HCI-Conscious Software Architecture

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Agenda

9:00-10:30 Intro to HCI and UI tools
10:30-10:45 Break
10:45-12:15 Usability and Software Architectures (Part 1)
12:15-1:15 Lunch
1:15-2:45 Usability and Software Architectures (Part 2)
2:45-3:00 Break
3:00-4:30 End-User Implications of Infrastructure
4:30-5:00 Homework discussion

Introductions

Instructor
Gregory AY - bowd

HCI
Software Engineering

Ubiquitous Computing

What is HCI?

Human-Computer Interaction: The study of people and computing technology and the way they influence each other

The 3 U's…

Utility (Usefulness), Usability, Ubiquity

Goals of this Course

- Introduction to history of implementation support for interactive systems
  - Dix, Finlay, Abowd & Beale (2004) *Human-Computer Interaction*. Chapter 8.
- Usability Architectural Patterns: how to trace architectural impact of "usability modifications"
  - John, B. E., Bass, L. J., Sanchez-Segura, M-I. & Adams, R. J. (2004) Bringing usability concerns to the design of software architecture. *Proceedings of EHCI and the 11th International Workshop on Design, Specification and Verification of Interactive Systems*, (Hamburg, Germany, July 11-13, 2004).
- End-user implications of middleware infrastructure
  - Edwards, W. K., Bellotti, V., Dey, A. K., and Newman, M. W. 2003. The challenges of user-centered design and evaluation for infrastructure. In *Proceedings of the CHI 2003* (Ft. Lauderdale, Florida, pp. 297-304.

History of UI Implementation Support

Programming tools provide layers of services for programmers

- windowing systems
  - core support for separate and simultaneous user-system activity
- programming the application and control of dialogue
- interaction toolkits
  - bring programming closer to level of user perception
- user interface management systems
  - controls relationship between presentation and functionality

Introduction

How does HCI affect the programmer?

Advances in coding have elevated programming

hardware specific

→ interaction-technique specific

Layers of development tools

- windowing systems
- interaction toolkits
- user interface management systems

Elements of windowing systems

Device independence

programming the abstract terminal device drivers

image models for output and (partially) input

- pixels
- PostScript (MacOS X, NextStep)
- Graphical Kernel System (GKS)
- Programmers' Hierarchical Interface to Graphics (PHIGS)

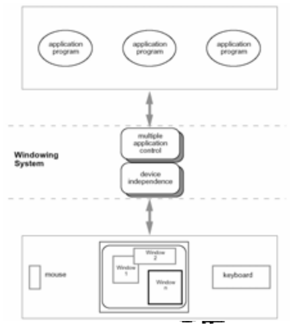
Resource sharing

achieving simultaneity of user tasks

window system supports independent processes

isolation of individual applications

roles of a windowing system



Architectures of windowing systems

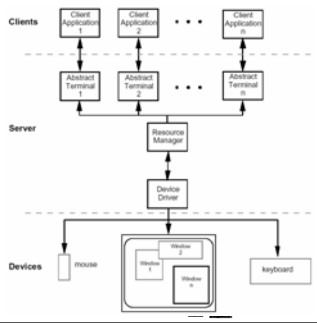
three possible software architectures
- all assume device driver is separate
- differ in how multiple application management is implemented

1. each application manages all processes
   - everyone worries about synchronization
   - reduces portability of applications

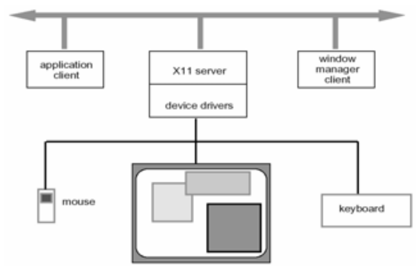
2. management role within kernel of operating system
   - applications tied to operating system

3. management role as separate application
   maximum portability

The client-server architecture



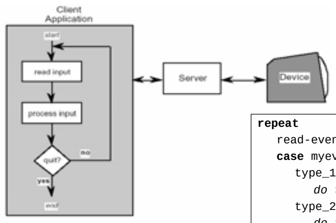
X Windows architecture



X Windows architecture (ctd)

- pixel imaging model with some pointing mechanism
- X protocol defines server-client communication
- separate window manager client enforces policies for input/output:
  - how to change input focus
  - tiled vs. overlapping windows
  - inter-client data transfer

Programming the application
read-evaluation loop



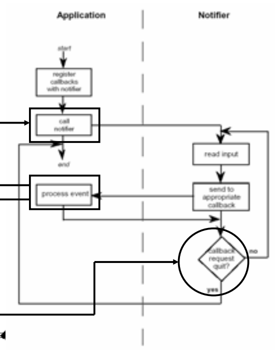
```
repeat
   read-event(myevent)
   case myevent.type
      type_1:
         do type_1 processing
      type_2:
         do type_2 processing
      ...
      type_n:
         do type_n processing
   end case
end repeat
```

Programming the application
notification-based

```
void main(String[] args) {
   Menu menu = new Menu();
   menu.setOption("Save");
   menu.setOption("Quit");
   menu.setAction("Save",mySave)
   menu.setAction("Quit",myQuit)
      ...
}

int mySave(Event e) {
   // save the current file
}

int myQuit(Event e) {
   // close down
}
```



going with the grain

System style affects the interfaces

- modal dialogue box
  - easy with event-loop (just have extra read-event loop)
  - hard with notification (need lots of mode flags)
- non-modal dialogue box
  - hard with event-loop (very complicated main loop)
  - easy with notification (just add extra handler)

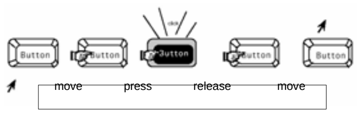
beware!

if you don't explicitly design it will just happen
implementation should not drive design

Using toolkits

Interaction objects

- input and output intrinsically linked



Toolkits provide this level of abstraction

- programming with interaction objects (or
- techniques, widgets, gadgets)
- promote consistency and generalizability
- through similar look and feel
- amenable to object-oriented programming

User Interface Management Systems (UIMS)

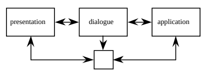
- UIMS add another level above toolkits
  - toolkits too difficult for non-programmers
- concerns of UIMS
  - conceptual architecture
  - implementation techniques
  - support infrastructure
- non-UIMS terms:
  - UI development system (UIDS)
  - UI development environment (UIDE)
    - e.g. Visual Basic

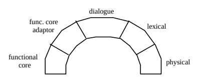
UIMS as conceptual architecture

- *separation* between application semantics and presentation
- improves:
  - portability – runs on different systems
  - reusability – components reused cutting costs
  - multiple interfaces – accessing same functionality
  - customizability – by designer and user

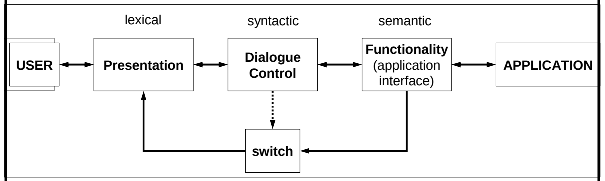
UIMS tradition – interface layers / logical components

- linguistic: lexical/syntactic/semantic
- Seeheim:
- Arch/Slinky





Seeheim model

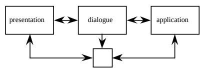


conceptual vs. implementation

Seeheim
- arose out of implementation experience
- but principal contribution is conceptual
- concepts part of 'normal' UI language

… because of Seeheim …
… we think differently!

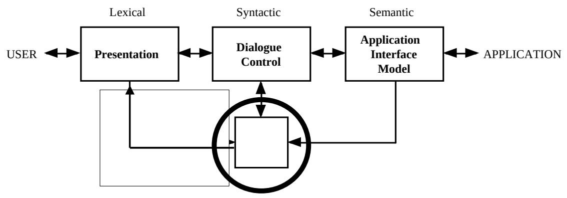
e.g. the lower box, the switch
- needed for implementation
- but not conceptual



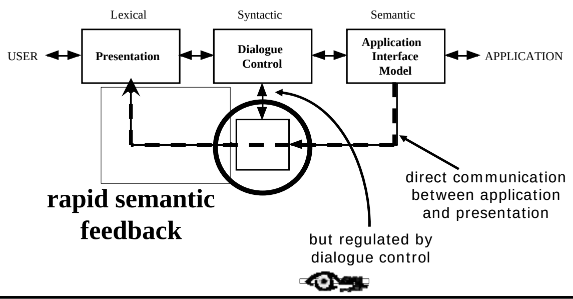
semantic feedback

- different kinds of feedback:
  - lexical – movement of mouse
  - syntactic – menu highlights
  - semantic – sum of numbers changes
- semantic feedback often slower
  - use rapid lexical/syntactic feedback
- but may need rapid semantic feedback
  - freehand drawing
  - highlight trash can or folder when file dragged

what's this?



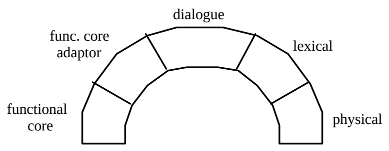
the bypass/switch



Lexical
Syntactic
Semantic
USER
Presentation
Dialogue Control
Application Interface Model
APPLICATION
rapid semantic feedback
direct communication between application and presentation
but regulated by dialogue control

Arch/Slinky

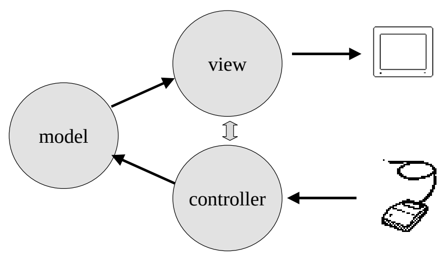
- more layers! – distinguishes lexical/physical
- like a 'slinky' spring different layers may be thicker (more important) in different systems
- or in different components



monolithic vs. components

- Seeheim has big components
- often easier to use smaller ones
  - esp. if using object-oriented toolkits
- Smalltalk used MVC – model–view–controller
  - model – internal logical state of component
  - view – how it is rendered on screen
  - controller – processes user input

MVC
model - view - controller



MVC issues

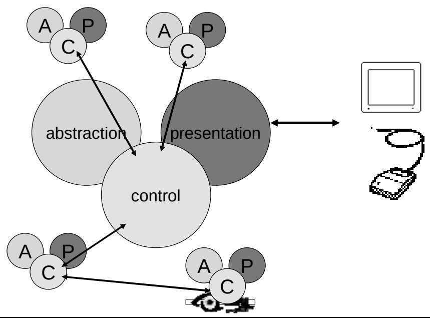
- MVC is largely pipeline model:
  input → control → model → view → output
- but in graphical interface
  - input only has meaning in relation to output

  e.g. mouse click
  - need to know *what* was clicked
  - controller has to decide what to do with click
  - but view knows what is shown where!
- in practice controller 'talks' to view
  - separation not complete

PAC model

- PAC model closer to Seeheim
  - abstraction – logical state of component
  - presentation – manages input and output
  - control – mediates between them
- manages hierarchy and multiple views
  - control part of PAC objects communicate
- PAC cleaner in many ways …
  but MVC used more in practice
  (e.g. Java Swing)

PAC
presentation - abstraction - control



The drift of dialogue control

- internal control
  (e.g., read-evaluation loop)
- external control
  (independent of application semantics or presentation)
- presentation control
  (e.g., graphical specification)

Summary

Levels of programming support tools

- Windowing systems
  - device independence
  - multiple tasks
- Paradigms for programming the application
  - read-evaluation loop
  - notification-based
- Toolkits
  - programming interaction objects
- UIMS
  - conceptual architectures for separation
  - techniques for expressing dialogue

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2:45-3:00 Break

3:00-4:30 End-User Implications of Infrastructure

4:30-5:00 Homework discussion

Source

These materials adapted from Usability and Software Architecture research at Carnegie Mellon School of Computer Science & Software Engineering Institute

http://www.cs.cmu.edu/~bej/usa/index.html

Specifically, tutorials on Usability-Supporting Architectural Patterns by Bonnie John, Len Bass, Natalia Juristo and Maribel Sanchez-Segura

Tutorial objectives: The scene

The usability analyses or user test data are in; the development team is poised to respond. The software had been carefully modularized so that modifications to the UI would be fast and easy. When the usability problems are presented, someone around the table exclaims, “Oh, no, we can’t change THAT!”

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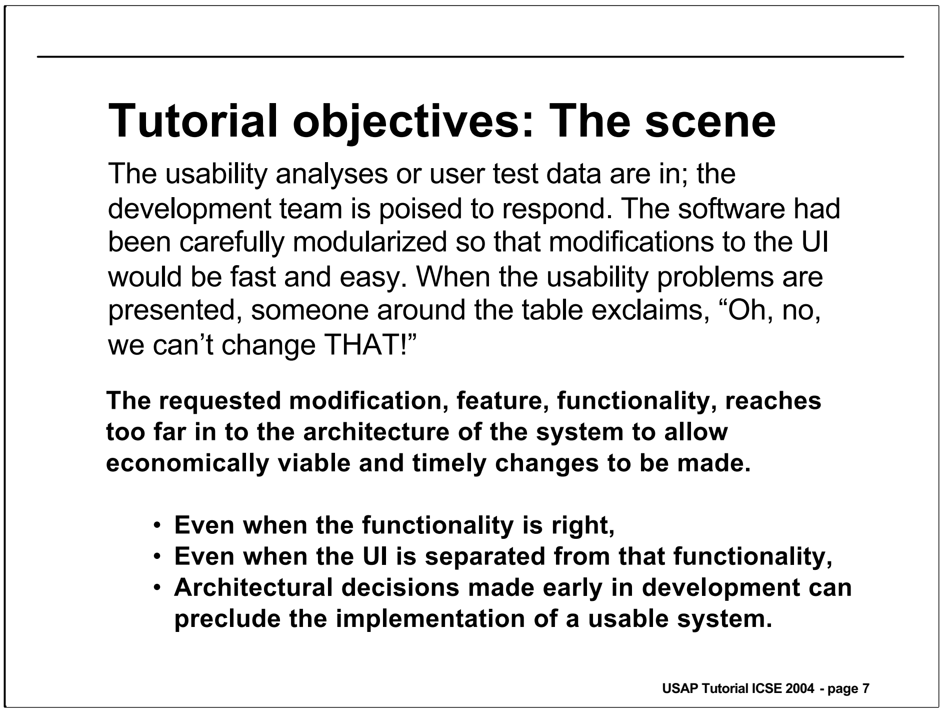

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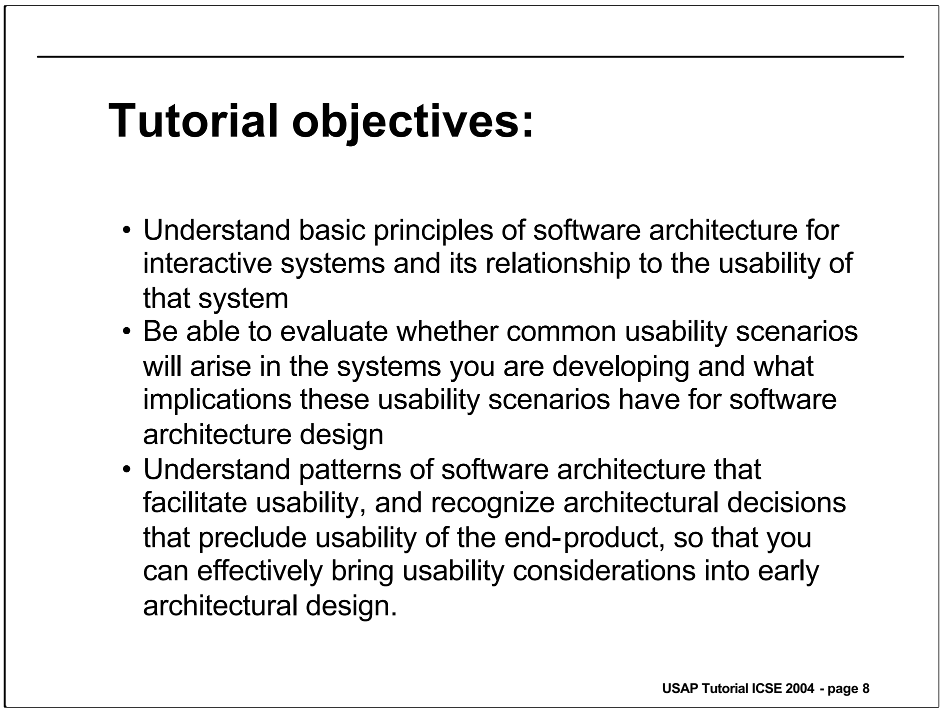
The requested modification, feature, functionality, reaches too far in to the architecture of the system to allow economically viable and timely changes to be made.

- **Even when the functionality is right,**
- **Even when the UI is separated from that functionality,**
- **Architectural decisions made early in development can preclude the implementation of a usable system.**



Tutorial objectives:

- Understand basic principles of software architecture for interactive systems and its relationship to the usability of that system
- Be able to evaluate whether common usability scenarios will arise in the systems you are developing and what implications these usability scenarios have for software architecture design
- Understand patterns of software architecture that facilitate usability, and recognize architectural decisions that preclude usability of the end-product, so that you can effectively bring usability considerations into early architectural design.

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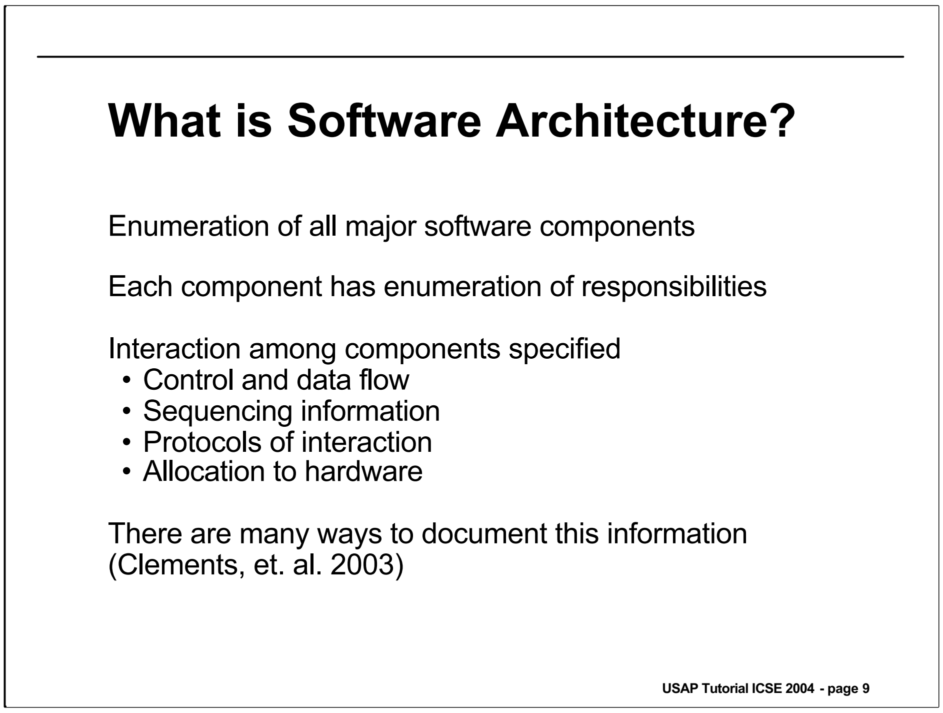

What is Software Architecture?

Enumeration of all major software components

Each component has enumeration of responsibilities

Interaction among components specified
- Control and data flow
- Sequencing information
- Protocols of interaction
- Allocation to hardware

There are many ways to document this information (Clements, et. al. 2003)

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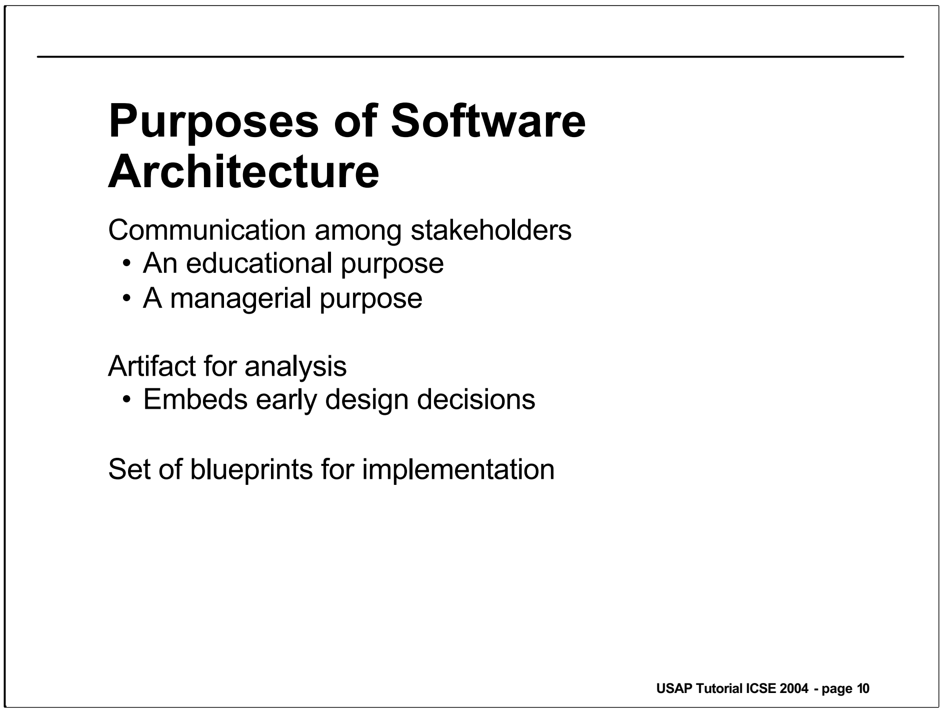
Clements, P., Bachmann, F., Bass, L., Garlan, D., Ivers, J., Little, R., Nord, R., & Stafford J., (2003) Documenting Software Architectures: Views and Beyond, Addison Wesley.



Purposes of Software Architecture

Communication among stakeholders
- An educational purpose
- A managerial purpose

Artifact for analysis
- Embeds early design decisions

Set of blueprints for implementation

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What does usability mean?

As many definitions as there are authors!

What’s important depends on context of use

Some commonly-seen aspects
- efficiency of use
- time to learn to use efficiently
- support for exploration and problem-solving
- user satisfaction (e.g., trust, pleasure, acceptance by discretionary users)

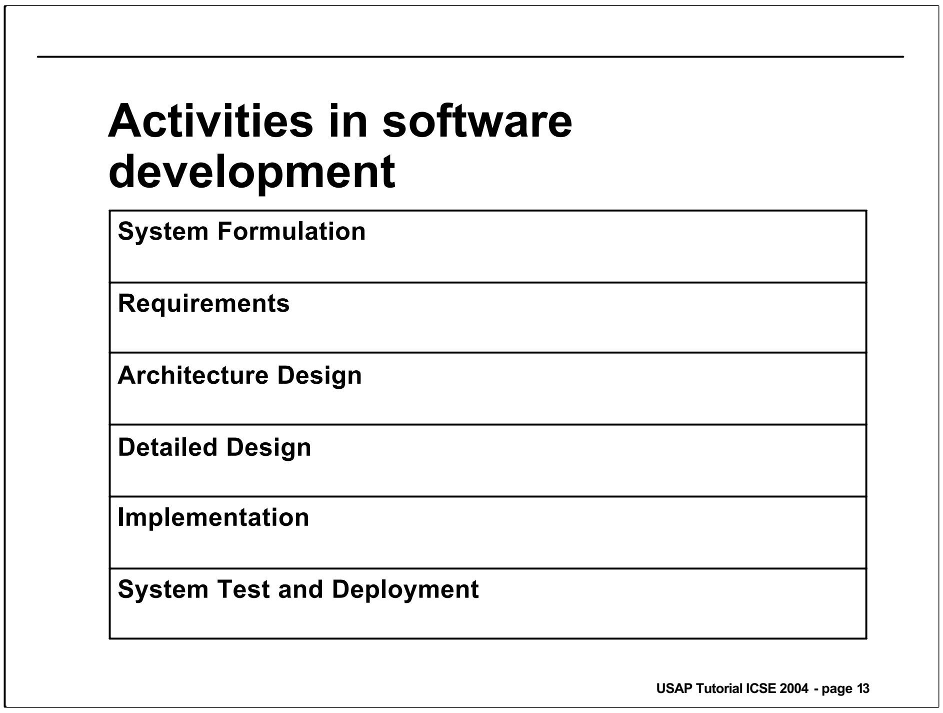
Our concern is which of these can be influenced by architectural decisions

A usability benefits hierarchy

Increases individual user effectiveness
- Expedites routine performance
  - Accelerates error-free portion of routine performance
  - Reduces the impact of routine user errors (slips)
- Improves non-routine performance
  - Supports problem-solving
  - Facilitates learning
- Reduces the impact of user errors caused by lack of knowledge (mistakes)
  - Prevents mistakes
  - Accommodates mistakes

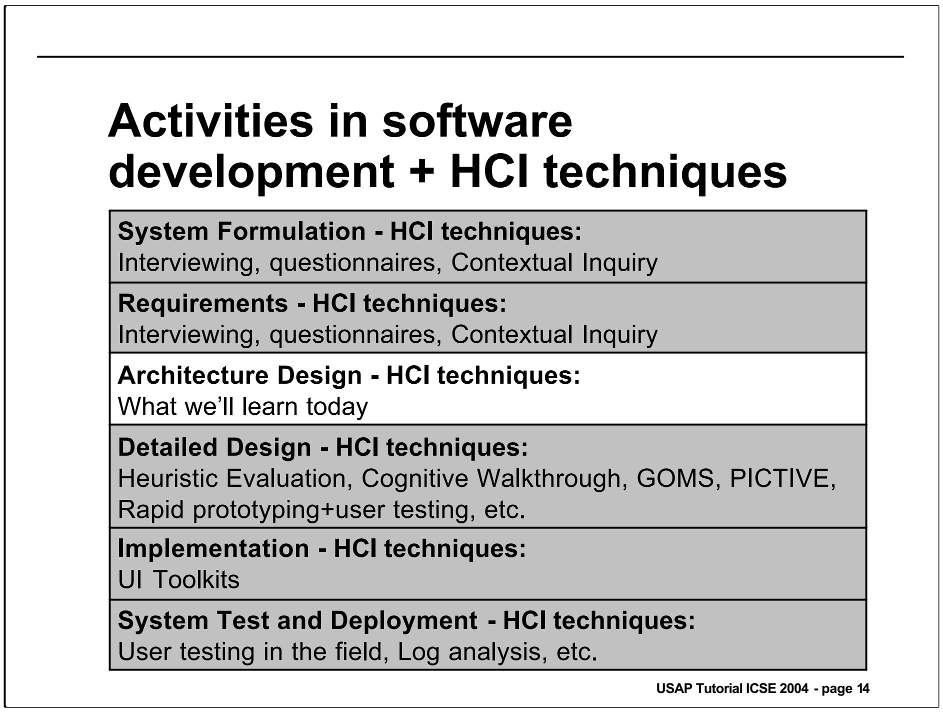
Reduces the impact of system errors
- Prevents system errors
- Tolerates system errors

Increases user confidence and comfort



Activities in software development

System Formulation
Requirements
Architecture Design
Detailed Design
Implementation
System Test and Deployment



Activities in software development + HCI techniques

System Formulation - HCI techniques: Interviewing, questionnaires, Contextual Inquiry
Requirements - HCI techniques: Interviewing, questionnaires, Contextual Inquiry
Architecture Design - HCI techniques: What we'll learn today
Detailed Design - HCI techniques: Heuristic Evaluation, Cognitive Walkthrough, GOMS, PICTIVE, Rapid prototyping+user testing, etc.
Implementation - HCI techniques: UI Toolkits
System Test and Deployment - HCI techniques: User testing in the field, Log analysis, etc.

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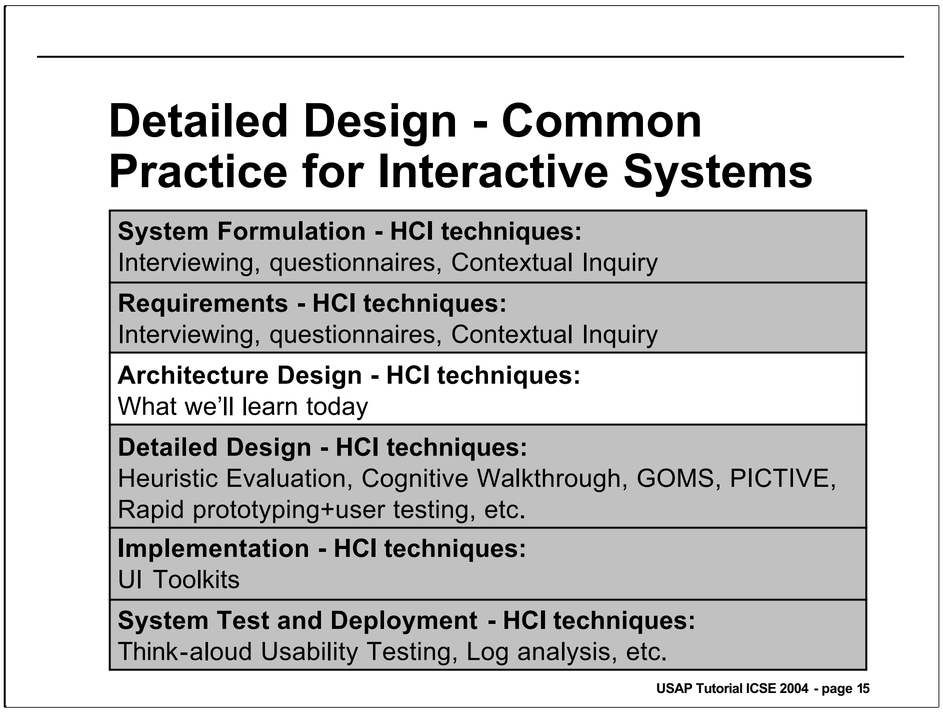

Detailed Design - Common Practice for Interactive Systems

System Formulation - HCI techniques: Interviewing, questionnaires, Contextual Inquiry
Requirements - HCI techniques: Interviewing, questionnaires, Contextual Inquiry
Architecture Design - HCI techniques: What we'll learn today
Detailed Design - HCI techniques: Heuristic Evaluation, Cognitive Walkthrough, GOMS, PICTIVE, Rapid prototyping+user testing, etc.
Implementation - HCI techniques: UI Toolkits
System Test and Deployment - HCI techniques: Think-aloud Usability Testing, Log analysis, etc.

