64 characters long.</td>
<td>Attribute</td>
<td>15.11.93</td>
</tr>
</tbody>
</table>
Data Dictionaries

- Ideally a database in their own right
- Remain intact for the lifetime of the project
- Useable by management and developers
- Useable by customer
  - if source-access is provided
  - legacy file formatting
  - as a description of processing entities (view technical details)
DD Examples on the Web

- www.cris.state.nc.us/datafrm.html
- nccs.urban.org/STalmDD.htm

- Use your browser for many other examples
Info in Data Dictionaries

- Can be handled by UML tool, e.g. in class diagrams and their documentation.

- Report generator may be able to give conventional data dictionary format.