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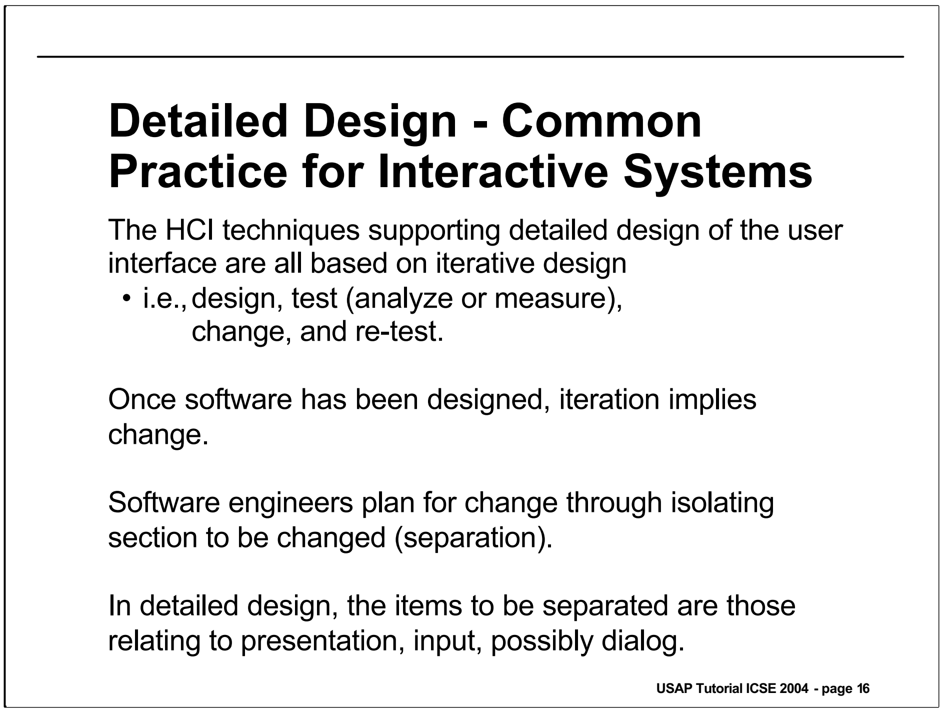

Detailed Design - Common Practice for Interactive Systems

The HCI techniques supporting detailed design of the user interface are all based on iterative design

- i.e., design, test (analyze or measure), change, and re-test.

Once software has been designed, iteration implies change.

Software engineers plan for change through isolating section to be changed (separation).

In detailed design, the items to be separated are those relating to presentation, input, possibly dialog.

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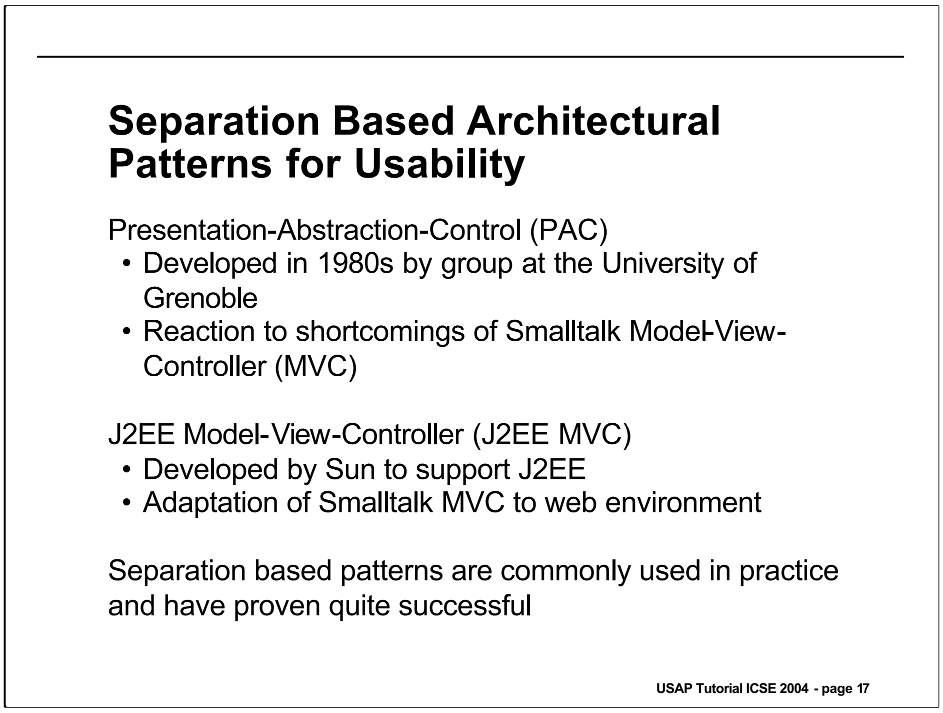
Separation Based Architectural Patterns for Usability

Presentation-Abstraction-Control (PAC)
- Developed in 1980s by group at the University of Grenoble
- Reaction to shortcomings of Smalltalk Model-View-Controller (MVC)

J2EE Model-View-Controller (J2EE MVC)
- Developed by Sun to support J2EE
- Adaptation of Smalltalk MVC to web environment

Separation based patterns are commonly used in practice and have proven quite successful

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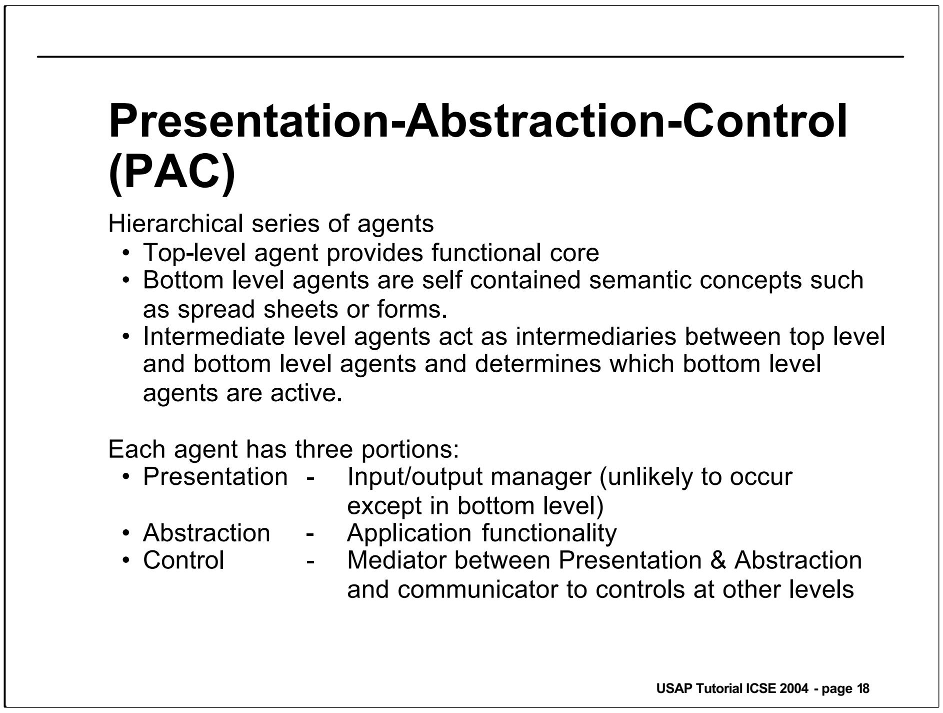
PAC is documented in:

Buschmann, F., Meuneir, R, Rohnert, H., Sommerlad, P. and Stal, M., (1996) Pattern-Oriented Software Architecture, A System of Patterns, Chichester, Eng: John Wiley and Sons.

J2EE-MVC is documented at http://java.sun.com/blueprints/patterns/MVC-detailed.html



Presentation-Abstraction-Control (PAC)

Hierarchical series of agents

- Top-level agent provides functional core
- Bottom level agents are self contained semantic concepts such as spread sheets or forms.
- Intermediate level agents act as intermediaries between top level and bottom level agents and determines which bottom level agents are active.

Each agent has three portions:

• Presentation	-	Input/output manager (unlikely to occur except in bottom level)
• Abstraction	-	Application functionality
• Control	-	Mediator between Presentation & Abstraction and communicator to controls at other levels

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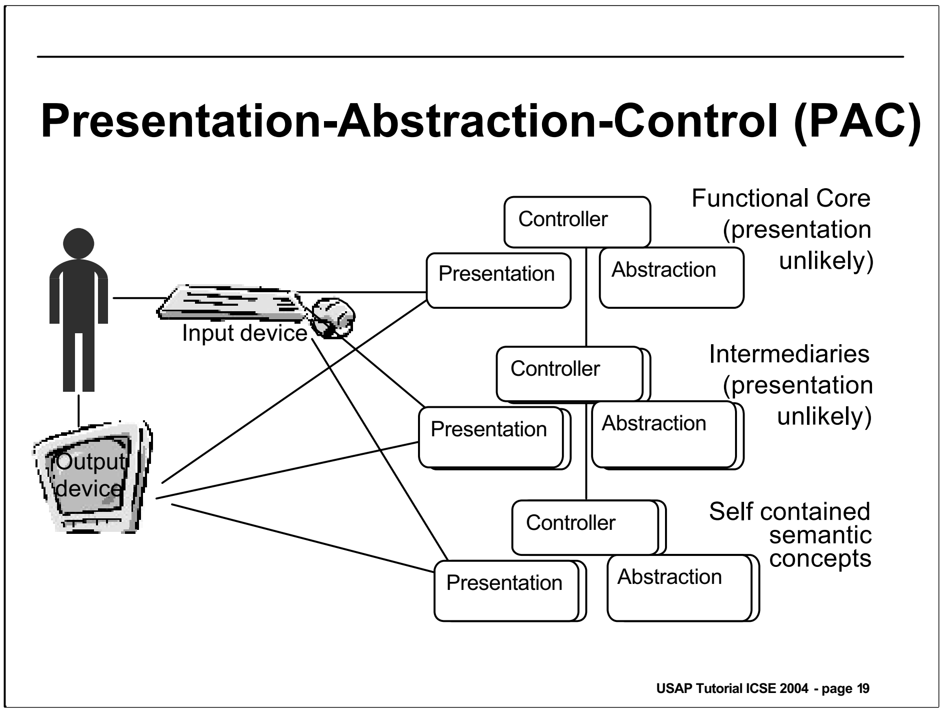

Presentation-Abstraction-Control (PAC)

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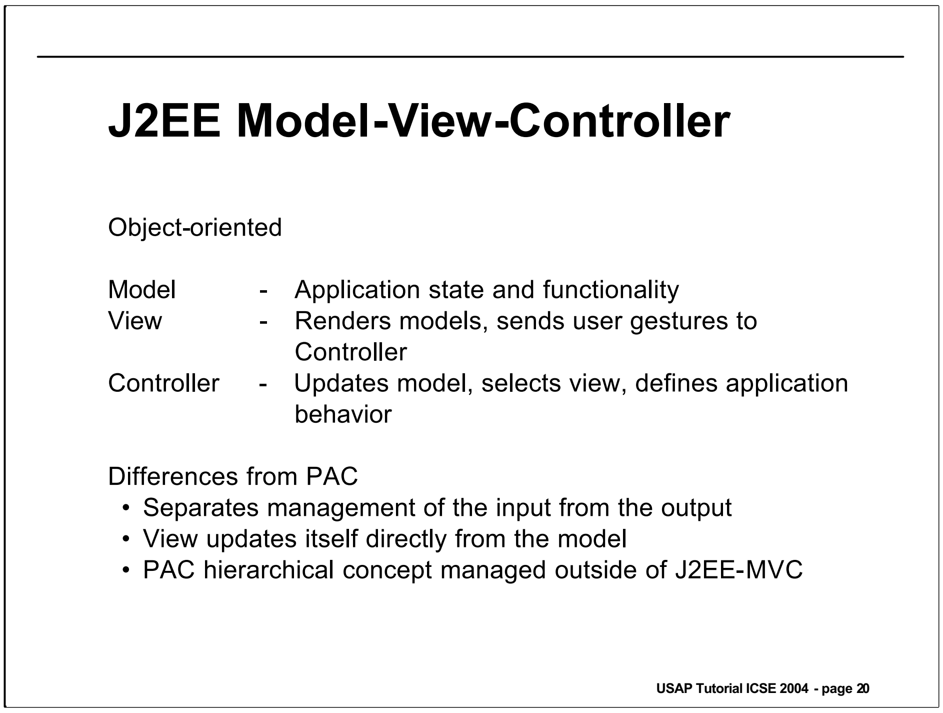
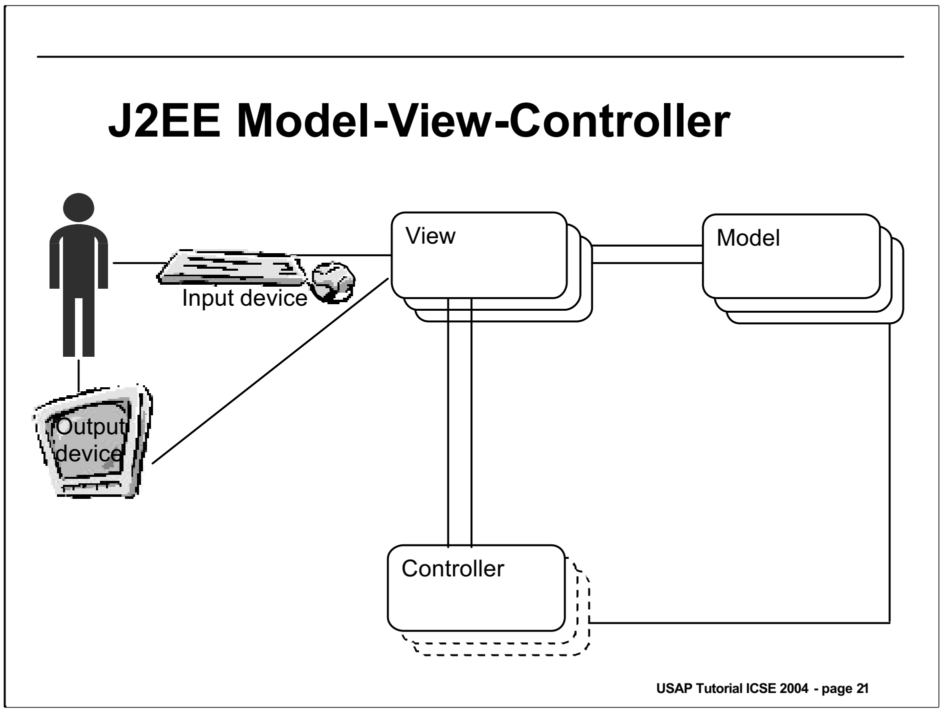


J2EE Model-View-Controller

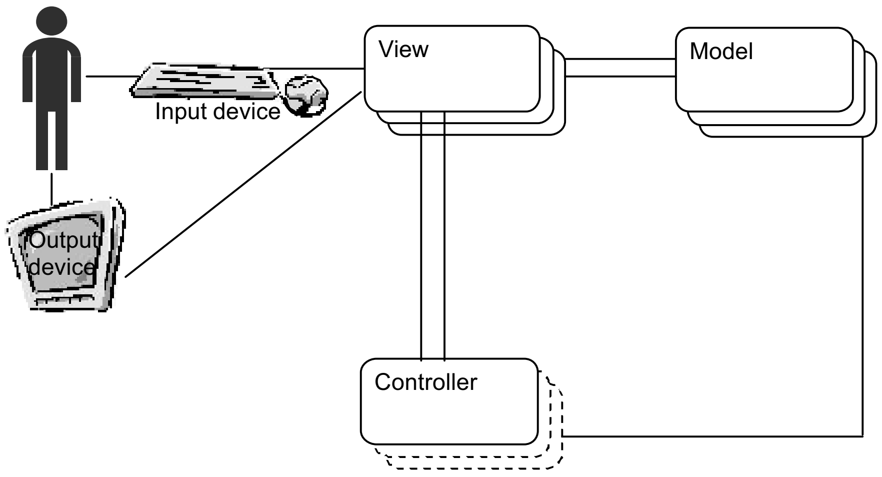
Object-oriented

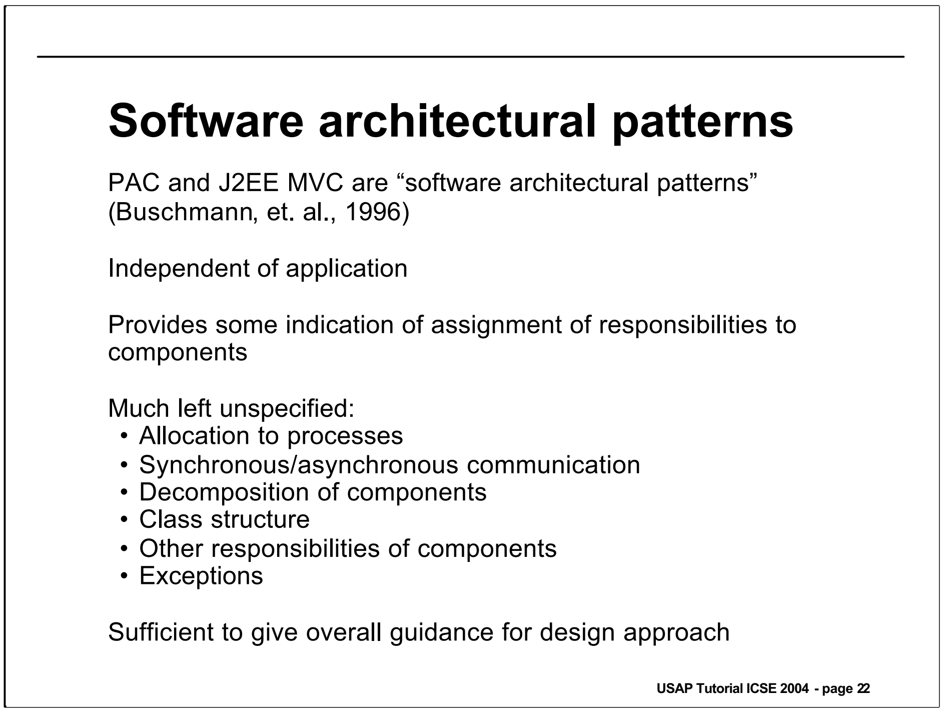
Model	-	Application state and functionality
View	-	Renders models, sends user gestures to Controller
Controller	-	Updates model, selects view, defines application behavior

Differences from PAC
- Separates management of the input from the output
- View updates itself directly from the model
- PAC hierarchical concept managed outside of J2EE-MVC



J2EE Model-View-Controller





Software architectural patterns

PAC and J2EE MVC are “software architectural patterns” (Buschmann, et. al., 1996)

Independent of application

Provides some indication of assignment of responsibilities to components

Much left unspecified:

- Allocation to processes
- Synchronous/asynchronous communication
- Decomposition of components
- Class structure
- Other responsibilities of components
- Exceptions

Sufficient to give overall guidance for design approach

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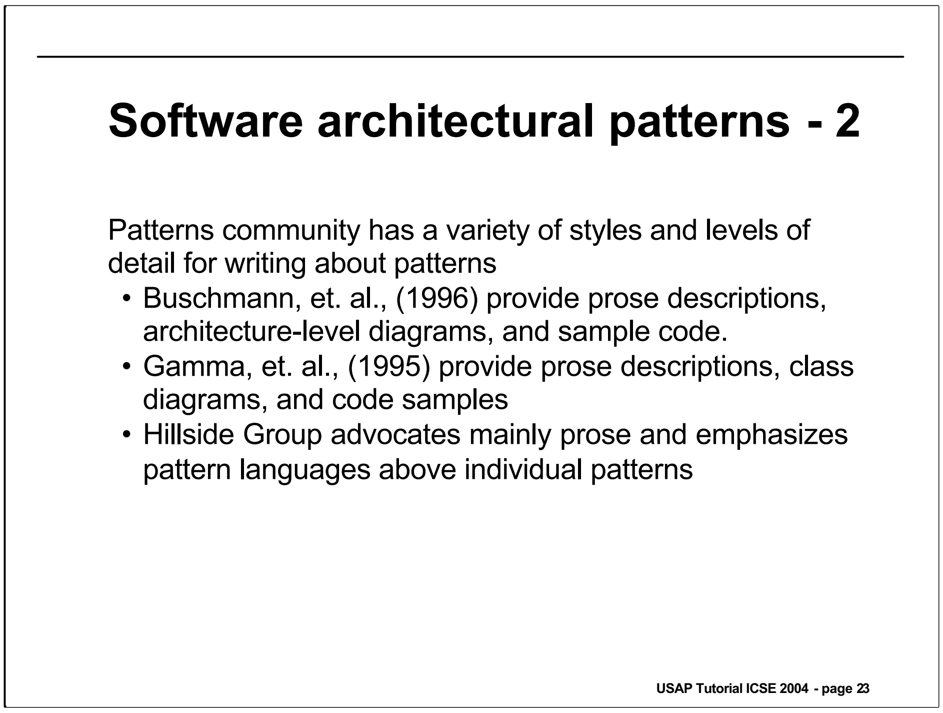
Buschmann, F., Meuneir, R, Rohnert, H., Sommerlad, P. and Stal, M., (1996) *Pattern-Oriented Software Architecture, A System of Patterns*, Chichester, Eng: John Wiley and Sons.


Software architectural patterns - 2

Patterns community has a variety of styles and levels of detail for writing about patterns
- Buschmann, et. al., (1996) provide prose descriptions, architecture-level diagrams, and sample code.
- Gamma, et. al., (1995) provide prose descriptions, class diagrams, and code samples
- Hillside Group advocates mainly prose and emphasizes pattern languages above individual patterns

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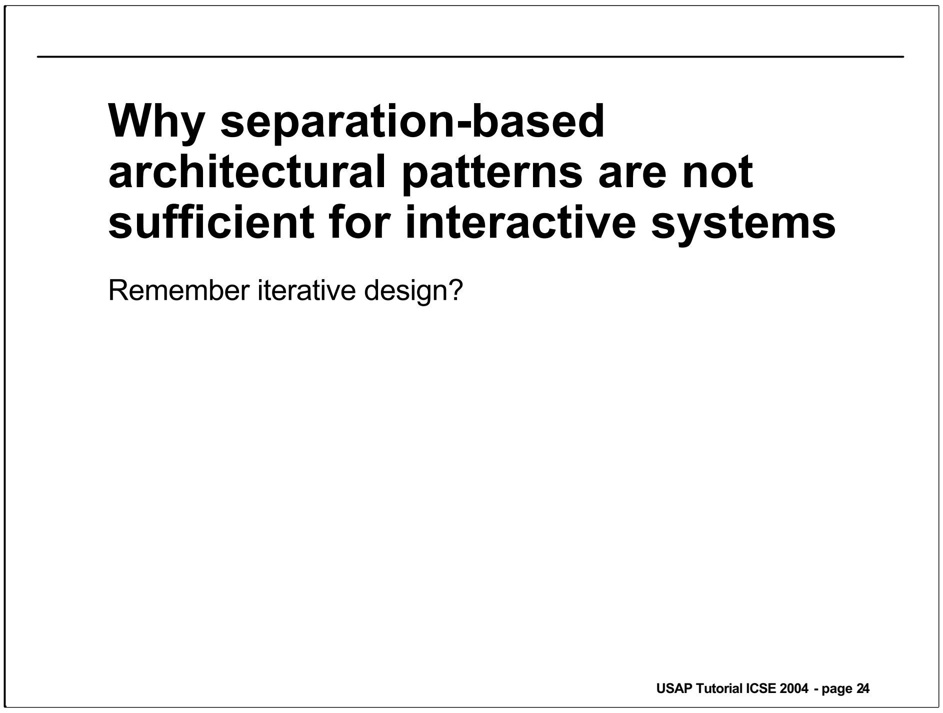
Buschmann, F., Meuneir, R, Rohnert, H., Sommerlad, P. and Stal, M., (1996) *Pattern-Oriented Software Architecture, A System of Patterns*, Chichester, Eng: John Wiley and Sons.

Gamma, E., Helm, R., Johnson, R., Vlissides, J. (1995). *Design Patterns.* Boston, Massachusetts: Addison-Wesley.

Information about the Hillside Group and patterns and pattern languages can be found at http://www.hillside.net/



Why separation-based architectural patterns are not sufficient for interactive systems

Remember iterative design?

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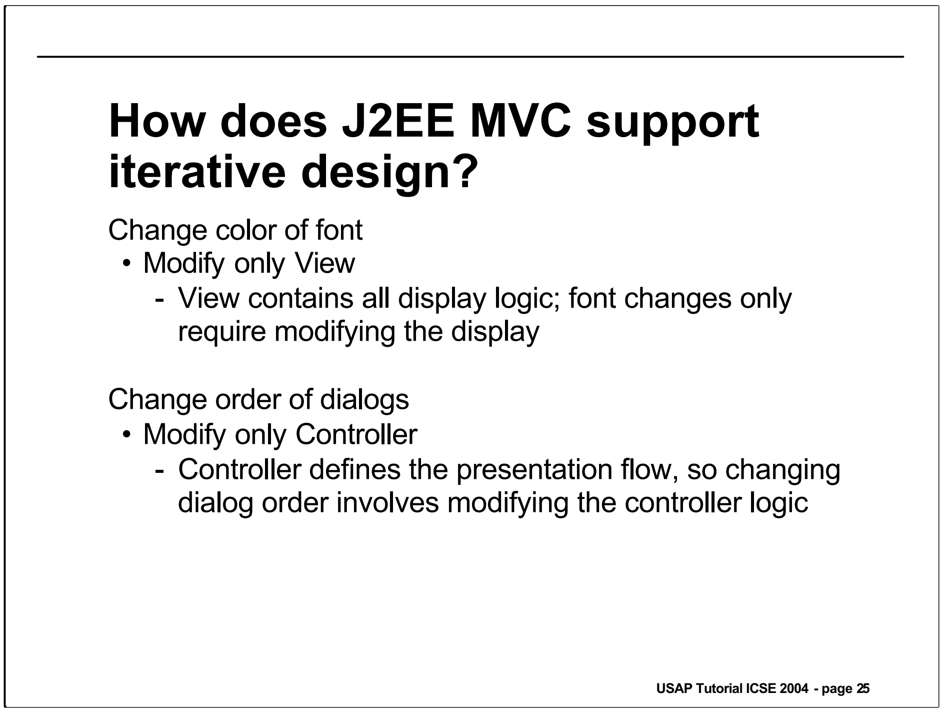

How does J2EE MVC support iterative design?

Change color of font

- Modify only View
  - View contains all display logic; font changes only require modifying the display

Change order of dialogs

- Modify only Controller
  - Controller defines the presentation flow, so changing dialog order involves modifying the controller logic

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What happens to other usability changes?

Add the ability to cancel a long-running command

- Requires modification of all three modules
  - View – must have cancel button or other means for user to specify cancel
  - Controller – logic to respond to the View's menu selection and execute the appropriate Model function
  - Model – free allocated resources, etc.

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Shortcomings of separation patterns for solving the “We can’t change THAT!” problem

With respect to adding the ability to cancel

- Involved all components
- Not much localization
- If requirement for cancel discovered late, then will require extensive modification to the architecture.

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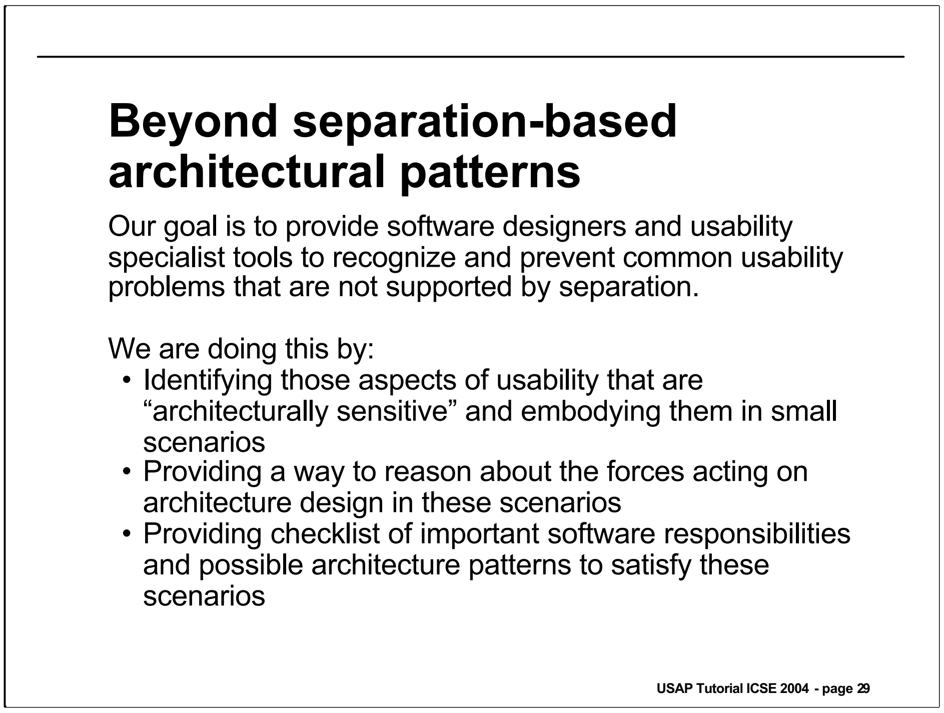

Beyond separation-based architectural patterns

Our goal is to provide software designers and usability specialist tools to recognize and prevent common usability problems that are not supported by separation.

We are doing this by:

- Identifying those aspects of usability that are “architecturally sensitive” and embodying them in small scenarios
- Providing a way to reason about the forces acting on architecture design in these scenarios
- Providing checklist of important software responsibilities and possible architecture patterns to satisfy these scenarios

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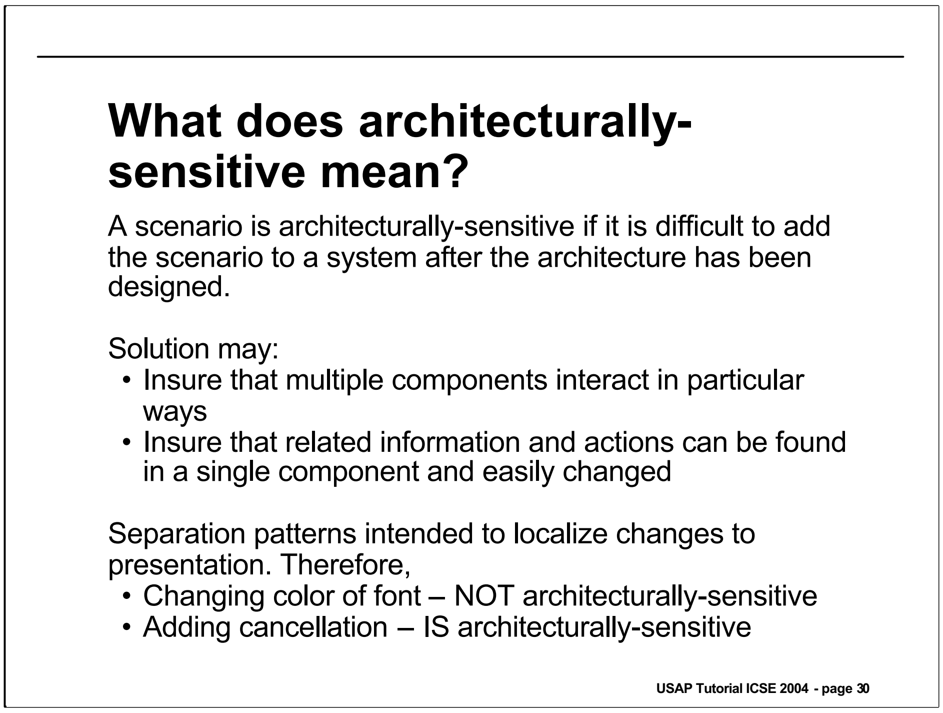

What does architecturally-sensitive mean?

A scenario is architecturally-sensitive if it is difficult to add the scenario to a system after the architecture has been designed.

Solution may:

- Insure that multiple components interact in particular ways
- Insure that related information and actions can be found in a single component and easily changed

Separation patterns intended to localize changes to presentation. Therefore,

- Changing color of font – NOT architecturally-sensitive
- Adding cancellation – IS architecturally-sensitive

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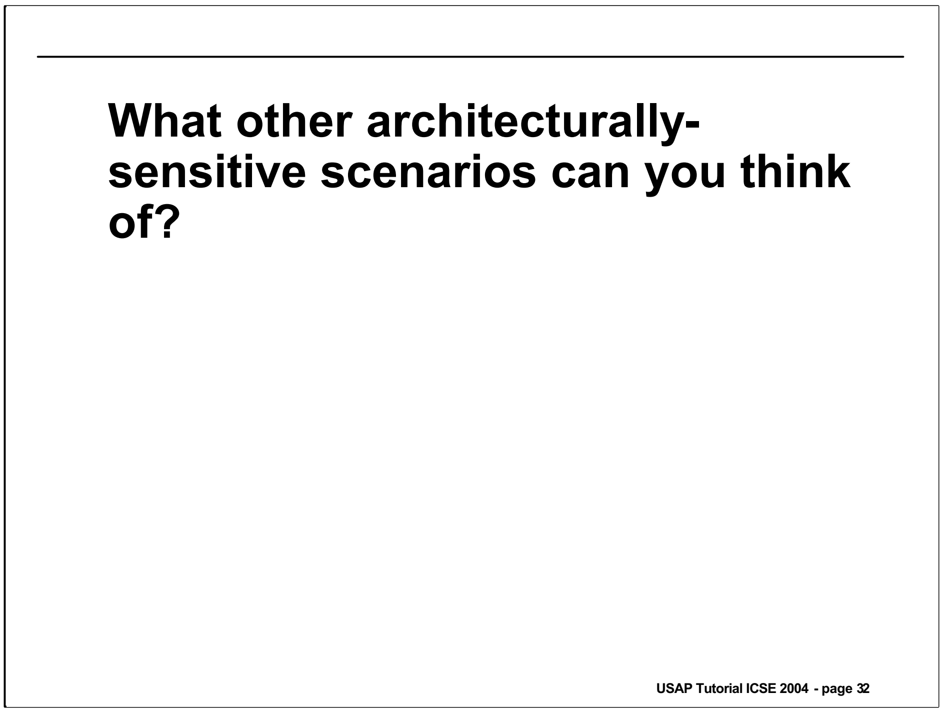
An architecturally-sensitive scenario: Canceling commands

The user issues a command then changes his or her mind, wanting to stop the operation and return the software to its pre-operation state. It doesn't matter why the user wants to stop; he or she could have made a mistake, the system could be unresponsive, or the environment could have changed.



What other architecturally-sensitive scenarios can you think of?

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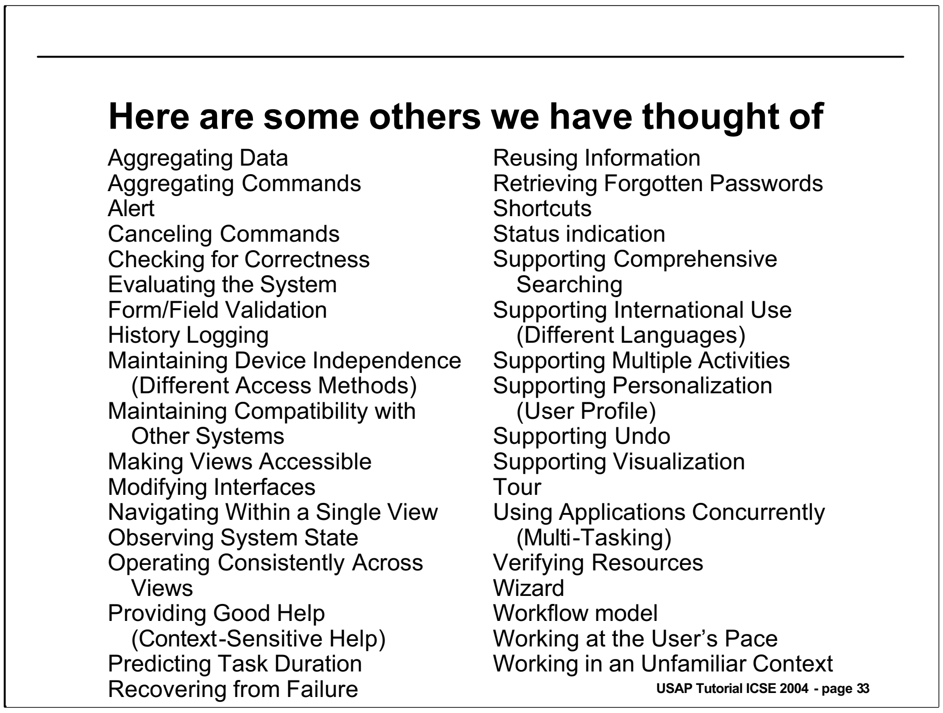

Here are some others we have thought of

Aggregating Data
Aggregating Commands
Alert
Canceling Commands
Checking for Correctness
Evaluating the System
Form/Field Validation
History Logging
Maintaining Device Independence (Different Access Methods)
Maintaining Compatibility with Other Systems
Making Views Accessible
Modifying Interfaces
Navigating Within a Single View
Observing System State
Operating Consistently Across Views
Providing Good Help (Context-Sensitive Help)
Predicting Task Duration
Recovering from Failure
Reusing Information
Retrieving Forgotten Passwords
Shortcuts
Status indication
Supporting Comprehensive Searching
Supporting International Use (Different Languages)
Supporting Multiple Activities
Supporting Personalization (User Profile)
Supporting Undo
Supporting Visualization
Tour
Using Applications Concurrently (Multi-Tasking)
Verifying Resources
Wizard
Workflow model
Working at the User's Pace
Working in an Unfamiliar Context

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This list of architecturally-sensitive usability scnearios is compiled from

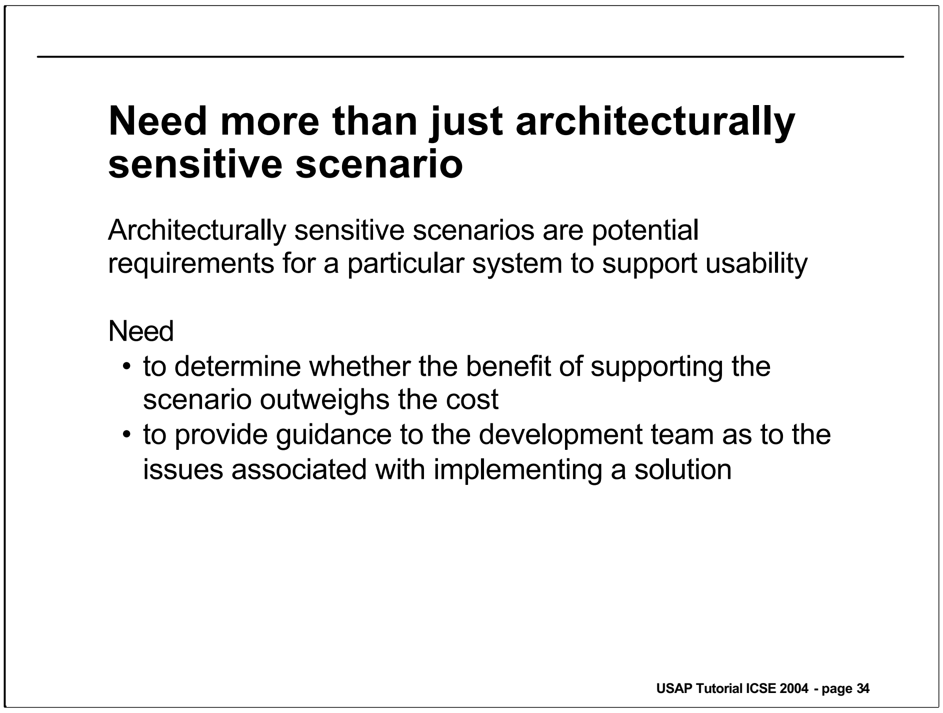
Bass, L., John, B. E., & Kates, J. (2001). *Achieving usability through software architecture* (CMU/SEI-2001-TR-005). Pittsburgh, PA: Software Engineering Institute.

http://www.sei.cmu.edu/publications/documents/01.reports/01tr005.html

And

Juristo , N., Moreno, A. M., & Sanchez, M. (2003) Deliverable D.3.4. Techniques, patterns and styles for architecture-level usability improvement. - ESPRIT project (IST-2001-32298)

http://www.ls.fi.upm.es/status/results/deliverables.html



Need more than just architecturally sensitive scenario

Architecturally sensitive scenarios are potential requirements for a particular system to support usability

Need
- to determine whether the benefit of supporting the scenario outweighs the cost
- to provide guidance to the development team as to the issues associated with implementing a solution

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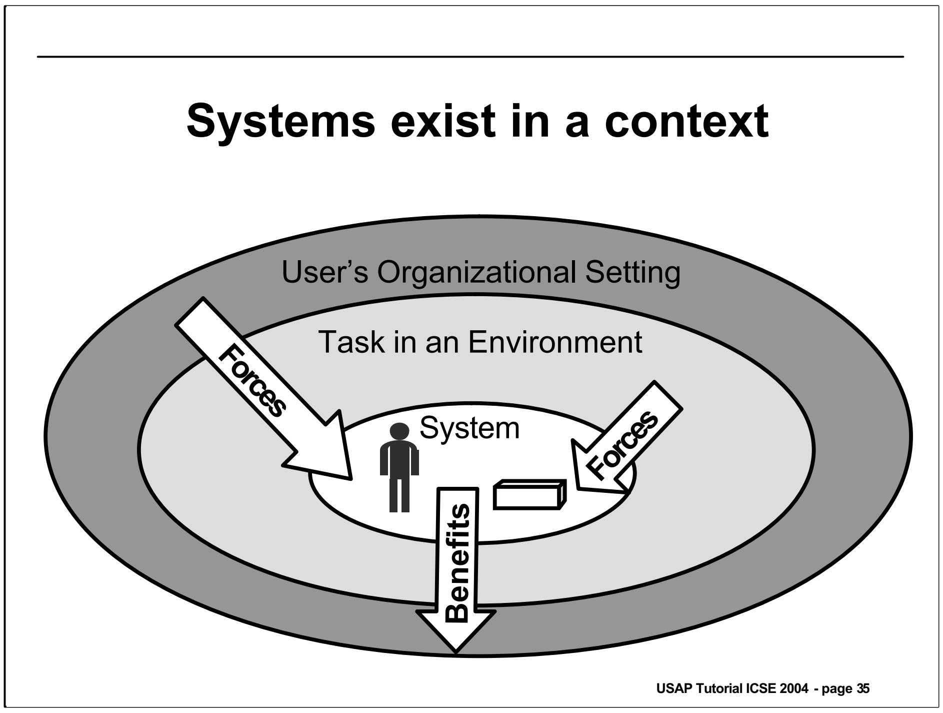
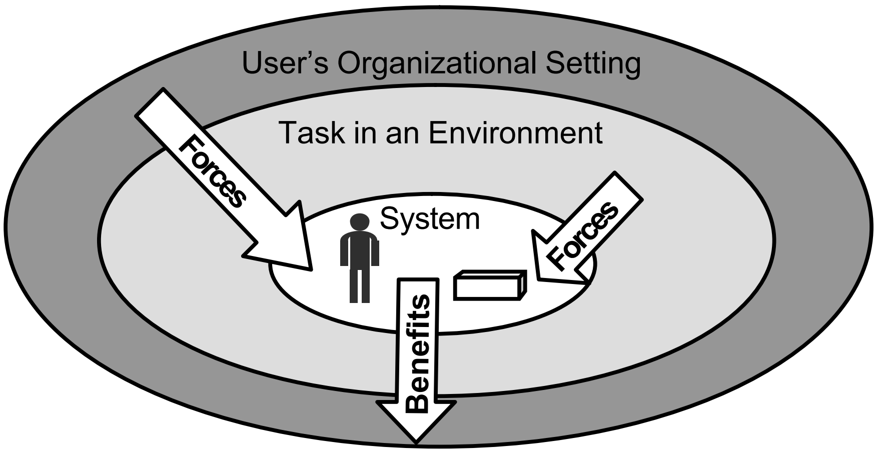
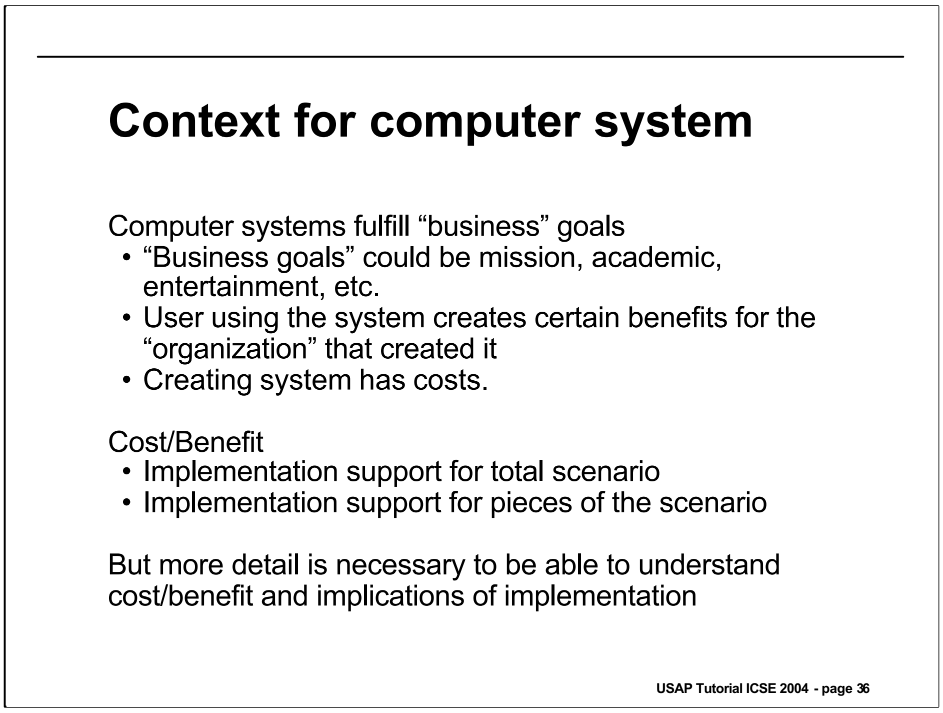


Systems exist in a context





Context for computer system

Computer systems fulfill “business” goals
- “Business goals” could be mission, academic, entertainment, etc.
- User using the system creates certain benefits for the “organization” that created it
- Creating system has costs.

Cost/Benefit
- Implementation support for total scenario
- Implementation support for pieces of the scenario

But more detail is necessary to be able to understand cost/benefit and implications of implementation

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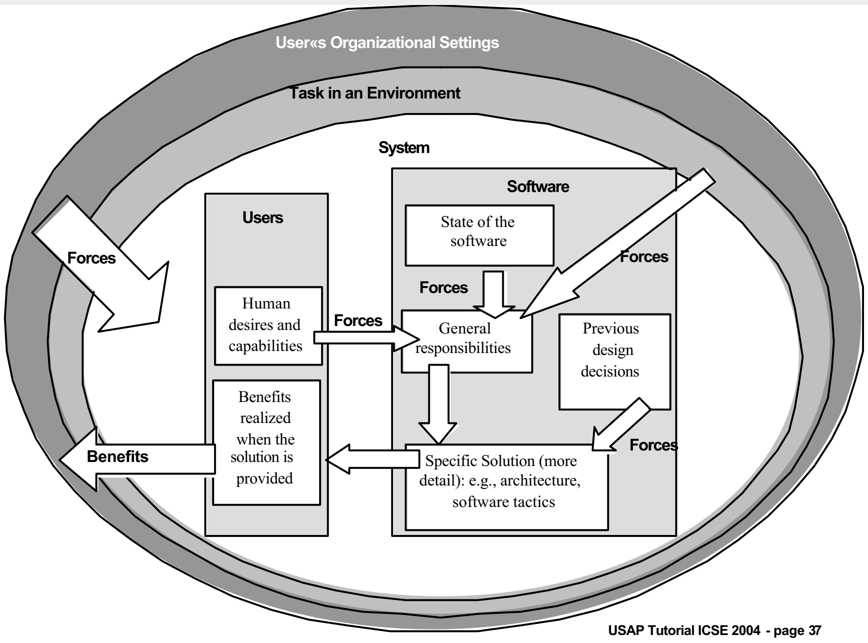
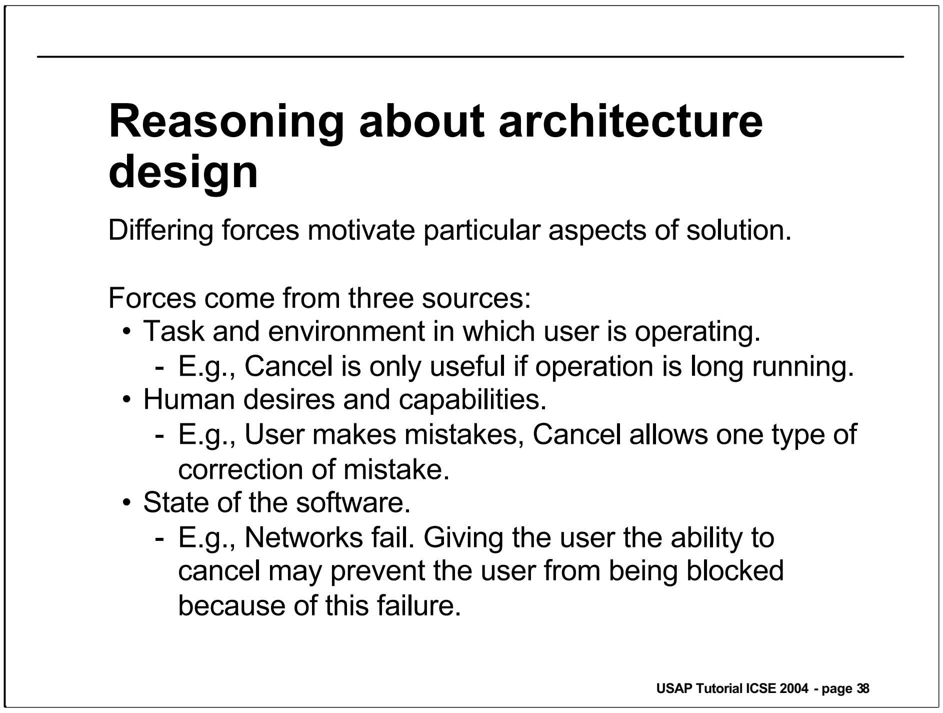
Forces acting on architecture design


User«s Organizational Settings
Task in an Environment
System
Software
Users
State of the software
Forces
Forces
Forces
Human desires and capabilities
Forces
General responsibilities
Previous design decisions
Benefits realized when the solution is provided
Forces
Benefits
Specific Solution (more detail): e.g., architecture, software tactics



Reasoning about architecture design

Differing forces motivate particular aspects of solution.

Forces come from three sources:

- Task and environment in which user is operating.
  - E.g., Cancel is only useful if operation is long running.
- Human desires and capabilities.
  - E.g., User makes mistakes, Cancel allows one type of correction of mistake.
- State of the software.
  - E.g., Networks fail. Giving the user the ability to cancel may prevent the user from being blocked because of this failure.

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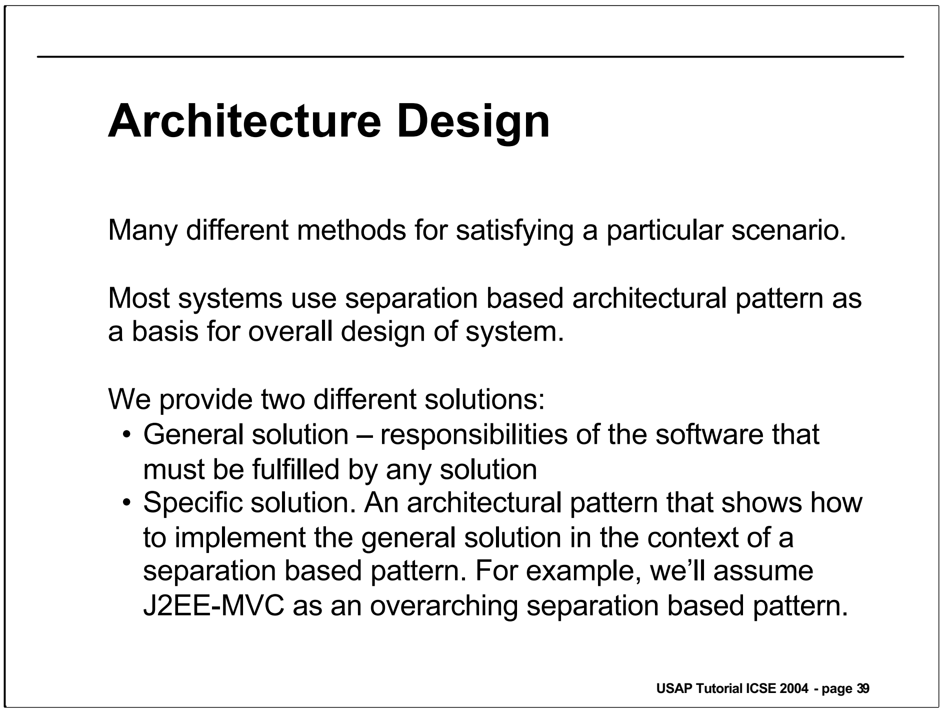

Architecture Design

Many different methods for satisfying a particular scenario.

Most systems use separation based architectural pattern as a basis for overall design of system.

We provide two different solutions:

- General solution – responsibilities of the software that must be fulfilled by any solution
- Specific solution. An architectural pattern that shows how to implement the general solution in the context of a separation based pattern. For example, we'll assume J2EE-MVC as an overarching separation based pattern.

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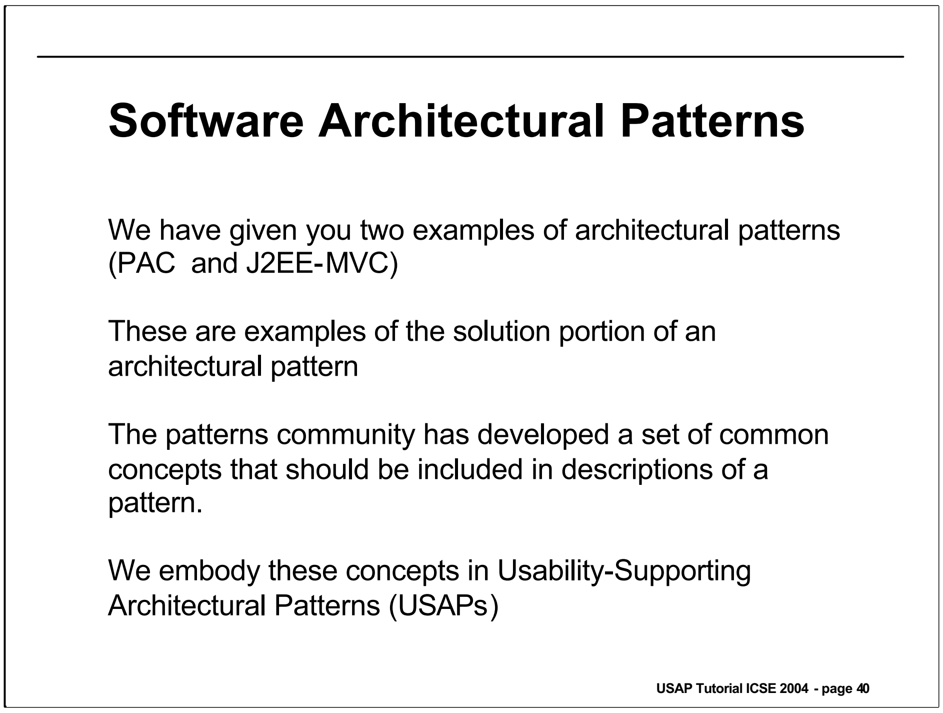

Software Architectural Patterns

We have given you two examples of architectural patterns (PAC and J2EE-MVC)

These are examples of the solution portion of an architectural pattern

The patterns community has developed a set of common concepts that should be included in descriptions of a pattern.

We embody these concepts in Usability-Supporting Architectural Patterns (USAPs)

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Usability-Supporting Architectural Patterns - 1

Context
- Situation – architecturally sensitive usability scenarios
- Conditions – constraints on when the situation is relevant
- Usability benefits – enumeration of benefits to the user from supporting this scenario

Problem - Forces in conflict
- Forces exerted by the task and environment
- Forces exerted by human desires and capabilities
- Forces exerted by the state of the software when the user wishes to apply the architecturally sensitive usability scenario

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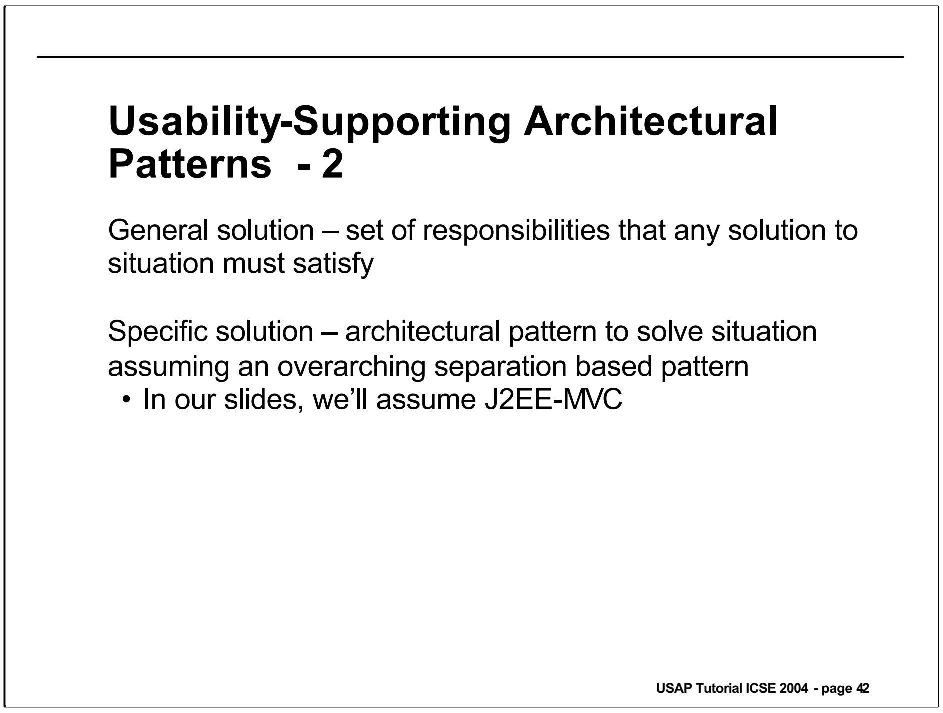

Usability-Supporting Architectural Patterns - 2

General solution – set of responsibilities that any solution to situation must satisfy

Specific solution – architectural pattern to solve situation assuming an overarching separation based pattern

- In our slides, we'll assume J2EE-MVC

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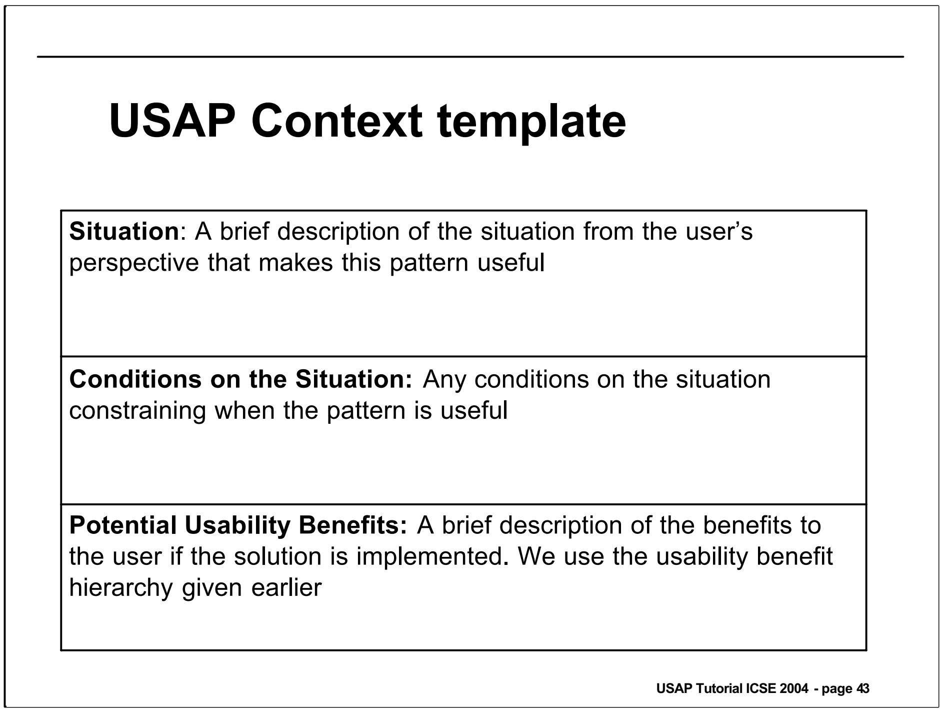

USAP Context template

Situation: A brief description of the situation from the user's perspective that makes this pattern useful
Conditions on the Situation: Any conditions on the situation constraining when the pattern is useful
Potential Usability Benefits: A brief description of the benefits to the user if the solution is implemented. We use the usability benefit hierarchy given earlier

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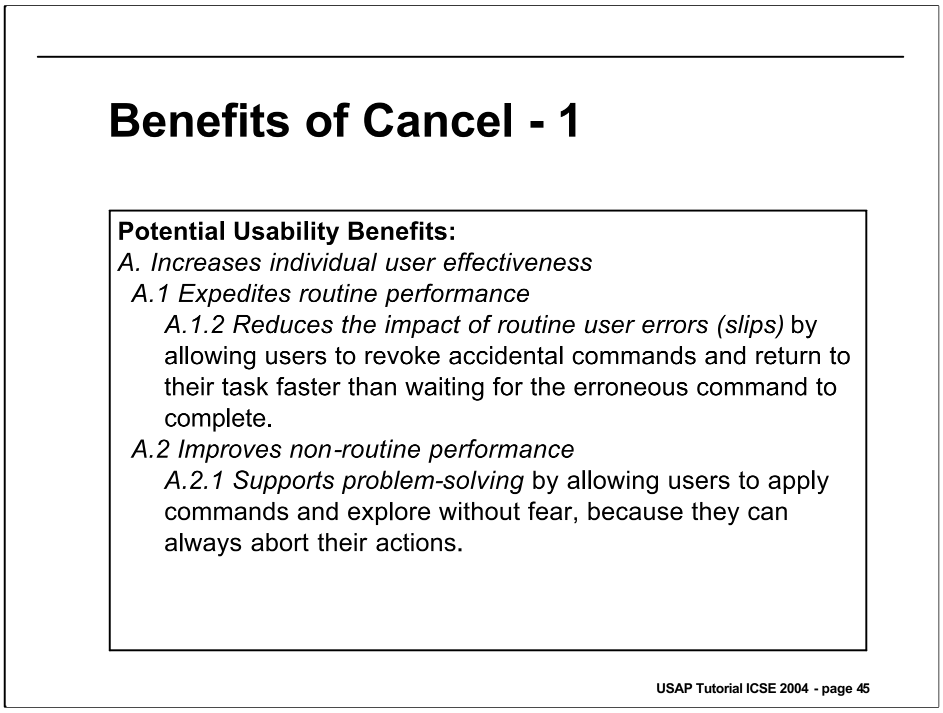
USAP Context for Cancel - 1

Situation: The user issues a command then changes his or her mind, wanting to stop the operation and return the software to its pre-operation state. It doesn't matter why the user wants to stop; he or she could have made a mistake, the system could be unresponsive, or the environment could have changed.
Conditions on the Situation: A user is working in a system where the software has long-running commands, i.e., more than one second. The cancellation command could be explicitly issued by the user, or through some sensing of the environment (e.g., a child's hand in a power car window).



Benefits of Cancel - 1

Potential Usability Benefits:

A. Increases individual user effectiveness

A.1 Expedites routine performance

A.1.2 Reduces the impact of routine user errors (slips) by allowing users to revoke accidental commands and return to their task faster than waiting for the erroneous command to complete.

A.2 Improves non-routine performance

A.2.1 Supports problem-solving by allowing users to apply commands and explore without fear, because they can always abort their actions.

Benefits of Cancel – 2

Potential Usability Benefits:

A. Increases individual user effectiveness

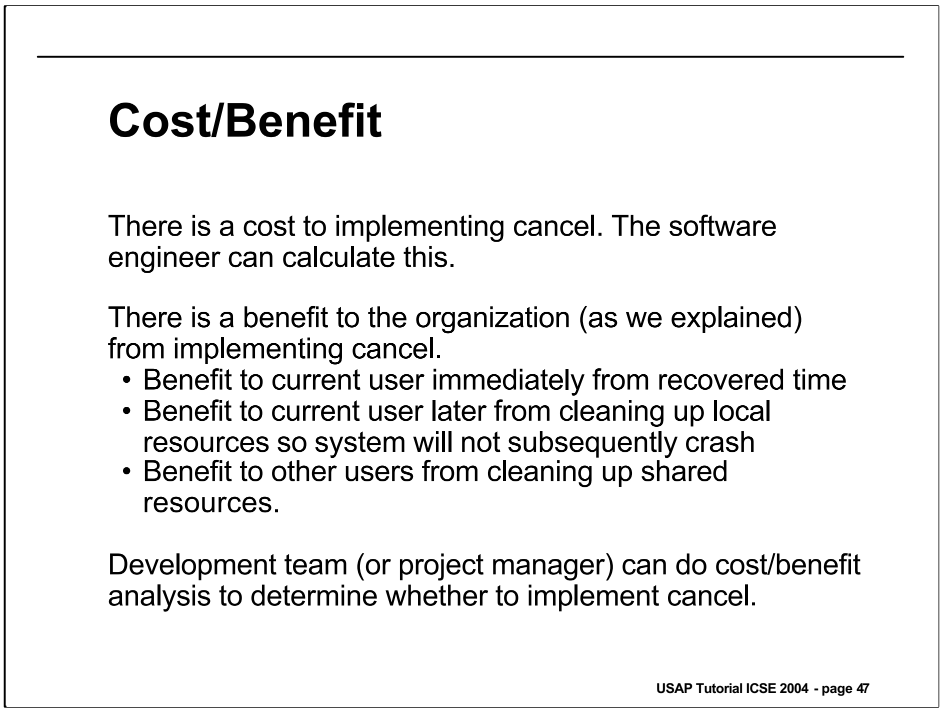
A.3 Reduces the impact of user errors caused by lack of knowledge (mistakes)

A.3.2 Accommodates mistakes by allowing users to abort commands they invoke through lack of knowledge and return to their task faster than waiting for the erroneous command to complete.

B. Reduces the impact of system errors

B.2 Tolerates system errors by allowing users to abort commands that aren't working properly (for example, a user cancels a download because the network is jammed).

C.Increases user confidence and comfort by allowing users to perform without fear because they can always abort their actions.



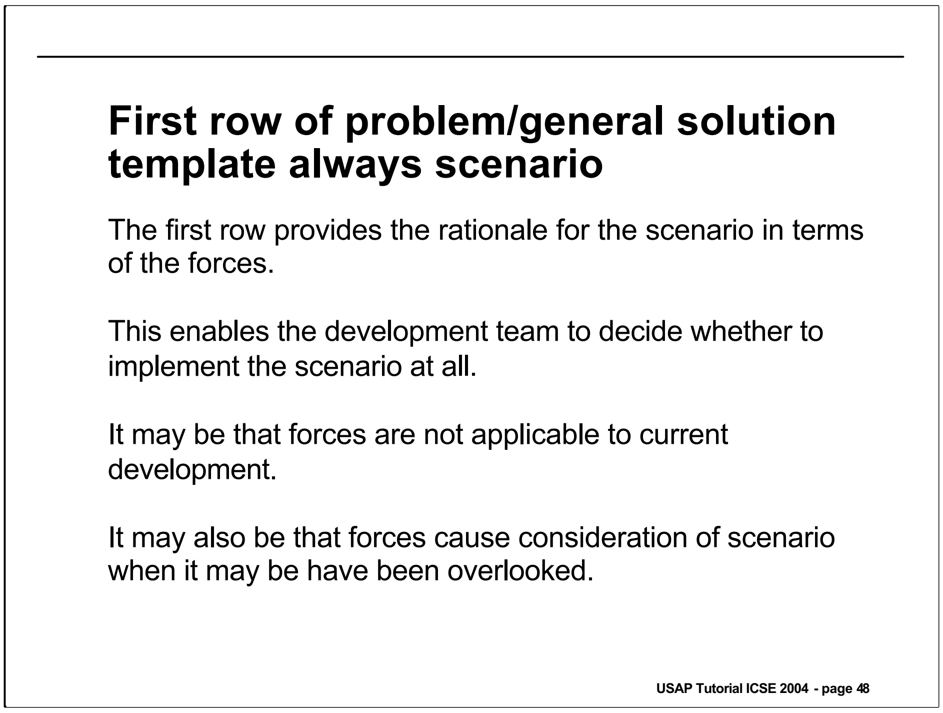
Cost/Benefit

There is a cost to implementing cancel. The software engineer can calculate this.

There is a benefit to the organization (as we explained) from implementing cancel.

- Benefit to current user immediately from recovered time
- Benefit to current user later from cleaning up local resources so system will not subsequently crash
- Benefit to other users from cleaning up shared resources.

Development team (or project manager) can do cost/benefit analysis to determine whether to implement cancel.



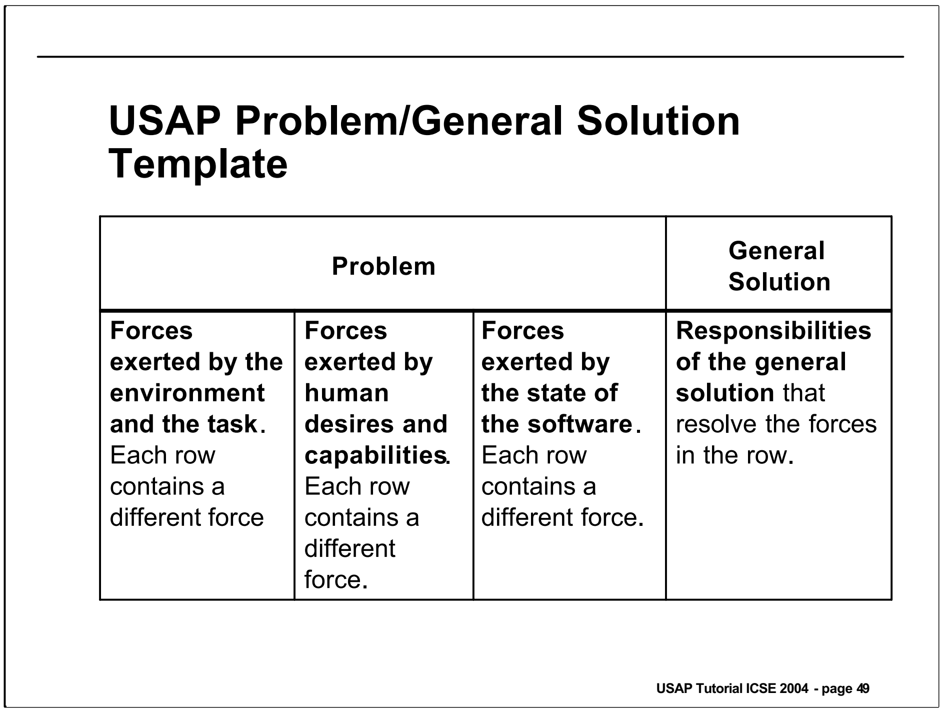
First row of problem/general solution template always scenario

The first row provides the rationale for the scenario in terms of the forces.

This enables the development team to decide whether to implement the scenario at all.

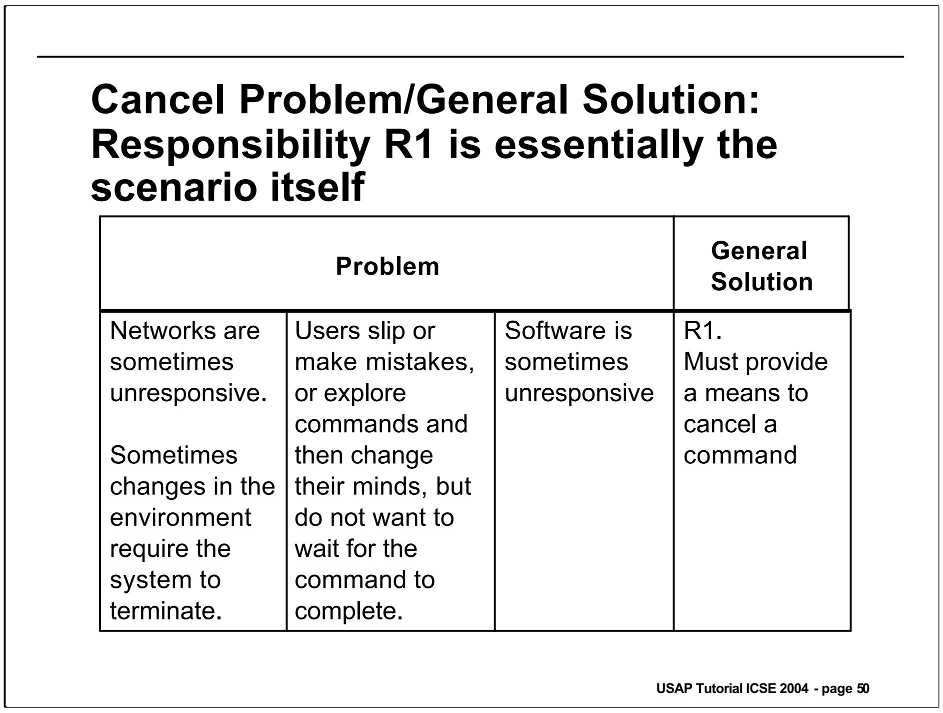
It may be that forces are not applicable to current development.

It may also be that forces cause consideration of scenario when it may be have been overlooked.



USAP Problem/General Solution Template

Problem			General Solution
Forces exerted by the environment and the task. Each row contains a different force	**Forces exerted by human desires and capabilities**. Each row contains a different force.	**Forces exerted by the state of the software**. Each row contains a different force.	**Responsibilities of the general solution** that resolve the forces in the row.



Cancel Problem/General Solution: Responsibility R1 is essentially the scenario itself

Problem			General Solution
Networks are sometimes unresponsive. Sometimes changes in the environment require the system to terminate.	Users slip or make mistakes, or explore commands and then change their minds, but do not want to wait for the command to complete.	Software is sometimes unresponsive	R1. Must provide a means to cancel a command

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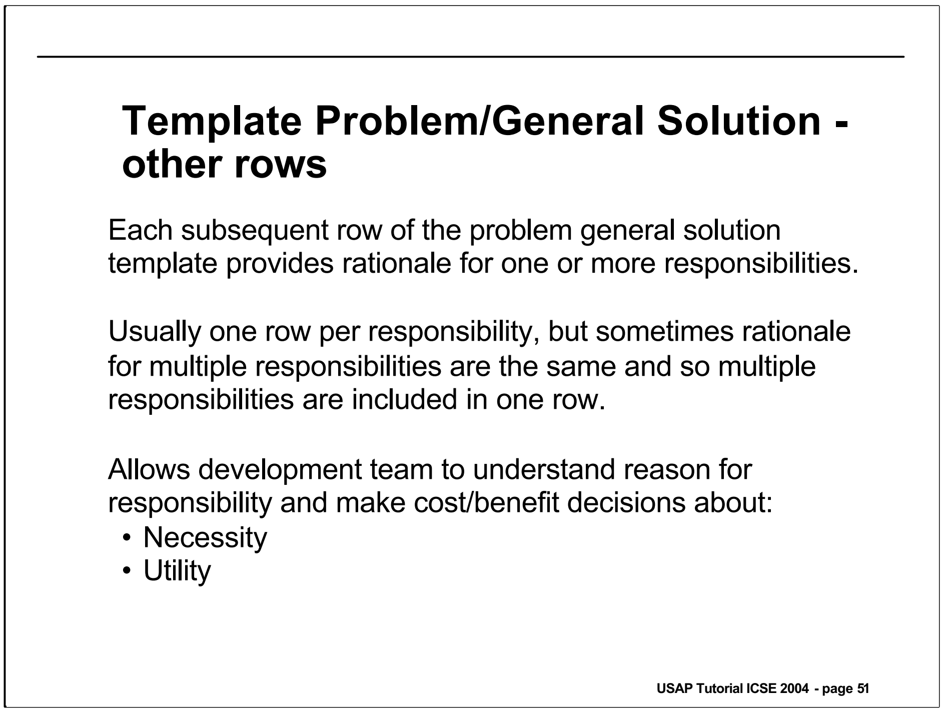

Template Problem/General Solution - other rows

Each subsequent row of the problem general solution template provides rationale for one or more responsibilities.

Usually one row per responsibility, but sometimes rationale for multiple responsibilities are the same and so multiple responsibilities are included in one row.

Allows development team to understand reason for responsibility and make cost/benefit decisions about:

- Necessity
- Utility

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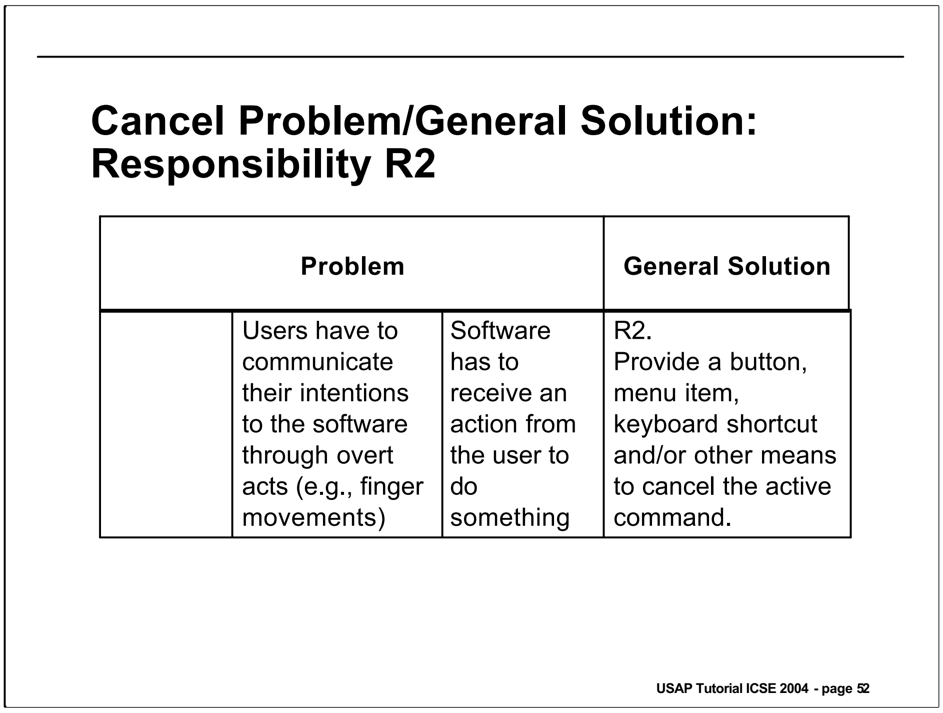

Cancel Problem/General Solution: Responsibility R2

Problem			General Solution
	Users have to communicate their intentions to the software through overt acts (e.g., finger movements)	Software has to receive an action from the user to do something	R2. Provide a button, menu item, keyboard shortcut and/or other means to cancel the active command.

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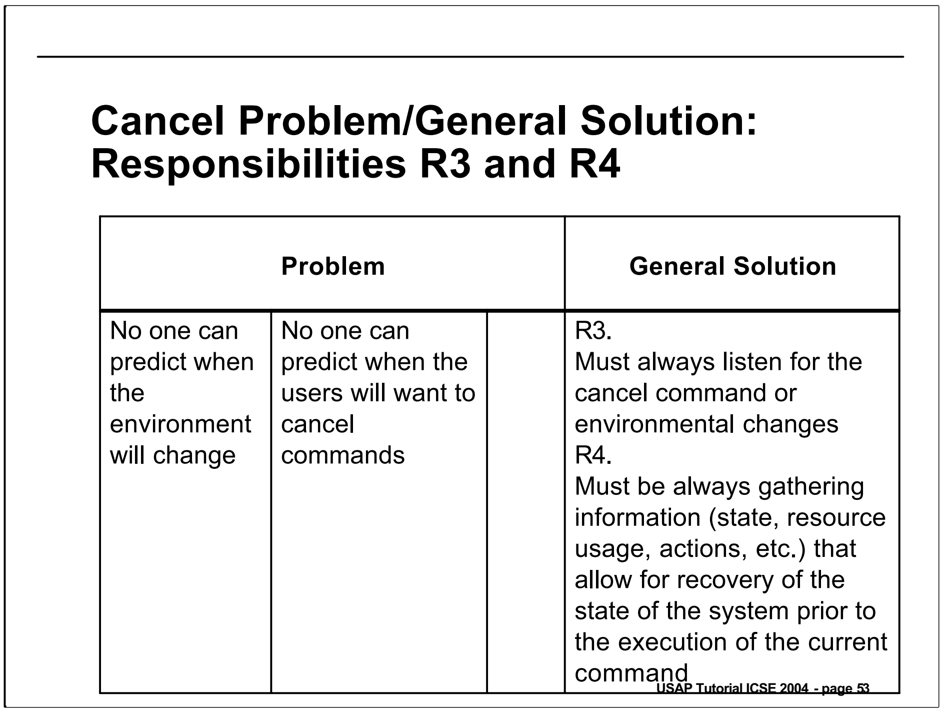
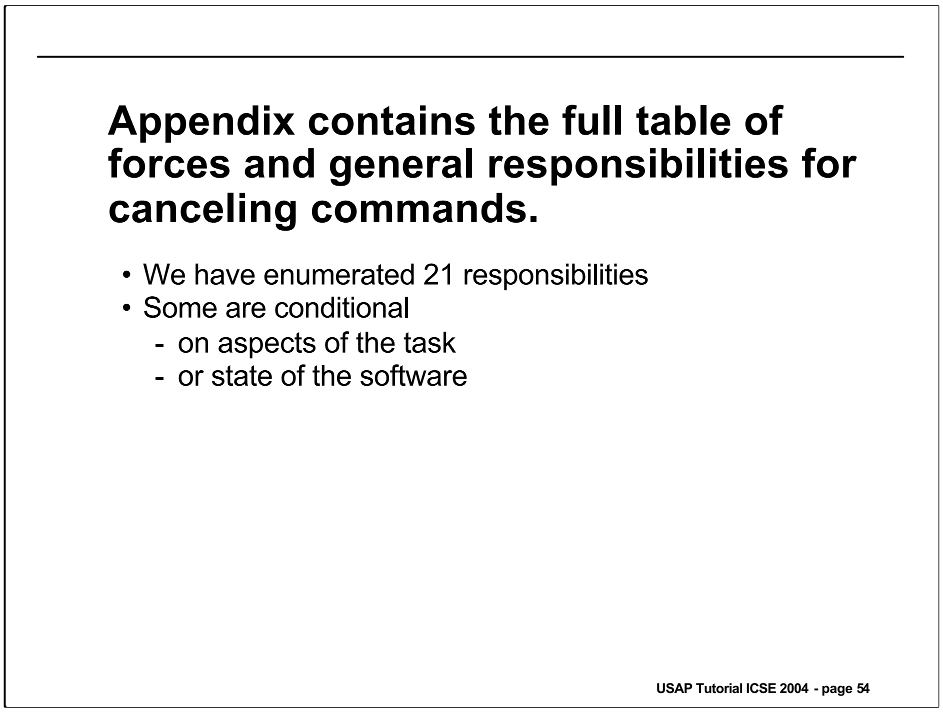


Cancel Problem/General Solution: Responsibilities R3 and R4

Problem			General Solution
No one can predict when the environment will change	No one can predict when the users will want to cancel commands		R3. Must always listen for the cancel command or environmental changes R4. Must be always gathering information (state, resource usage, actions, etc.) that allow for recovery of the state of the system prior to the execution of the current command



Appendix contains the full table of forces and general responsibilities for canceling commands.

- We have enumerated 21 responsibilities
- Some are conditional
  - on aspects of the task
  - or state of the software

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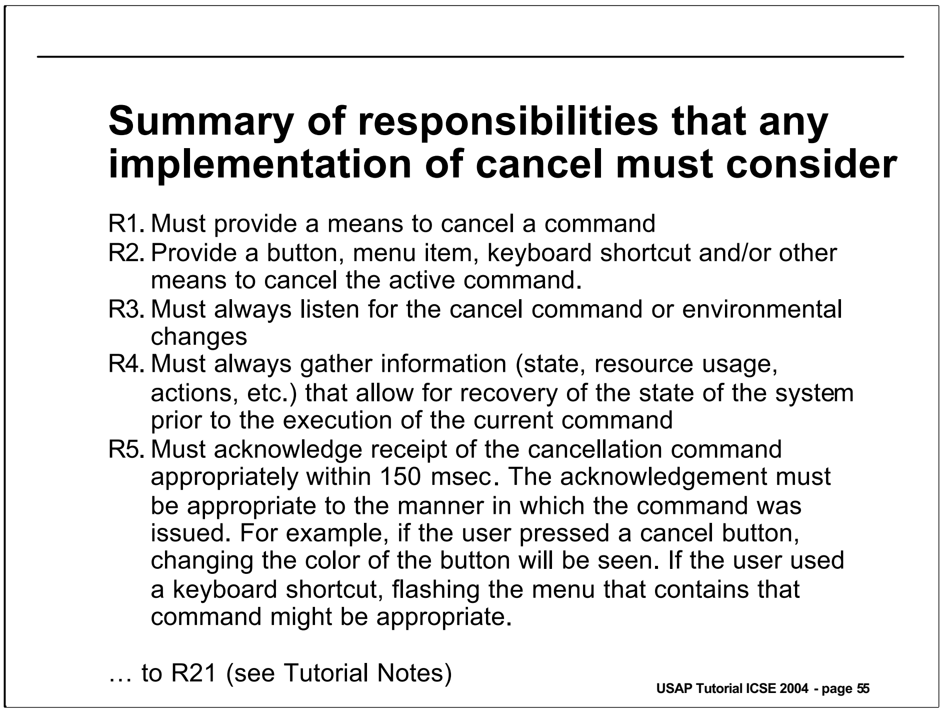

Summary of responsibilities that any implementation of cancel must consider

R1. Must provide a means to cancel a command
R2. Provide a button, menu item, keyboard shortcut and/or other means to cancel the active command.
R3. Must always listen for the cancel command or environmental changes
R4. Must always gather information (state, resource usage, actions, etc.) that allow for recovery of the state of the system prior to the execution of the current command
R5. Must acknowledge receipt of the cancellation command appropriately within 150 msec. The acknowledgement must be appropriate to the manner in which the command was issued. For example, if the user pressed a cancel button, changing the color of the button will be seen. If the user used a keyboard shortcut, flashing the menu that contains that command might be appropriate.

… to R21 (see Tutorial Notes)

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Either the command itself is responsive

R6. The command must have the ability to cancel itself (I.e., it must fulfill Responsibilities R10 to R21 (e.g., an object-oriented system would have a cancel method in each object)

Or the command itself is not responsive

R7. An active portion of the application must ask the infrastructure to cancel the command, or

R8. The infrastructure itself must provide a means to request the cancellation of the application (e.g., task manager on Windows, force quit on MacOS)

R9. If either R7 or R8, then the infrastructure must have the ability to cancel the active command (I.e., it must fulfill Responsibilities R10 to R21)

If the command has invoked collaborating processes

R10. The collaborating processes have to be informed of the cancellation of the invoking command (these processes have their own responsibilities that they must perform in response to this information, possibly treat it as a cancellation.). The information given to collaborating processes may include the request for cancellation, the progress of cancellation, and/or the completion of cancellation.

Continuation of responsibilities that any implementation of cancel must consider

Either the system is capable of rolling back all changes to the state prior to execution of the command.

R11. Restore the system back to its state prior to execution of the command.

Or the system is not capable of rolling back all changes to the state prior to execution of the command.

R12. Restore the system back to as close to the state prior to execution of the command as possible

R13. Inform the user of the difference between the prior state and the restored state.

Either all resource can be restored

R14. Resources must be freed

Or some resources has been irrevocably consumed and cannot be restored

R15. Inform the user of the partially-restored resources in a manner that they will see it.

For critical tasks with incomplete state or resource restoration,

R16. Require acknowledgement from the user that they are aware of the partially-restored nature of the cancellation.

R17. Return control to the user, or not, depending on the forces from the task

R18. If control cannot be returned to the user, inform the user of this fact (and ideally, why that is the case)

R19. Estimate the time it will take to cancel within 20%

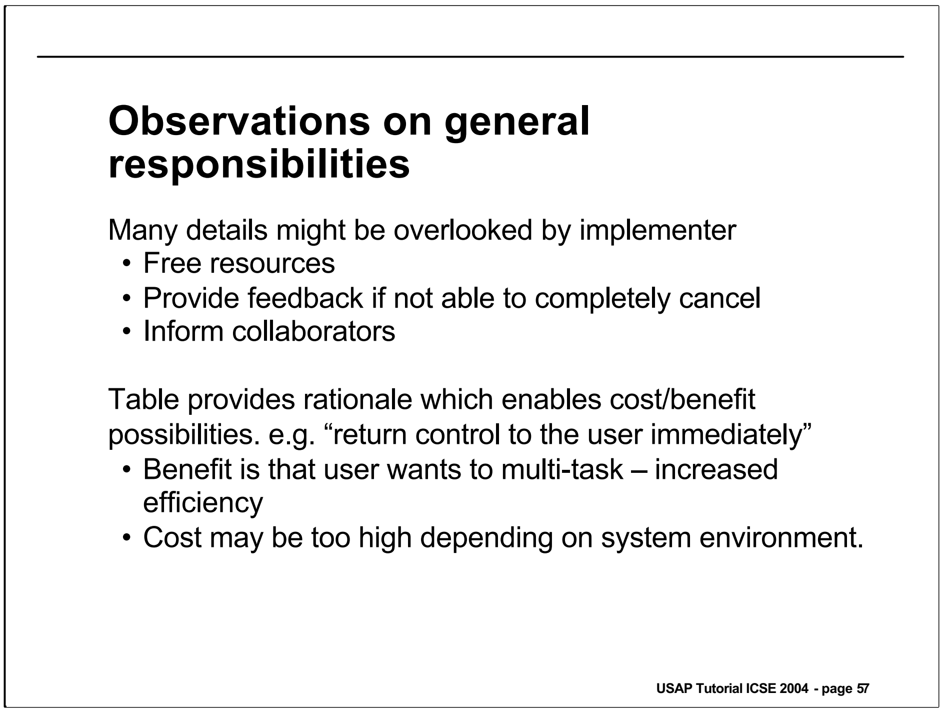
R20. Inform the user of this estimate.

· If the estimate is between 1 and 10 seconds, changing the cursor shape is sufficient.

· If the estimate is more than 10 seconds, and time estimate is with 20%, then a progress indicator is better.

· If estimate is more than 10 seconds but cannot be estimated accurately, consider other alternatives (see TN, footnote 8)

R21. Once the cancellation has finished the system must provide feedback to the user that cancellation is finished, e.g., if cursor was changed to busy indicator, change it back to normal; if progress bar was displayed was displayed, remove it; if dialog box was provided, close it.



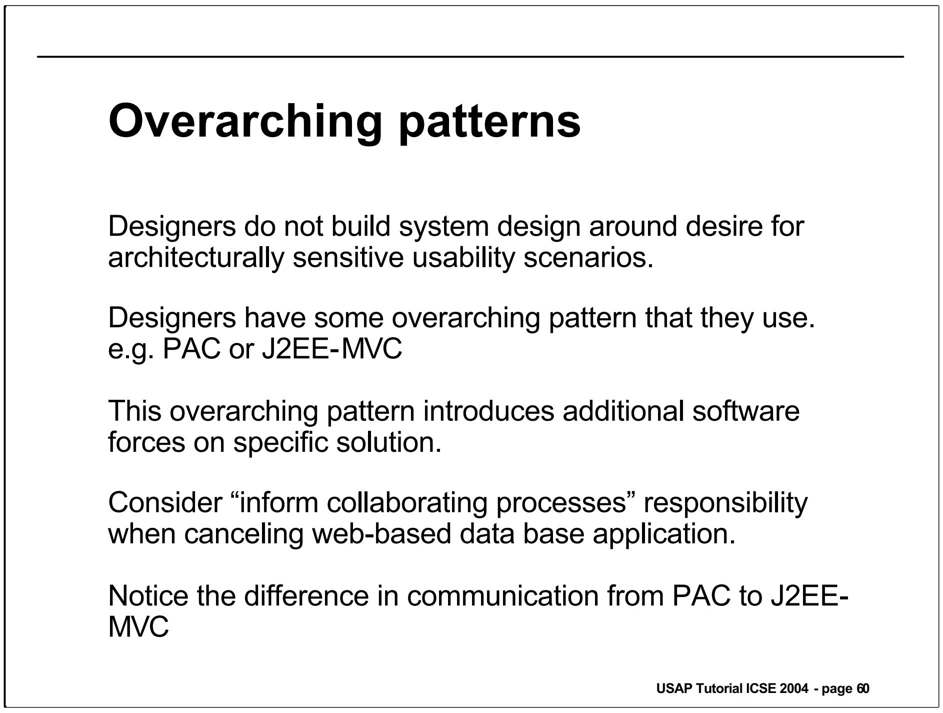
Observations on general responsibilities

Many details might be overlooked by implementer

- Free resources
- Provide feedback if not able to completely cancel
- Inform collaborators

Table provides rationale which enables cost/benefit possibilities. e.g. “return control to the user immediately”

- Benefit is that user wants to multi-task – increased efficiency
- Cost may be too high depending on system environment.



Overarching patterns

Designers do not build system design around desire for architecturally sensitive usability scenarios.

Designers have some overarching pattern that they use. e.g. PAC or J2EE-MVC

This overarching pattern introduces additional software forces on specific solution.

Consider “inform collaborating processes” responsibility when canceling web-based data base application.

Notice the difference in communication from PAC to J2EE-MVC

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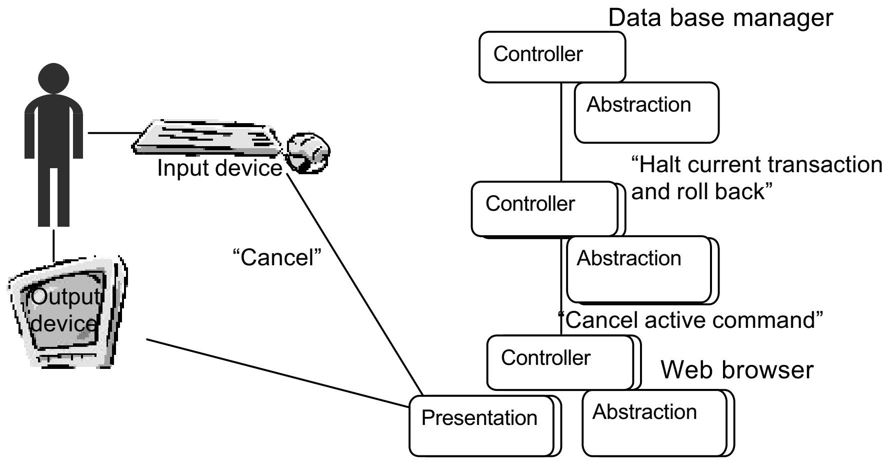
Presentation-Abstraction-Control (PAC)



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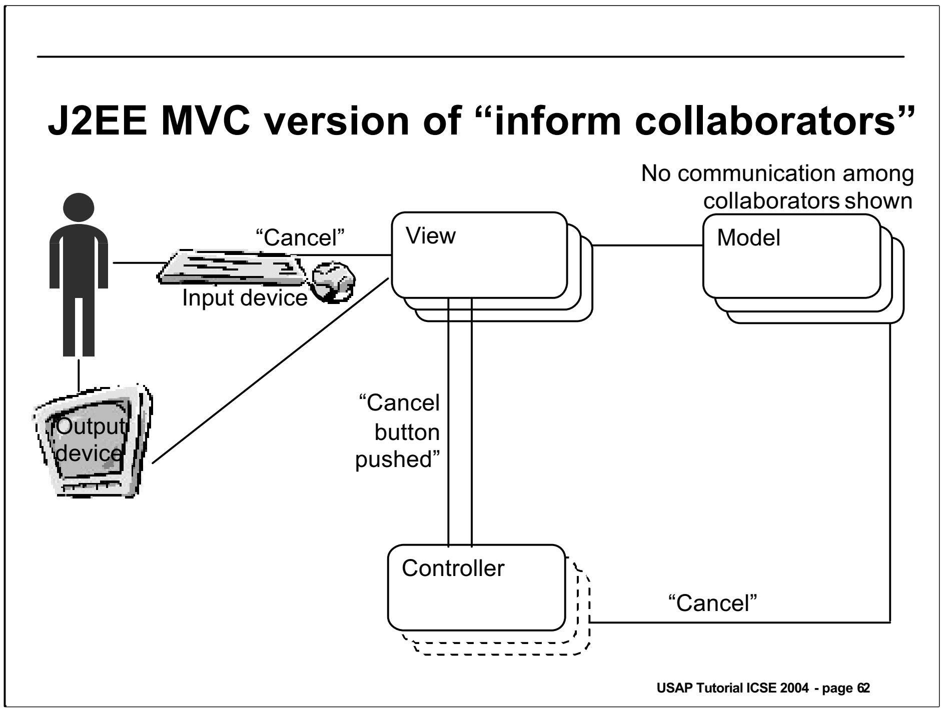
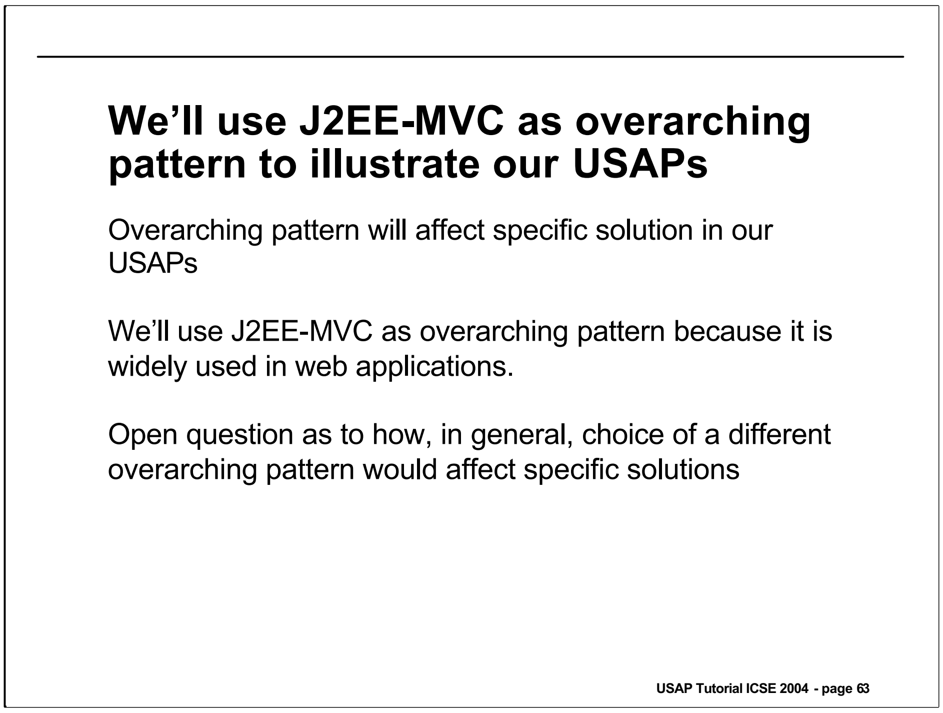


J2EE MVC version of “inform collaborators”

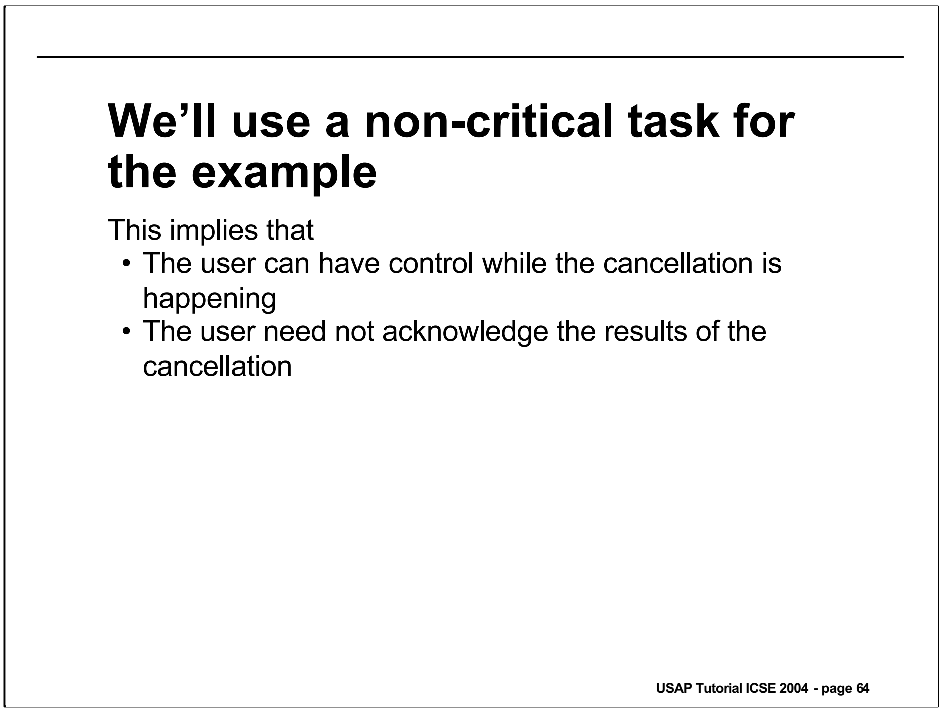


We’ll use J2EE-MVC as overarching pattern to illustrate our USAPs

Overarching pattern will affect specific solution in our USAPs

We’ll use J2EE-MVC as overarching pattern because it is widely used in web applications.

Open question as to how, in general, choice of a different overarching pattern would affect specific solutions



We’ll use a non-critical task for the example

This implies that

- The user can have control while the cancellation is happening
- The user need not acknowledge the results of the cancellation

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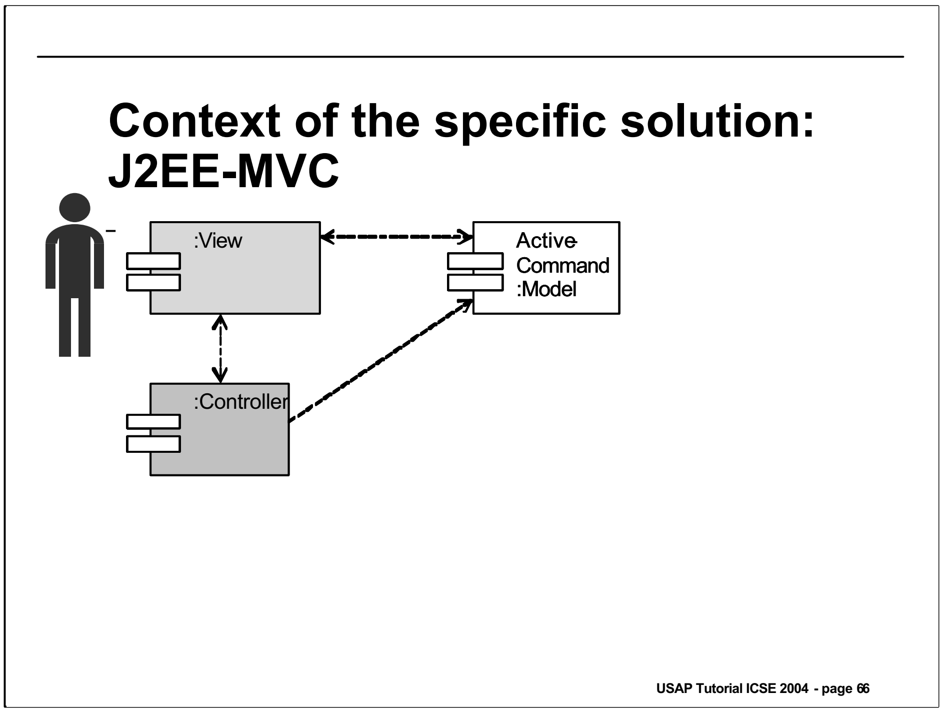
Specific Solution

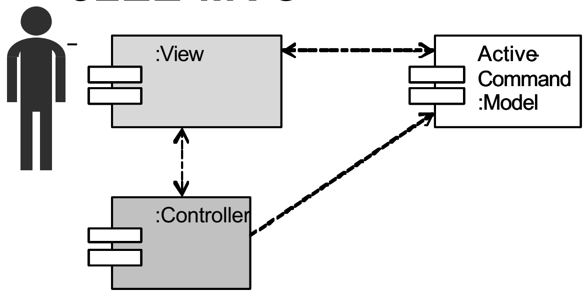
Architectural view: Presentation of one (or more) aspects of the architecture.

Common views:

- Component Diagram – shows major units of software but does not show dynamic behavior or assignment of units to various processors.
- Sequence Diagram – shows sequence of activities for a single thread through the system



Context of the specific solution: J2EE-MVC



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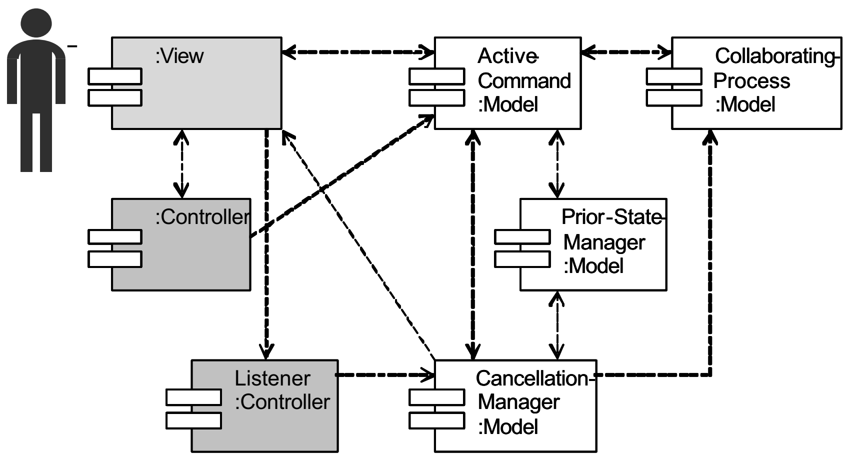
Component diagram for a specific solution to Cancel



:View
Active Command :Model
Collaborating Process :Model
:Controller
Prior-State Manager :Model
Listener :Controller
Cancellation Manager :Model

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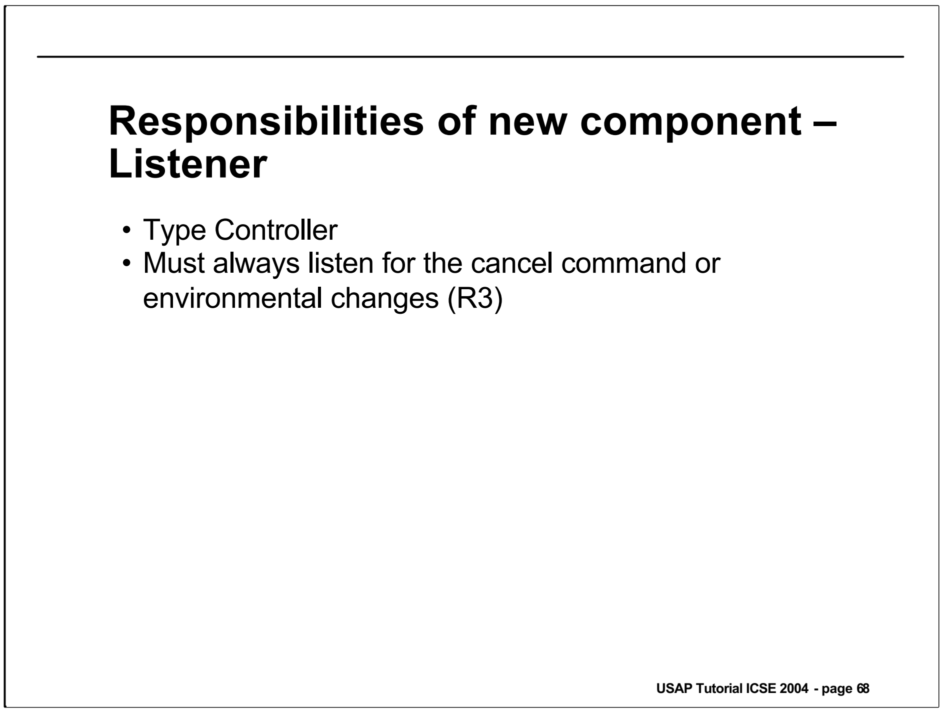
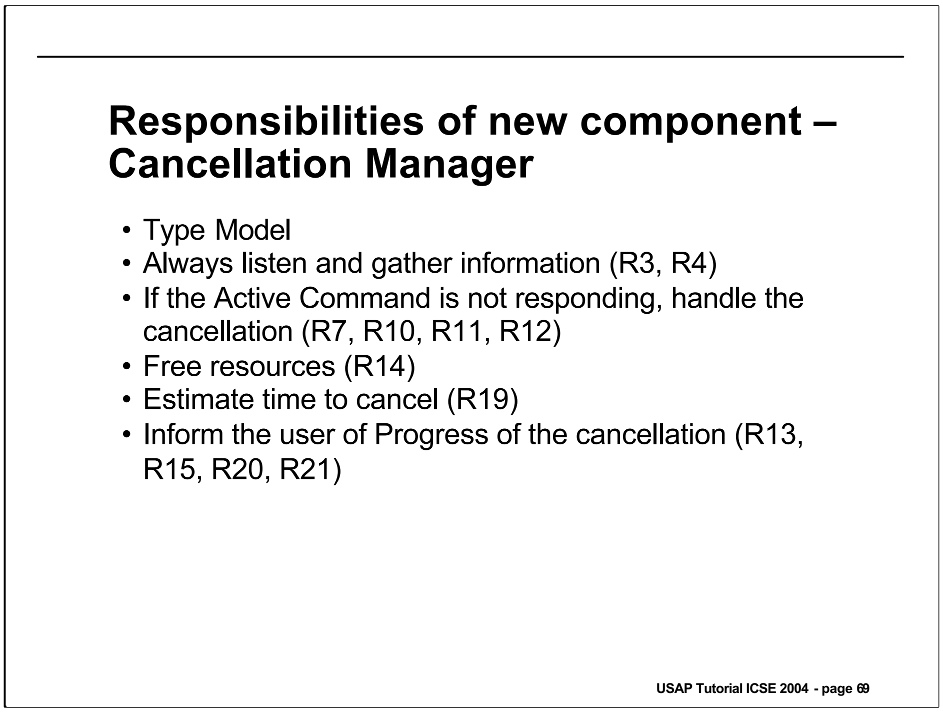


Responsibilities of new component – Listener

- Type Controller
- Must always listen for the cancel command or environmental changes (R3)



Responsibilities of new component – Cancellation Manager

- Type Model
- Always listen and gather information (R3, R4)
- If the Active Command is not responding, handle the cancellation (R7, R10, R11, R12)
- Free resources (R14)
- Estimate time to cancel (R19)
- Inform the user of Progress of the cancellation (R13, R15, R20, R21)

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Full text of responsibilities assigned to the Cancellation Manager in this example solution

R3. Must always listen for the cancel command or environmental changes

R4. Must always gather information (state, resource usage, actions, etc.) that allow for recovery of the state of the system prior to the execution of the current command

R7. An active portion of the application must ask the infrastructure to cancel the command,

If R7, then R10. The collaborating processes have to be informed of the cancellation of the invoking command (these processes have their own responsibilities that they must perform in response to this information, possibly treat it as a cancellation.). The information given to collaborating processes may include the request for cancellation, the progress of cancellation, and/or the completion of cancellation.

If R7, then R11. Restore the system back to its state prior to execution of the command. OR R12. Restore the system back to as close to the state prior to execution of the command as possible

If R12, then R13. Inform the user of the difference between the prior state and the restored state.

R14. All resources that can be freed must be freed.

If any resources are not capable of being freed, then R15. Inform the user of the partially-restored resources in a manner that they will see it.

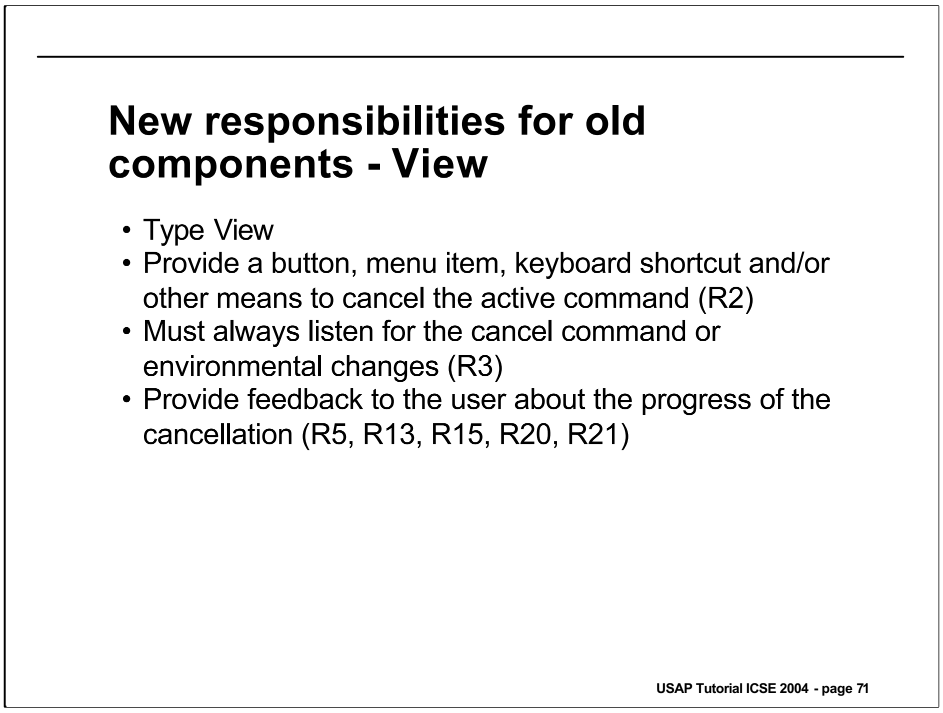
R19. Estimate the time it will take to cancel within 20%

R20. Inform the user of this estimate.

R21. Once the cancellation has finished the system must provide feedback to the user that cancellation is finished, e.g., if cursor was changed to busy indicator, change it back to normal; if progress bar was displayed was displayed, remove it; if dialog box was provided, close it.

Responsibilities of new component – Prior State Manager

- Type Model
- Must always gather information (state, resource usage, actions, etc.) that allow for recovery of the state of the system prior to the execution of the current command (R4)
- If the Active Command is not responding (R7), work with the Cancellation Manager to restore the system back to its state prior to execution of the command (R11) or as close as possible to that state (R12)



New responsibilities for old components - View

- Type View
- Provide a button, menu item, keyboard shortcut and/or other means to cancel the active command (R2)
- Must always listen for the cancel command or environmental changes (R3)
- Provide feedback to the user about the progress of the cancellation (R5, R13, R15, R20, R21)

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Full text of responsibilities assigned to the View in this examp le solution

R2. Provide a button, menu item, keyboard shortcut and/or other means to cancel the active command

R3. Must always listen for the cancel command or environmental changes

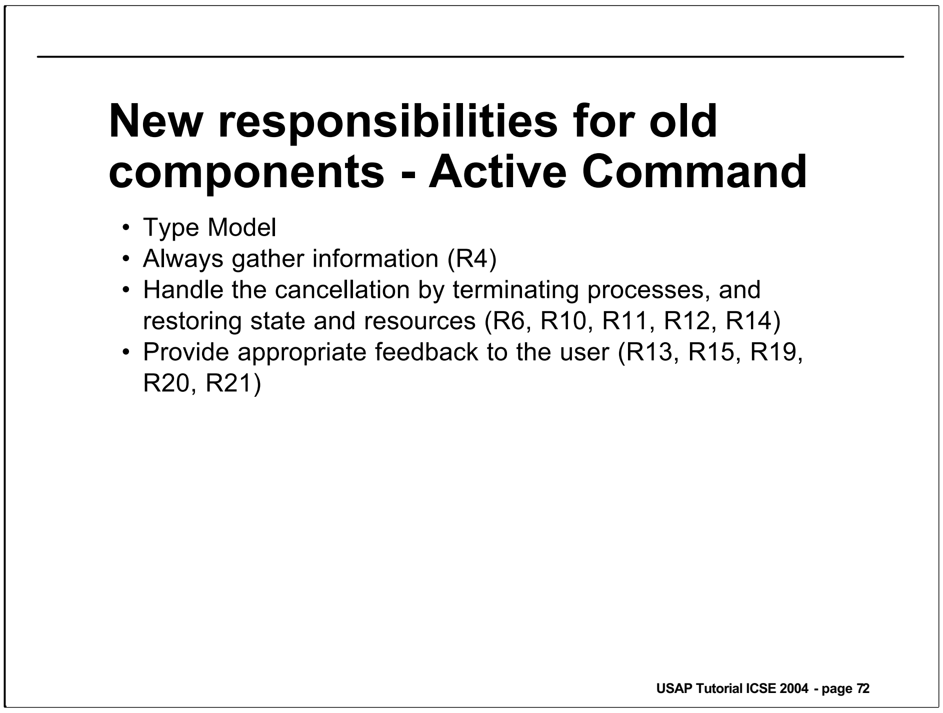
R5. Must acknowledge receipt of the cancellation command appropriately within 150 msec.

If any module did R12, then R13. Inform the user of the difference between the prior state and the restored state.

If any module did R14, then R15. Inform the user of the partially-restored resources in a manner that they will see it.

R20. Inform the user of the time estimate.

R21. Once the cancellation has finished the system must provide feedback to the user that cancellation is finished, e.g., if cursor was changed to busy indicator, change it back to normal; if progress bar was displayed was displayed, remove it; if dialog box was provided, close it.



New responsibilities for old components - Active Command

- Type Model
- Always gather information (R4)
- Handle the cancellation by terminating processes, and restoring state and resources (R6, R10, R11, R12, R14)
- Provide appropriate feedback to the user (R13, R15, R19, R20, R21)

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Full text of responsibilities assigned to the Active Command in this example solution

R4. Must always gather information (state, resource usage, actions, etc.) that allow for recovery of the state of the system prior to the execution of the current command

R6. The command must respond by canceling itself (I.e., it must fulfill Responsibilities R10 to R21 (e.g., an object-oriented system would have a cancel method in each object)

If R6 then R10. The collaborating processes have to be informed of the cancellation of the invoking command (these processes have their own responsibilities that they must perform in response to this information, possibly treat it as a cancellation.). The information given to collaborating processes may include the request for cancellation, the progress of cancellation, and/or the completion of cancellation.

If R6, then R11. Restore the system back to its state prior to execution of the command. Or R12. Restore the system back to as close to the state prior to execution of the command as possible

If R12, then R13. Inform the user of the difference between the prior state and the restored state.

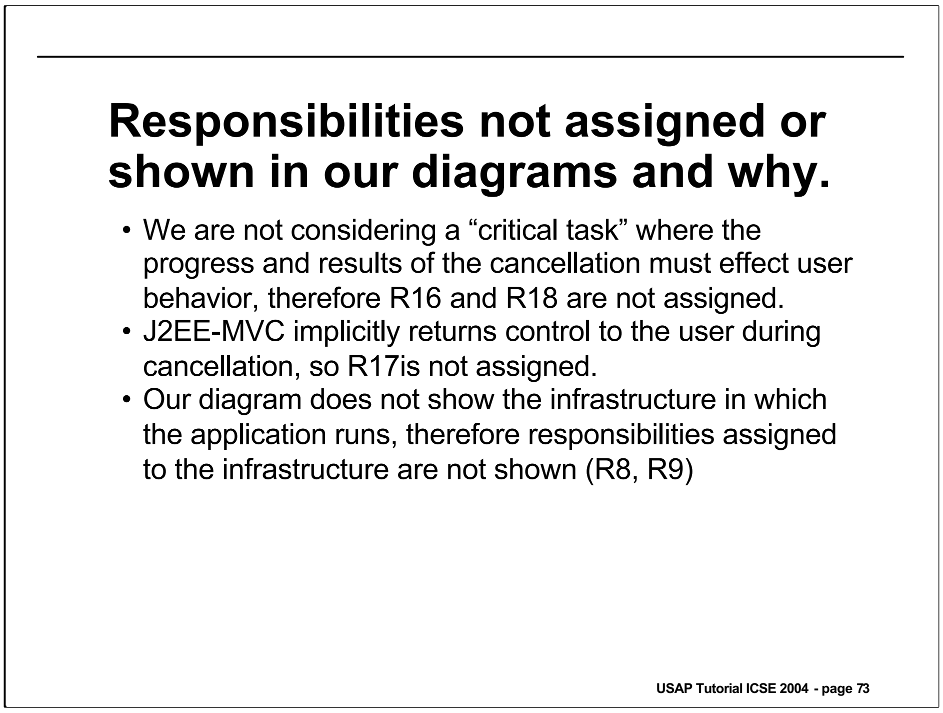
R14. Resources that can be freedmust be freed

If any resources are not capable of being freed, then R15. Inform the user of the partially-restored resources in a manner that they will see it.

R19. Estimate the time it will take to cancel within 20%

R20. Inform the user of this estimate.

R21. Once the cancellation has finished the system must provide feedback to the user that cancellation is finished, e.g., if cursor was changed to busy indicator, change it back to normal; if progress bar was displayed was displayed, remove it; if dialog box was provided, close it.


Responsibilities not assigned or shown in our diagrams and why.

- We are not considering a “critical task” where the progress and results of the cancellation must effect user behavior, therefore R16 and R18 are not assigned.
- J2EE-MVC implicitly returns control to the user during cancellation, so R17is not assigned.
- Our diagram does not show the infrastructure in which the application runs, therefore responsibilities assigned to the infrastructure are not shown (R8, R9)

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List of responsibilities not assigned to our components or not shown in the diagrams.

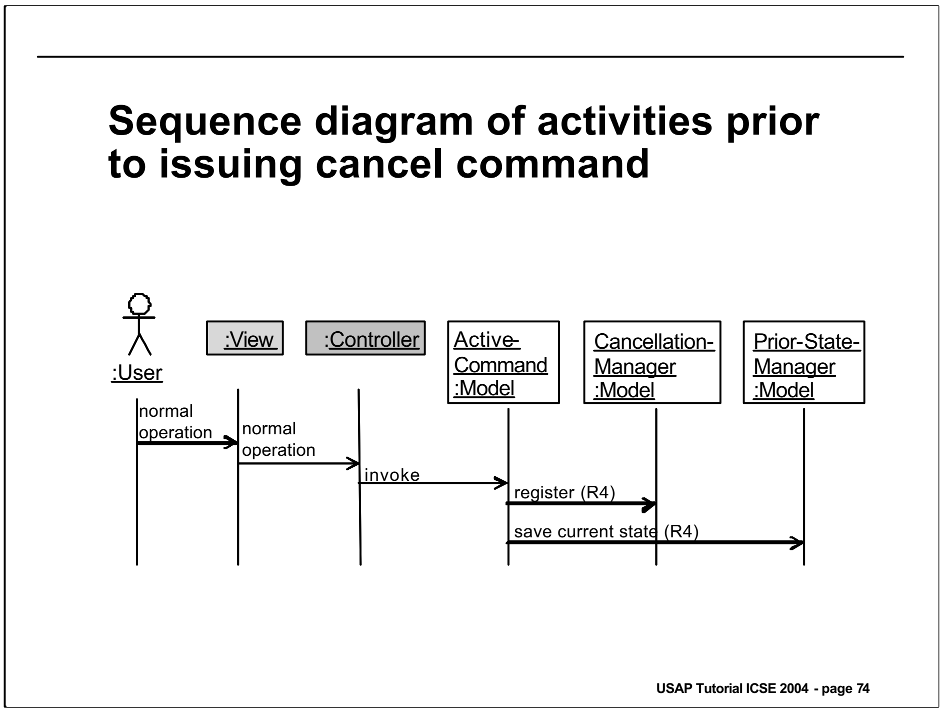
R8. The infrastructure itself must provide a means to request the cancellation of the application (e.g., task manager on Windows, force quit on MacOS)

R9. If either R7 or R8, then the infrastructure must have the ability to cancel the active command (I.e., it must fulfill Responsibilities R10 to R21)

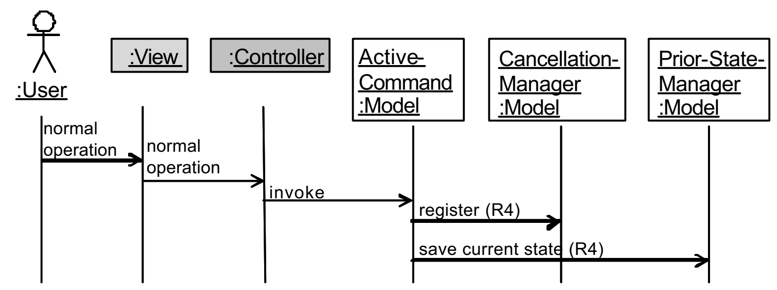
R16 Require acknowledgement from the user that they are aware of the partially-restored nature of the cancellation. (we’re not doing a “critical task” in this example)

R17. Return control to the user, or not, depending on the forces from the task (implicit in J2EE-MVC)

R18. If control cannot be returned to the user, inform the user of this fact (and ideally, why that is the case) (we’re not doing a “critical task” in this example)



Sequence diagram of activities prior to issuing cancel command



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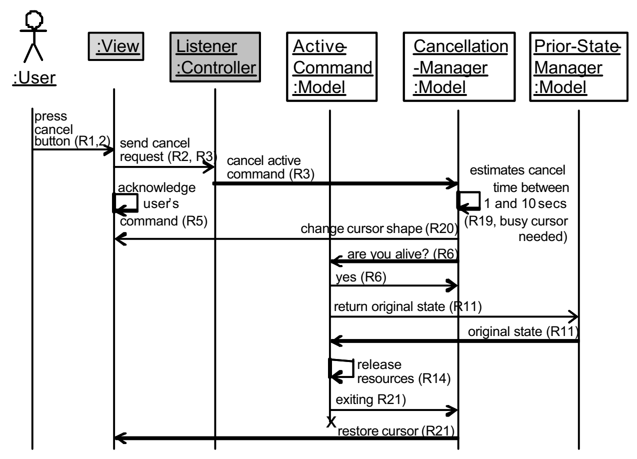
Xxx put in note about the components that don't show up in this sequence

Sequence diagram of activities after issuing cancel command


:User
:View
Listener :Controller
Active-Command :Model
Cancellation-Manager :Model
Prior-State-Manager :Model
press cancel button (R1,2)
send cancel request (R2, R3)
cancel active command (R3)
estimates cancel time between 1 and 10 secs (R19, busy cursor needed)
acknowledge user's command (R5)
change cursor shape (R20)
are you alive? (R6)
yes (R6)
return original state (R11)
original state (R11)
release resources (R14)
exiting R21)
X
restore cursor (R21)

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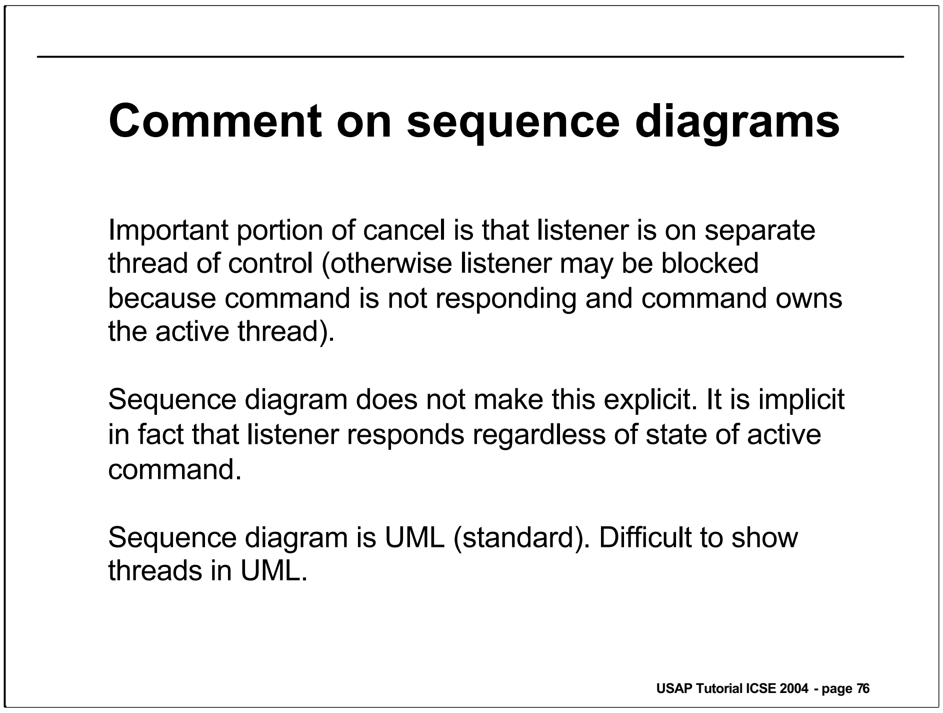
Xxx put in note about the components that don't show up in this sequence

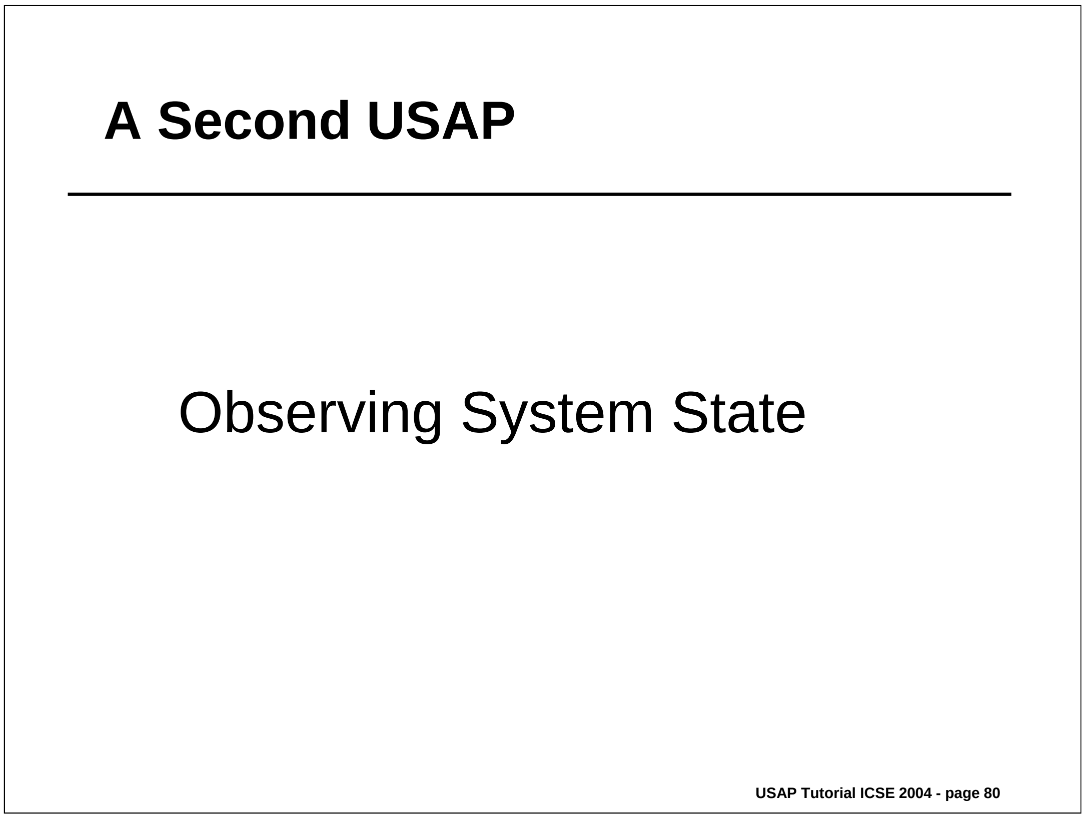


Comment on sequence diagrams

Important portion of cancel is that listener is on separate thread of control (otherwise listener may be blocked because command is not responding and command owns the active thread).

Sequence diagram does not make this explicit. It is implicit in fact that listener responds regardless of state of active command.

Sequence diagram is UML (standard). Difficult to show threads in UML.



A Second USAP

Observing System State

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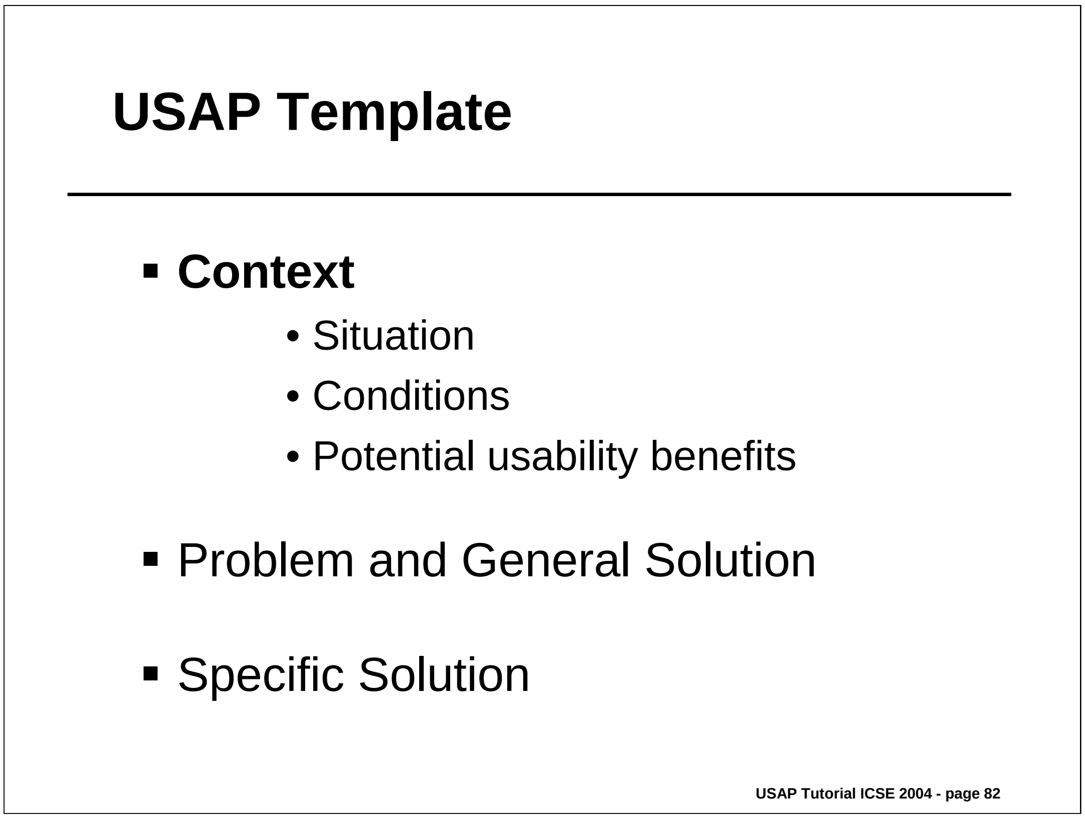
Types of Feedback

- **Observing System state**: To inform users of the internal system state and state changes.
- **Progress indicator**: To inform users that the system is processing an action that will take some time to complete.
- **Interaction Feedback**: To inform users that the system has registered a user interaction, that is, that the system has heard users.
- **Warning**: To inform users of any irreversible action.



USAP Template

- **Context**
  - Situation
  - Conditions
  - Potential usability benefits
- Problem and General Solution
- Specific Solution

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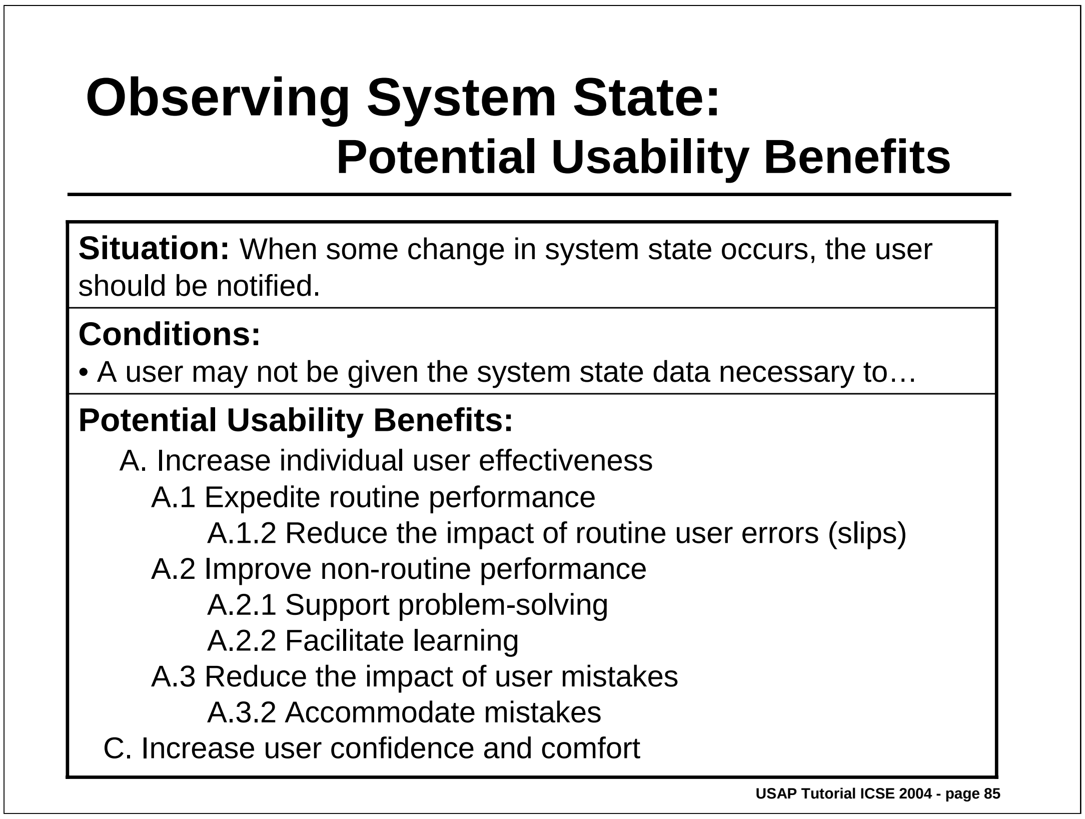
Observing System State: Situation

Situation: When some change in system state occurs, the user should be notified, specially when the state change affects to state information that is displayed.
Conditions
Potential Usability Benefits

Observing System State: Conditions

Situation: When some change in system state occurs, the user should be notified.
Conditions: • A user may not be given the system state data necessary to operate the system (e.g., uninformative error messages, no file size given for folders). • The system state may be given in a way that violates human tolerances (e.g., displayed too quickly for people to read). • The system state may also be given unclearly, thereby confusing the user. • System designers should account for human needs and capabilities when deciding what aspects of a system state to display and how to do so.
Potential Usability Benefits



Observing System State: Potential Usability Benefits

Situation: When some change in system state occurs, the user should be notified.
Conditions: • A user may not be given the system state data necessary to…
Potential Usability Benefits: A. Increase individual user effectiveness A.1 Expedite routine performance A.1.2 Reduce the impact of routine user errors (slips) A.2 Improve non-routine performance A.2.1 Support problem-solving A.2.2 Facilitate learning A.3 Reduce the impact of user mistakes A.3.2 Accommodate mistakes C. Increase user confidence and comfort

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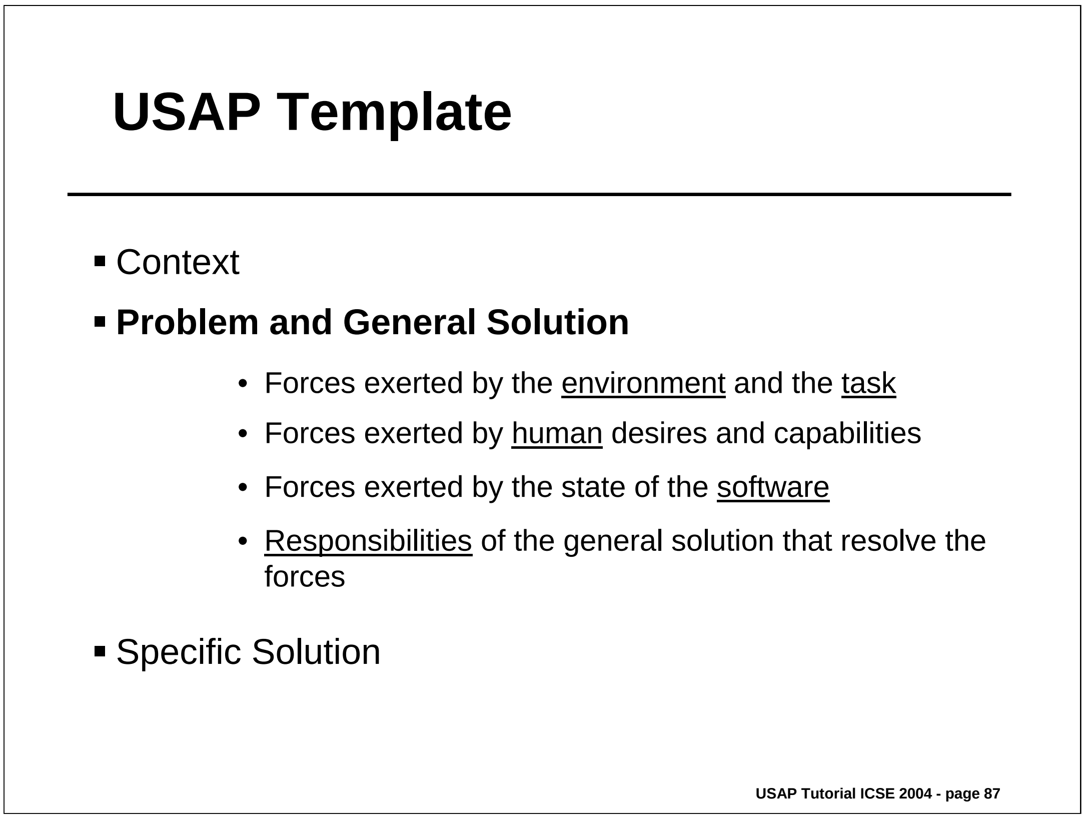
USAP Template

- Context
- **Problem and General Solution**
- Specific Solution



USAP Template

- Context
- **Problem and General Solution**
  - Forces exerted by the environment and the task
  - Forces exerted by human desires and capabilities
  - Forces exerted by the state of the software
  - Responsibilities of the general solution that resolve the forces
- Specific Solution

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Observing System State: Human Forces (1/2)

1. When some change in system state occurs, the user should be notified (HF01)

2. If the system fails, the user should be notified (HF02)

3. Users need to be alerted of the fact that a command does not respond (HF03)

Observing System State: Environmental Forces

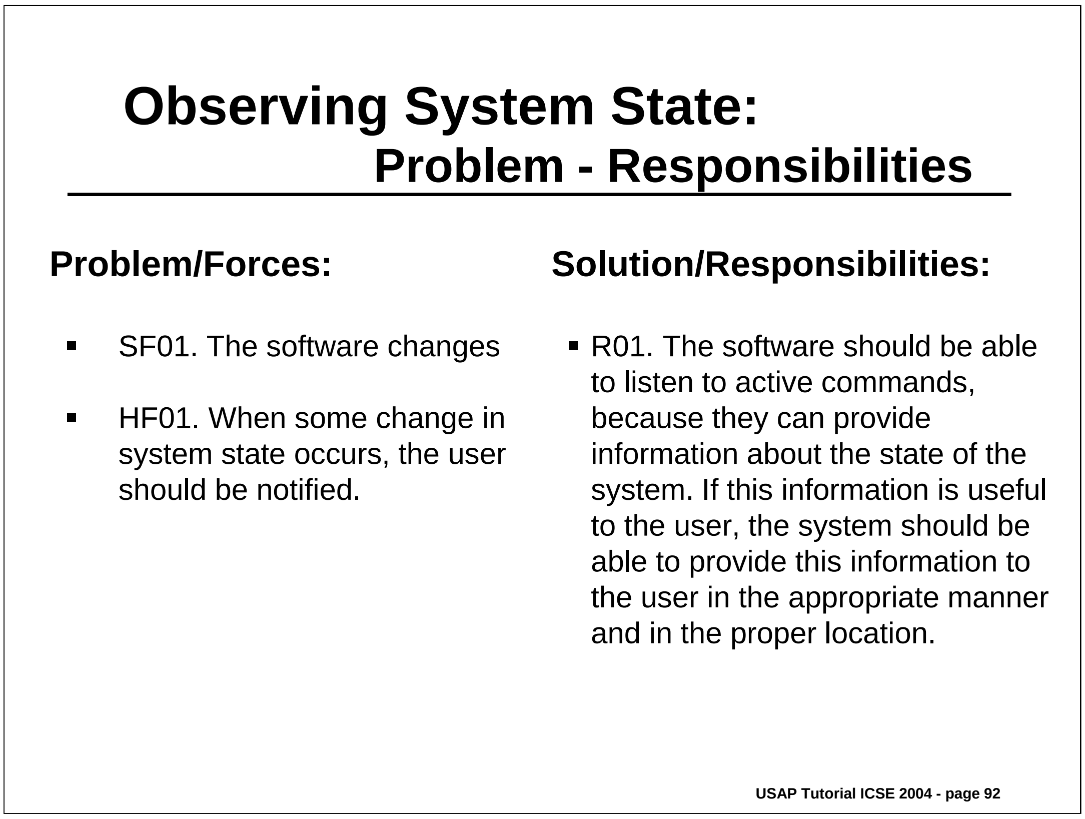
1. Resources, be it the network, a database, etc., can become not operational (EF01)

Observing System State: System Forces (1/2)

1. System state changes (SF01)
2. Systems sometimes fail (SF02)
3. Commands sometimes die (SF03)

Observing System State:
Problem - Responsibilities

Problem			General Solution
Forces exerted by the environment and the task	Forces exerted by human desires and capabilities	Forces exerted by the state of the software	Responsibilities of the software system that resolve the forces



Observing System State: Problem - Responsibilities

Problem/Forces:

- SF01. The software changes
- HF01. When some change in system state occurs, the user should be notified.

Solution/Responsibilities:

- R01. The software should be able to listen to active commands, because they can provide information about the state of the system. If this information is useful to the user, the system should be able to provide this information to the user in the appropriate manner and in the proper location.

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Observing System State: Problem - Responsibilities

Problem/Forces:

- SF03. Commands sometimes fail to be operational
- HF02: If the system fails, the user should be notified
- HF03: To alert users of the fact that a command does not respond

Solution/Responsibilities:

- R02: As active commands can fail, the software system should be able to check at any time whether a given command is being executed and, if the command fails, inform users that the command is not operational.

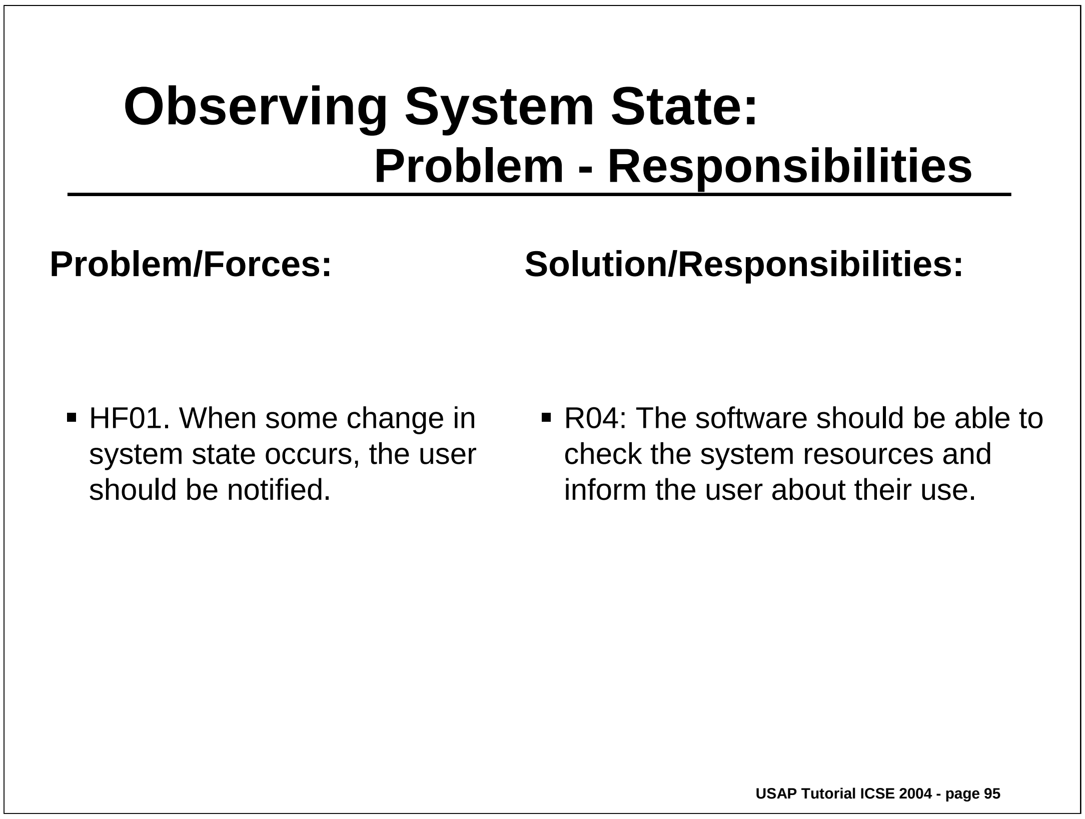
Observing System State: Problem - Responsibilities

Problem/Forces:

- EF1: Resources, be it the network, a database, etc., can become not operational

Solution/Responsibilities:

- R03: The software should be able to listen to or query external resources, like networks or databases, about their state, to inform properly the user if any resource is not performing properly.



Observing System State: Problem - Responsibilities

Problem/Forces:

- HF01. When some change in system state occurs, the user should be notified.

Solution/Responsibilities:

- R04: The software should be able to check the system resources and inform the user about their use.

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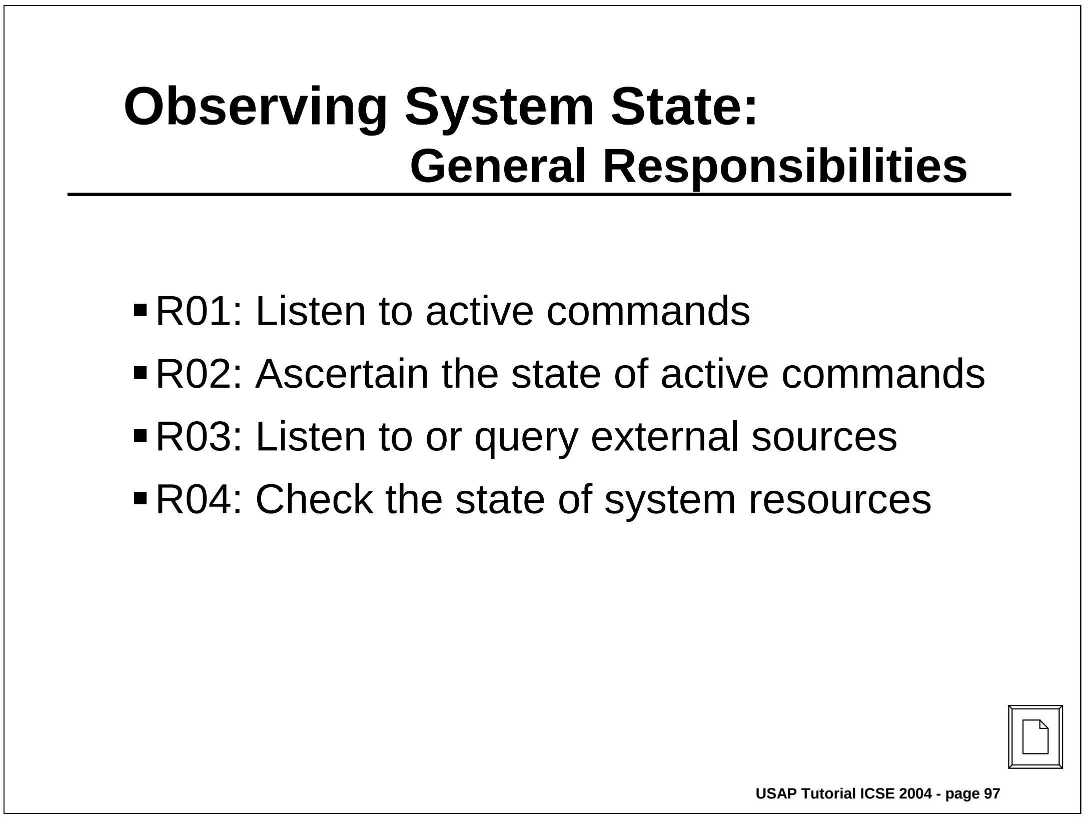
USAP Template

- Context
- Problem and General Solution
- **Specific Solution**
  - General responsibilities
  - Forces exerted by previous design decisions
  - Allocation of responsibilities to specific components
  - Rationale



Observing System State: General Responsibilities

- R01: Listen to active commands
- R02: Ascertain the state of active commands
- R03: Listen to or query external sources
- R04: Check the state of system resources

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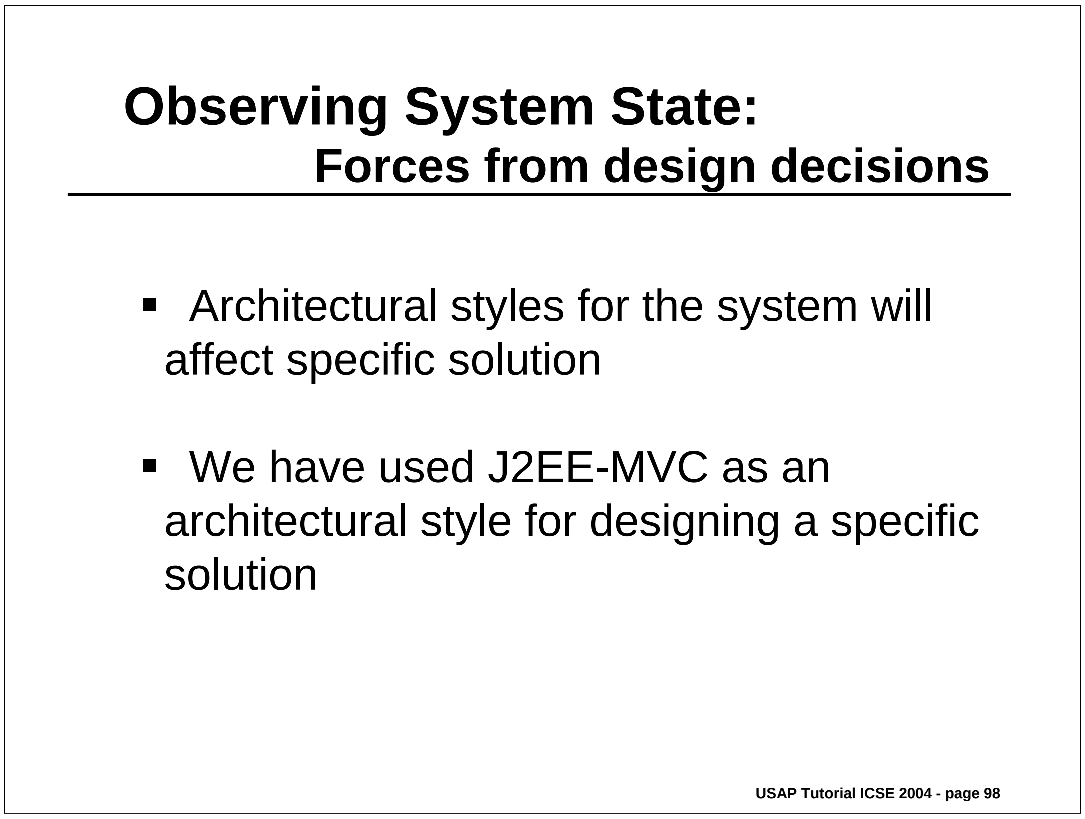

Observing System State: Forces from design decisions

- Architectural styles for the system will affect specific solution
- We have used J2EE-MVC as an architectural style for designing a specific solution

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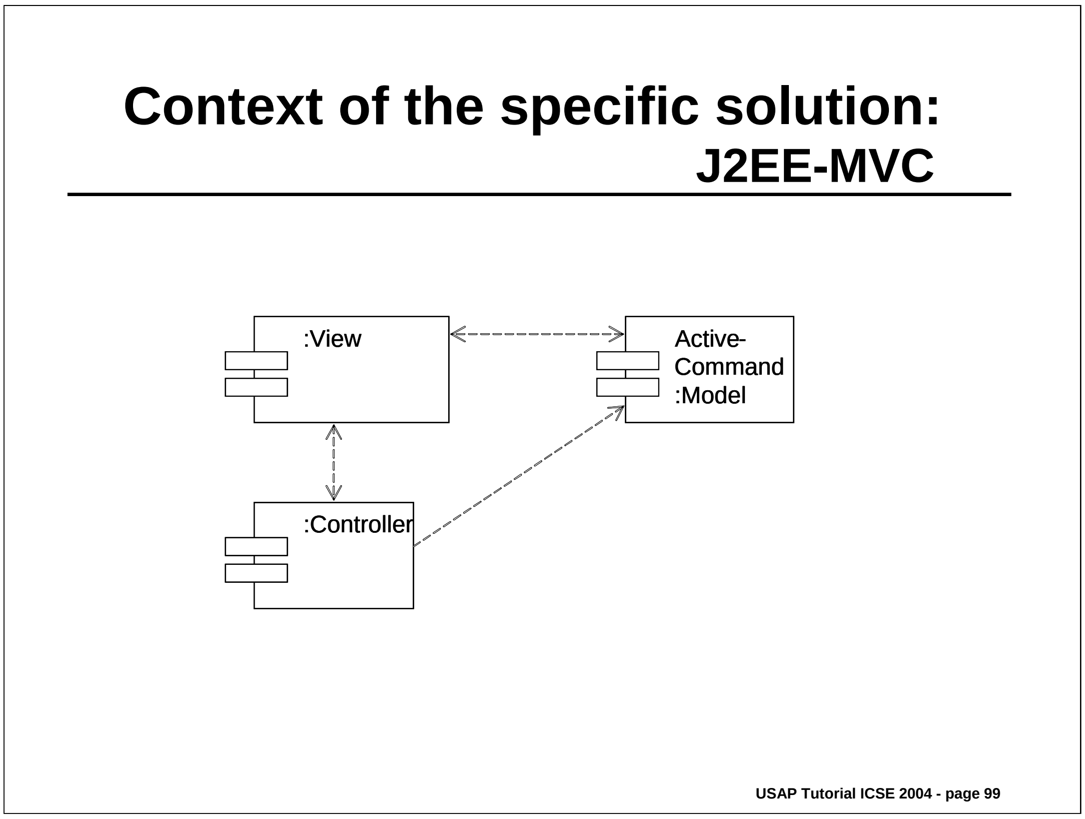
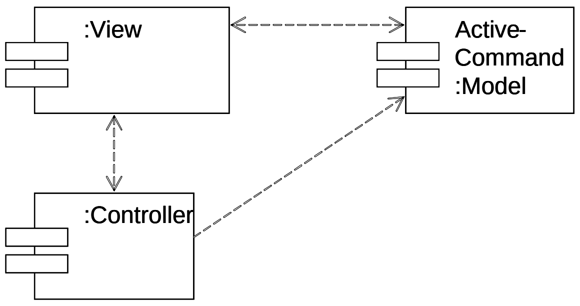
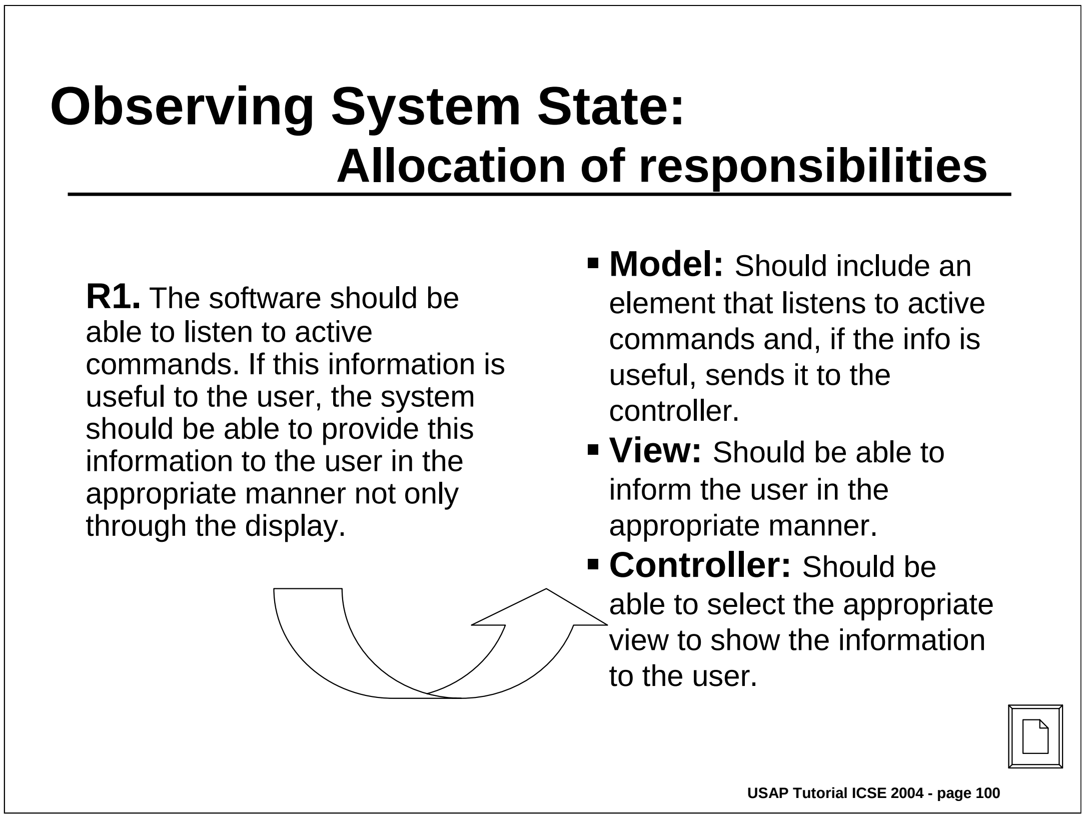


Context of the specific solution: J2EE-MVC

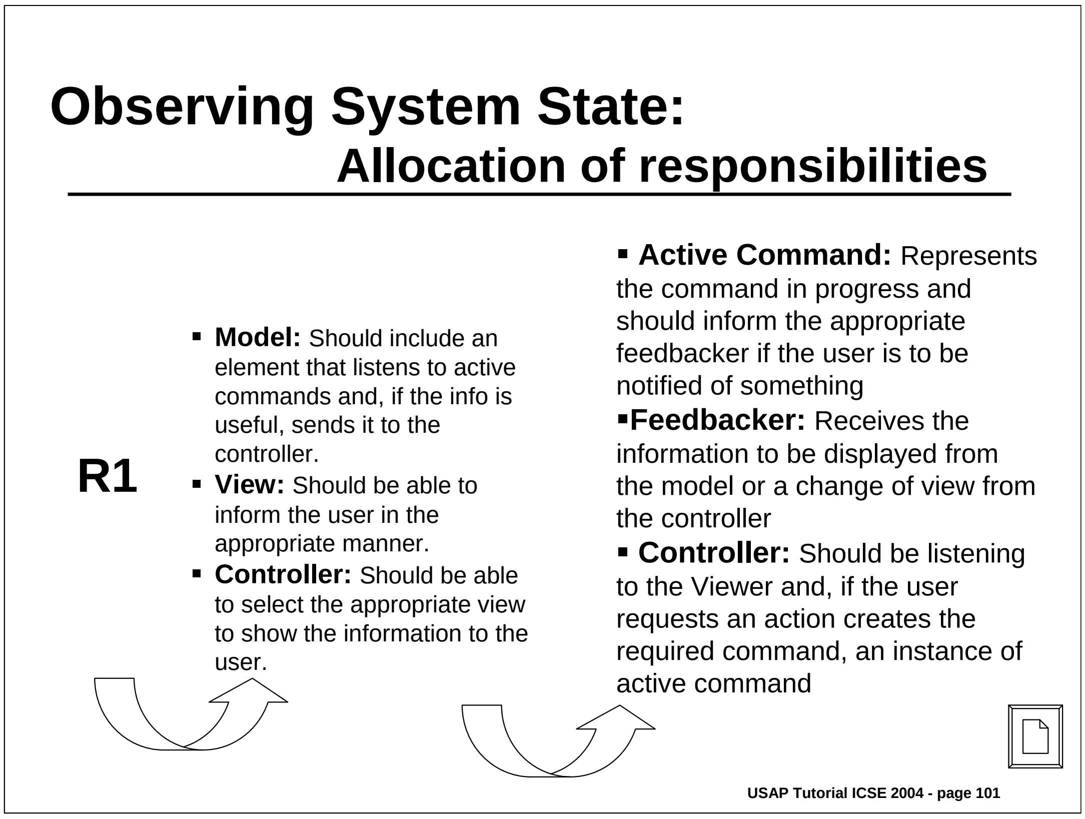




Observing System State: Allocation of responsibilities

R1. The software should be able to listen to active commands. If this information is useful to the user, the system should be able to provide this information to the user in the appropriate manner not only through the display.

- **Model:** Should include an element that listens to active commands and, if the info is useful, sends it to the controller.
- **View:** Should be able to inform the user in the appropriate manner.
- **Controller:** Should be able to select the appropriate view to show the information to the user.



Observing System State: Allocation of responsibilities

R1

- **Model:** Should include an element that listens to active commands and, if the info is useful, sends it to the controller.
- **View:** Should be able to inform the user in the appropriate manner.
- **Controller:** Should be able to select the appropriate view to show the information to the user.

- **Active Command:** Represents the command in progress and should inform the appropriate feedbacker if the user is to be notified of something
- **Feedbacker:** Receives the information to be displayed from the model or a change of view from the controller
- **Controller:** Should be listening to the Viewer and, if the user requests an action creates the required command, an instance of active command

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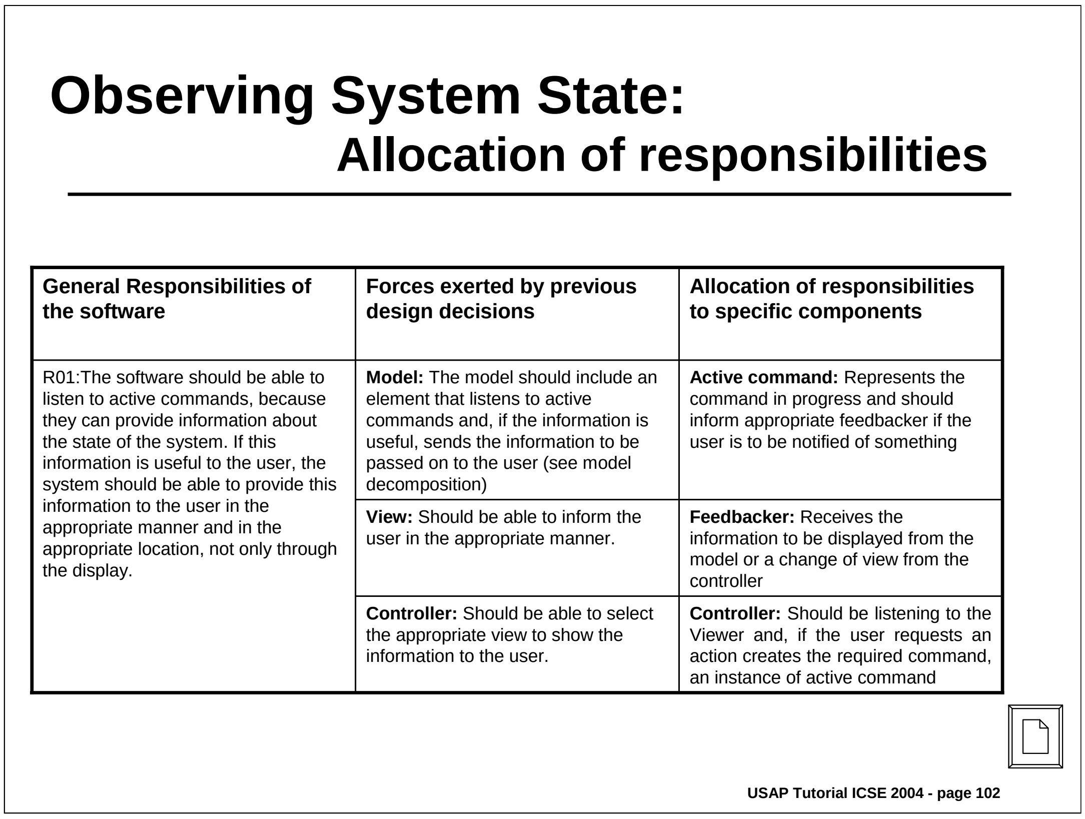

Observing System State: Allocation of responsibilities

General Responsibilities of the software	Forces exerted by previous design decisions	Allocation of responsibilities to specific components
R01:The software should be able to listen to active commands, because they can provide information about the state of the system. If this information is useful to the user, the system should be able to provide this information to the user in the appropriate manner and in the appropriate location, not only through the display.	**Model:** The model should include an element that listens to active commands and, if the information is useful, sends the information to be passed on to the user (see model decomposition)	**Active command:** Represents the command in progress and should inform appropriate feedbacker if the user is to be notified of something
	View: Should be able to inform the user in the appropriate manner.	**Feedbacker:** Receives the information to be displayed from the model or a change of view from the controller
	Controller: Should be able to select the appropriate view to show the information to the user.	**Controller:** Should be listening to the Viewer and, if the user requests an action creates the required command, an instance of active command

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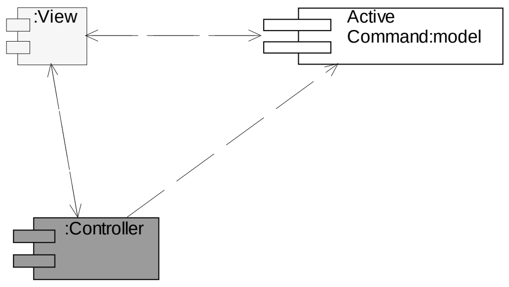
Observing System State: Specific Solution

- Check whether or not the ongoing command is dead.
- Check whether or not external resources are dead.
- Check whether or not the system has enough resources to execute the ongoing command.

Observing System State: Specific Solution



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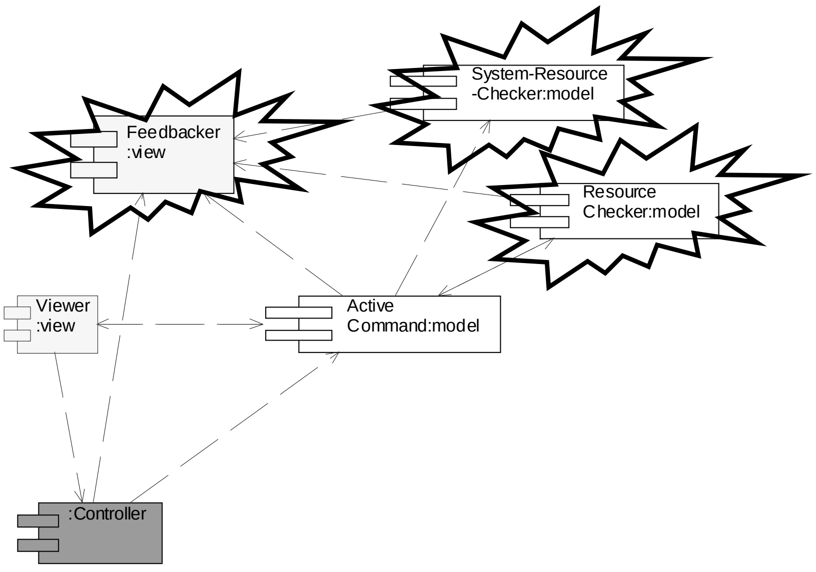
Observing System State: Specific Solution



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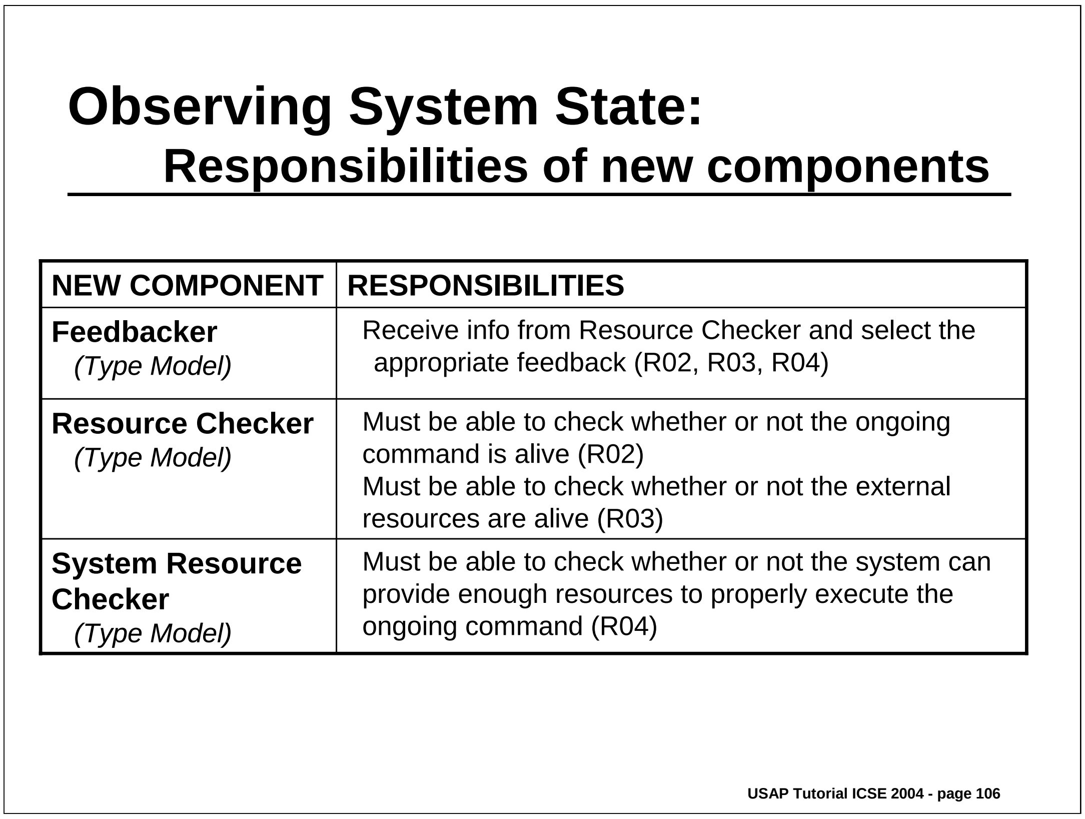

Observing System State: Responsibilities of new components

NEW COMPONENT	RESPONSIBILITIES
Feedbacker *(Type Model)*	Receive info from Resource Checker and select the appropriate feedback (R02, R03, R04)
Resource Checker *(Type Model)*	Must be able to check whether or not the ongoing command is alive (R02) Must be able to check whether or not the external resources are alive (R03)
System Resource Checker *(Type Model)*	Must be able to check whether or not the system can provide enough resources to properly execute the ongoing command (R04)

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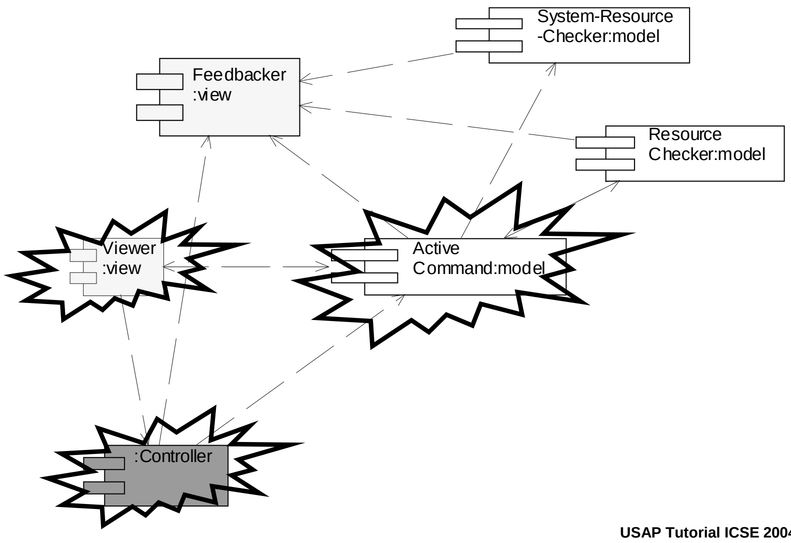
Observing System State: Specific Solution



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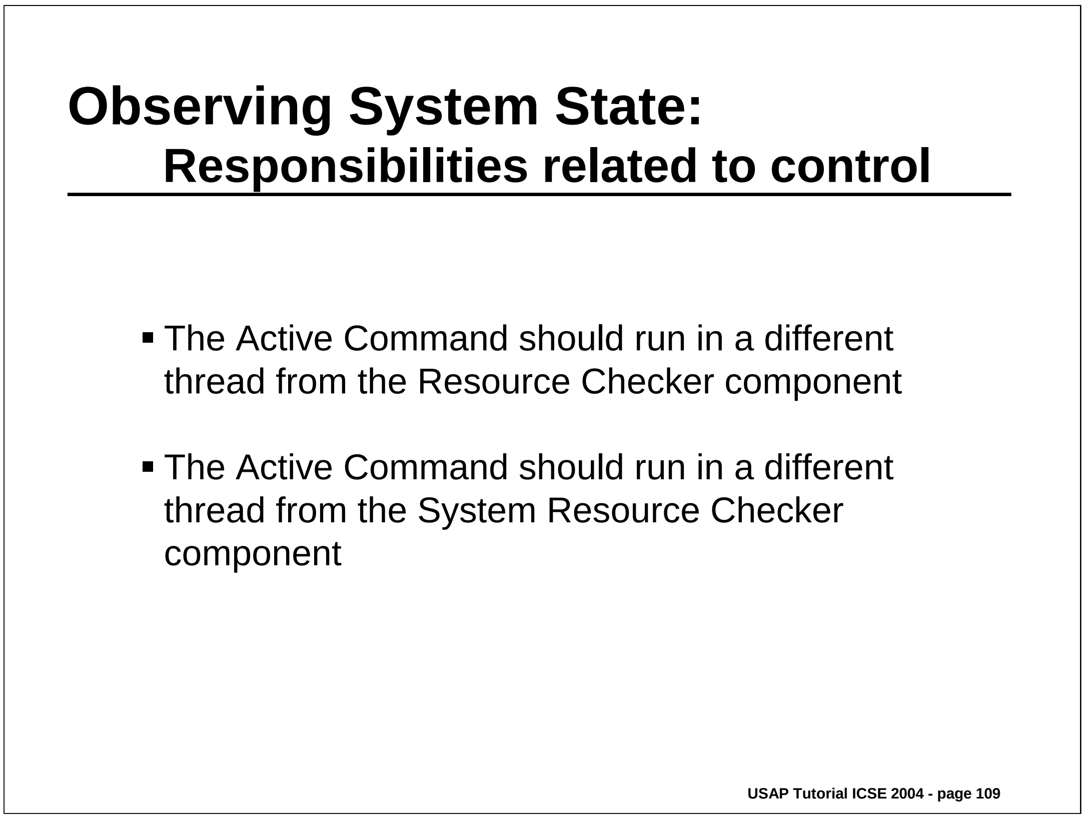
Observing System State: Responsibilities of old components

OLD COMPONENT	RESPONSABILITIES
Viewer (Type View)	Must be able to gather user requests.
Controller *(Type Controller)*	Must always listen for the viewer requests to create the respective active command.
Active Command *(Type Model)*	Represents the command in progress and should inform the Feedbacker about any change produced.



Observing System State: Responsibilities related to control

- The Active Command should run in a different thread from the Resource Checker component
- The Active Command should run in a different thread from the System Resource Checker component

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Observing System State: Specific Solution

Imagine we are faced with a situation where:

- The ongoing command is dead

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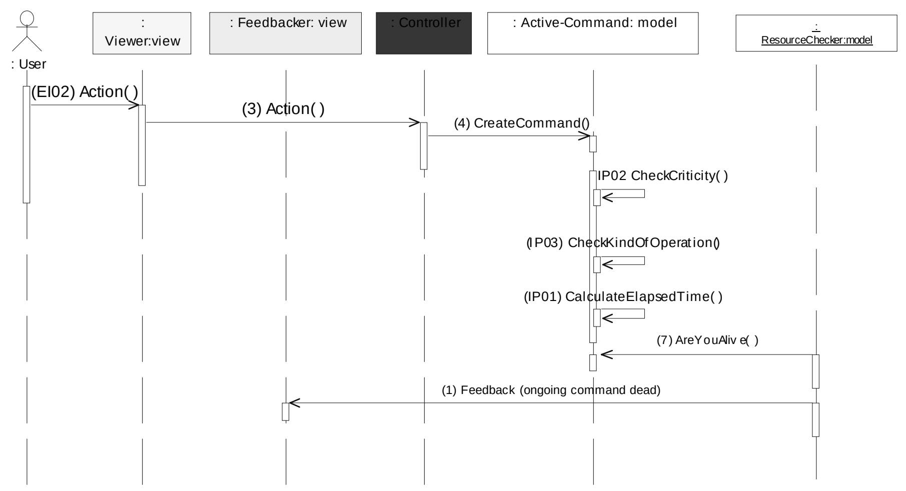
Observing System State:
Specific Solution



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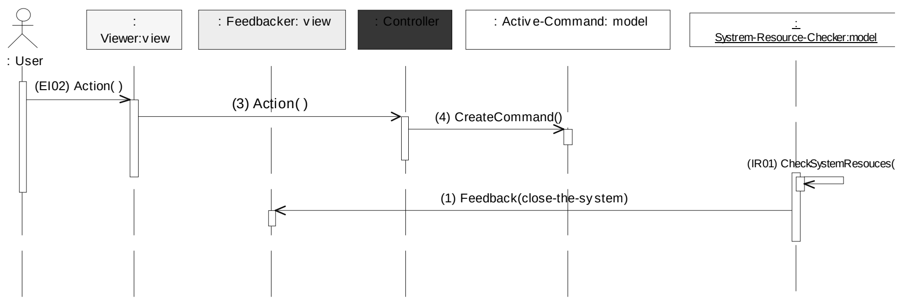
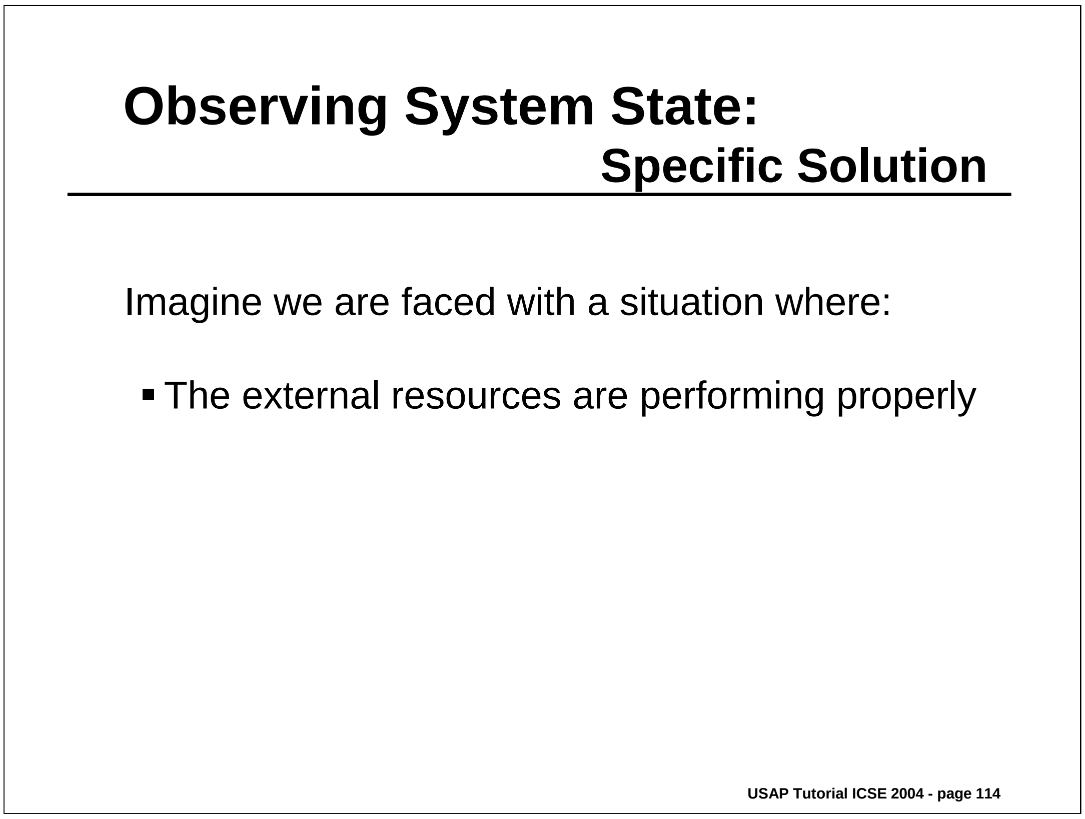
Observing System State:
Specific Solution

Imagine we are faced with a situation where:

- There are not enough resources to execute the ongoing command

Observing System State:
Specific Solution



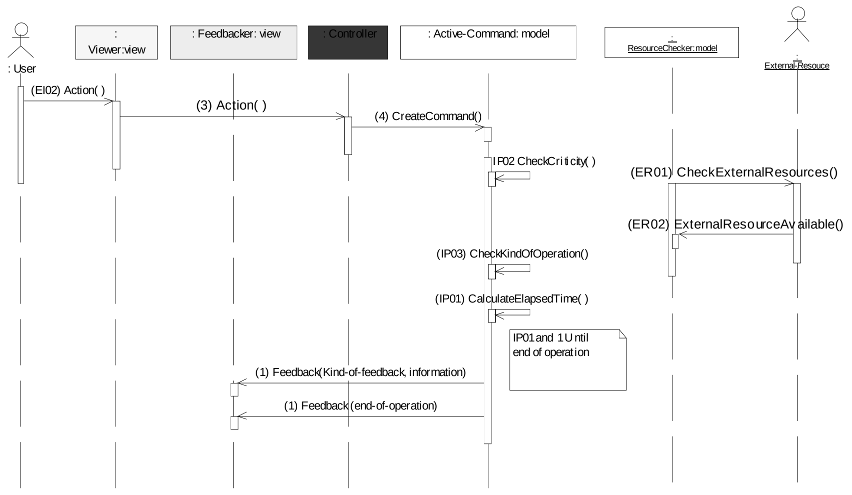


Observing System State:
Specific Solution

Imagine we are faced with a situation where:

- The external resources are performing properly

Observing System State:
Specific Solution



: User
: Viewer:view
: Feedbacker: view
: Controller
: Active-Command: model
: ResourceChecker:model
: External-Resouce
(EI02) Action( )
(3) Action( )
(4) CreateCommand()
IP02 CheckCriticity( )
(ER01) CheckExternalResources()
(ER02) ExternalResourceAvailable()
(IP03) CheckKindOfOperation()
(IP01) CalculateElapsedTime( )
IP01 and 1 Until end of operation
(1) Feedback(Kind-of-feedback, information)
(1) Feedback (end-of-operation)

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Tutorial Summary

Software architectural design can support iterative design through separation based patterns, but some usability issues are difficult to resolve through iterative design.

Architecturally sensitive scenarios are examples of problems that are difficult to implement once architecture is designed.

USAPs are an attempt to capture some of these problems, provide rationale to support cost/benefit analysis, provide general set of responsibilities for any solution, and provide sample specific solution to further guide software designer.

Currently have about two dozen architecturally sensitive scenarios and are in process of turning these into USAPs.

Agenda

9:00-10:30 Intro to HCI and UI tools
10:30-10:45 Break
10:45-12:15 Usability and Software Architectures (Part 1)
12:15-1:15 Lunch
1:15-2:45 Usability and Software Architectures (Part 2)
2:45-3:00 Break
3:00-4:30 End-User Implications of Infrastructure
4:30-5:00 Homework discussion

Stuck in the Middle

How do you evaluate the worthiness of infrastructure (e.g., middleware, architecture, toolkit)?

Recall example of read-eval loop versus notification-based programming for interactive dialogue.

Let's look at a detailed example of an infrastructure/toolkit and then explore the evaluation question.

Context-Aware Computing

Effective use of context is the key to a ubicomp environment that does the right thing.

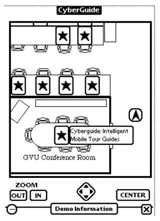
Supporting the right abstractions and services for handling context makes it easier to design, build and evolve context-aware applications.

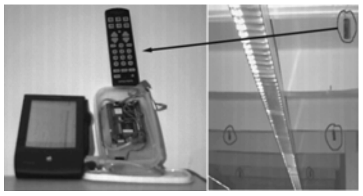
The Importance of Context

- What is context?
  - any information that can be used to characterize the situation of an entity
  - emphasis on implicit context, that applications do not have access to
- C-A research is slowed by difficulty of development

Why are C-A Applications Hard to Build?

Cyberguide case study: no separation of concerns





Separation of Concerns

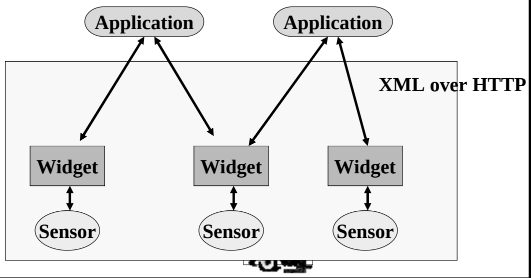
- Acquisition
- Representation
- Storage
- Distribution
- Reaction

Inspiration

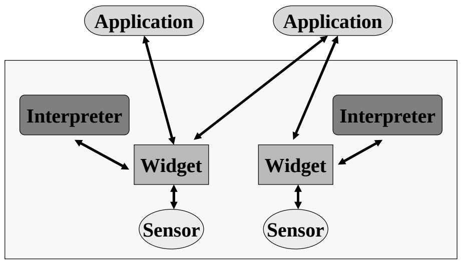
- Analogy to GUI toolkits
- What is the context equivalent to the GUI widget or interactor?

The Context Toolkit

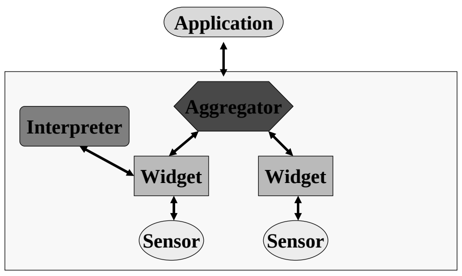
- Simplify application's view of world



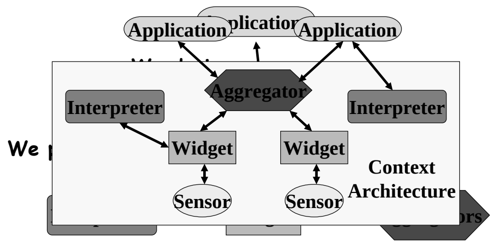
Flexible Representation



Focus on Entities



Focus on Context, not Source



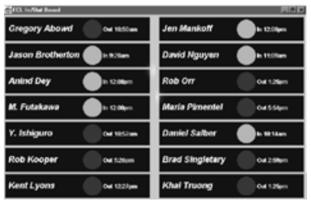
Evaluating the CTK

So, how do we determine if CTK is a good solution to developing context-aware applications?

Look at apps it can be used to develop.

Applications

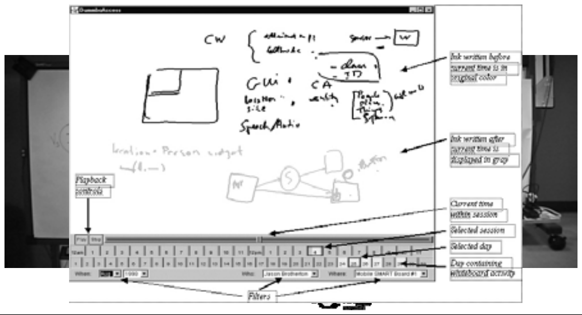
- In/Out Board and Context-Aware Mailing List (CHI'99) – simple, reusable



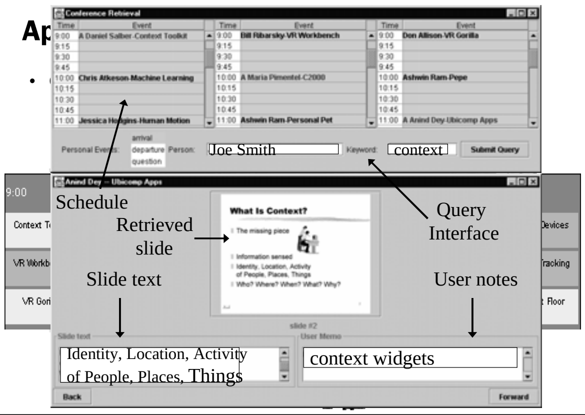
Gregory Abowd	Out 10:50am	Jen Mankoff	In 12:08pm
Jason Brotherton	In 9:26am	David Nguyen	In 11:09am
Anind Dey	In 12:08pm	Rob Orr	Out 1:25pm
M. Futakawa	In 12:08pm	Maria Pimentel	Out 5:54pm
Y. Ishiguro	Out 10:52am	Daniel Salber	In 10:14am
Rob Kooper	Out 5:26pm	Brad Singletary	Out 2:59pm
Kent Lyons	Out 12:27pm	Khai Truong	Out 1:25pm

Applications

- Serendipitous Capture – evolving application


Ink written before current time is in original color
Ink written after current time is displayed in gray
Playback controls
Current time within session
Selected session
Selected day
Day containing whiteboard activity
Filters

Ap



Time	Event	Time	Event	Time	Event
9:00	A Daniel Salber-Context Toolkit	9:00	Bill Ribarsky-VR Workbench	9:00	Don Allison-VR Gorilla
9:15		9:15		9:15	
9:30		9:30		9:30	
9:45		9:45		9:45	
10:00	Chris Atkeson-Machine Learning	10:00	A Maria Pimentel-C2000	10:00	Ashwin Ram-Pepe
10:15		10:15		10:15	
10:30		10:30		10:30	
10:45		10:45		10:45	
11:00	Jessica Hodgins-Human Motion	11:00	Ashwin Ram-Personal Pet	11:00	A Anind Dey-Ubicomp Apps

Personal Events: arrival / departure / question Person: Joe Smith Keyword: context

What Is Context?
- The missing piece
- Information sensed
- Identity, Location, Activity of People, Places, Things
- Who? Where? When? What? Why?

Slide text: Identity, Location, Activity of People, Places, Things

User Memo: context widgets

Lessons Learned

- Lesson 1—Prioritize core infrastructure features.
- Lesson 2—First, build prototypes that express the core objectives of the infrastructure.
- Lesson 3—Any test-application built to demonstrate the infrastructure must also satisfy the usual criteria of usability and usefulness.
- Lesson 4—Initial proof-of-concept applications should be lightweight.

Lessons Learned (cont'd)

- Lesson 5—Be clear about that your test-application prototypes will tell you about your infrastructure.
- Lesson 6—Do not confuse the design and testing of experimental infrastructure with the provision of an infrastructure for experimental application developers.
- Lesson 7—Be sure to define a limited scope for testapplications and permissible uses of the infrastructure.
- Lesson 8—There is no point in faking components and data if you want to test for user experience benefits.

Homework/Exam Option 1

Read the following article:

Eelke Folmer, Jilles van Gurp, Jan Bosch (2004) Architecture-Level Usability Assessment. *Proceedings of EHCI*, Hamburg.

Write a 1-page (500 words) comparison of the assessment technique described in this paper with the SEI Usability and Software Architecture techique described today.

Homework/Exam Option 2

If you have ever been involved in the development of a middleware solution or toolkit, provide a half-page (250 words) description of the middleware/toolkit and then a half-page (250 words) reflection on which of the "lessons learned" applied to your development team experience with the effectiveness or ineffectiveness of your middleware/toolkit. Finally, provide one example of a usability feature that would be difficult to implement with your middleware/toolkit.

Software Architecture Analysis of Usability

Eelke Folmer, Jilles van Gurp, Jan Bosch

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Studies of software engineering projects [1,2] show that a large number of usability related change requests are made after its deployment. Fixing usability problems during the later stages of development often proves to be costly, since many of the necessary changes require changes to the system that cannot be easily accommodated by its software architecture. These high costs prevent developers from meeting all the usability requirements, resulting in systems with less than optimal usability. The successful development of a usable software system therefore must include creating a software architecture that supports the right level of usability. Unfortunately, no architecture-level usability assessment techniques exist. To support software architects in creating a software architecture that supports usability, we present a scenario based assessment technique that has been successfully applied in several cases. Explicit evaluation of usability during architectural design may reduce the risk of building a system that fails to meet its usability requirements and may prevent high costs incurring adaptive maintenance activities once the system has been implemented.

1 Introduction

One of the key problems with many of today's software is that they do not meet their quality requirements very well. In addition, it often proves hard to make the necessary changes to a system to improve its quality. A reason for this is that many of the necessary changes require changes to the system that cannot be easily accommodated by the software architecture [3] The software architecture, the fundamental organization of a system embodied in its components, their relationships to each other and to the environment and the principles guiding its design and evolution [4] does not support the required level of quality.

The work in this paper is motivated by the fact that this also applies to usability. Usability is increasingly recognized as an important consideration during software development; however, many well-known software products suffer from usability issues that cannot be repaired without major changes to the software architecture of these products. This is a problem for software development because it is very expensive to ensure a particular level of usability after the system has been implemented. Studies [1,2] confirm that a significant large part of the maintenance costs of software systems is spent on dealing with usability issues. These high costs can be explained because some usability requirements will not be discovered until the software has been implemented or deployed. This is caused by the following:

- Usability requirements are often weakly specified.
- Usability requirements engineering techniques have only a limited ability to capture all requirements.
- Usability requirements may change during development.

Discovering requirements late is a problem inherent to all software development and is something that cannot be easily solved. The real problem is that it often proves to be hard and expensive to make the necessary changes to a system to improve its usability. Reasons for why this is so hard:

- Usability is often only associated with interface design but usability does also depend on issues such as the information architecture, the interaction architecture and other quality attributes (such as efficiency and reliability) that are all determined by the software architecture. Usability should therefore also be realized at the architectural level.
- Many of the necessary usability changes to a system cannot be easily be accommodated by the software architecture. Some changes that may improve usability require a substantial degree of modification. For example changes that relate to the interactions that take place between the system and the user, such as undo to a particular function or system wide changes such as imposing a consistent look and feel in the interface.

The cost of restructuring the system during the later stages of development has proven to be an one order of magnitude higher than the costs of an initial development [3]. The high costs spent on usability during maintenance can to an extent be explained by the high costs for fixing architecture-related usability issues. Because during design different tradeoffs have to be made, for example between cost and quality, these high costs may prevent developers from meeting all the usability requirements. The challenge is therefore to cost effectively usable software e.g. minimizing the costs & time that are spent on usability.

Based upon successful experiences [5] with architectural assessment of maintainability as a tool for cost effective developing maintainable software, we developed architectural analysis of usability as an important tool to cost effectively development usable software i.e. if any problems are detected at this stage, it is still possible to change the software architecture with relative cheap costs. Software architecture analysis contributes to making sure the software architecture supports usability. Software architecture analysis does not solve the problem of discovering usability requirements late. However, it contributes to an increased awareness of the limitations the software architecture may place on the level of usability that can be achieved. Explicit evaluation of software architectures regarding usability is a technique to come up with a more usable first version of a software architecture that might allow for more "usability tuning" on the detailed design level, hence, preventing some of the high costs incurring adaptive maintenance activities once the system has been implemented.

In [6] an overview is provided of usability evaluation techniques that can be used during the different stages of development, unfortunately, no usability assessment techniques exists that explicitly focus on the assessment of the software architecture. The contribution of this paper is an assessment technique that assists software architects in designing a software architecture that supports usability called SALUTA (Scenario based Architecture Level UsabiliTy Analysis).

The remainder of this paper is organized as follows. In the next section, the relationship between software architecture and usability is discussed. Section 3 discusses various approaches to software architecture analysis. Section 4 presents an overview of the main steps of SALUTA. Section 5 presents some examples from a case study for performing usability analysis in practice and discusses the validation of the method. Finally the paper is concluded in section 6.

2 Relationship between Usability and Software Architecture

A software architecture description such as a decomposition of the system into components and relations with its environment may provide information on the support for particular quality attributes. Specific relationships between software architecture (such as - styles, -patterns etc) and quality attributes (maintainability, efficiency) have been described by several authors. [7,8,3]. For example [7] describes the architectural pattern layers and the positive effect this pattern may have on exchangeability and the negative effect it may have on efficiency.

Until recently [9,10] such relationships between usability and software architecture had not been described nor investigated. In [10] we defined a framework that expresses the relationship between usability and software architecture based on our comprehensive survey [6]. This framework is composed of an integrated set of design solutions such as usability patterns and usability properties that have a positive effect on usability but are difficult to retrofit into applications because they have architectural impact. The framework consists of the following concepts:

2.1 Usability attributes

A number of usability attributes have been selected from literature that appear to form the most common denominator of existing notions of usability:

– Learnability - how quickly and easily users can begin to do productive work with a system that is new to them, combined with the ease of remembering the way a system must be operated.
– Efficiency of use - the number of tasks per unit time that the user can perform using the system.
– Reliability in use the error rate in using the system and the time it takes to recover from errors.
– Satisfaction - the subjective opinions of the users of the system.

2.2 Usability properties

A number of usability properties have been selected from literature that embody the heuristics and design principles that researchers in the usability field consider to have a direct positive influence on usability. They should be considered as high-level design primitives that have a known effect on usability and most likely have architectural implications. Some examples:

- Providing Feedback - The system should provide at every (appropriate) moment feedback to the user in which case he or she is informed of what is going on, that is, what the system is doing at every moment.
- Consistency - Users should not have to wonder whether different words, situations, or actions mean the same thing. Consistency has several aspects:
  - Visual consistency: user interface elements should be consistent in aspect and structure.
  - Functional consistency: the way to perform different tasks across the system should be consistent.
  - Evolutionary consistency: in the case of a software product family, consistency over the products in the family is an important aspect.

2.3 Architecture sensitive usability patterns

A number of usability patterns have been identified that should be applied during the design of a system's software architecture, rather than during the detailed design stage. This set of patterns has been identified from various cases in industry, modern software, literature surveys as well as from existing (usability) pattern collections. Some examples:

- Actions on multiple objects - Actions need to be performed on objects, and users are likely to want to perform these actions on two or more objects at one time [11].
- Multiple views - The same data and commands must be potentially presented using different human-computer interface styles for different user preferences, needs or disabilities [12].
- User profiles - The application will be used by users with differing abilities, cultures, and tastes [11].

Unlike the design patterns, architecturally sensitive patterns do not specify a specific design solution in terms of objects and classes. Instead, potential architectural implications that face developers looking to solve the problem the architecturally sensitive pattern represents are outlined. For example, to facilitate actions on multiple objects, a provision needs to be made in the architecture for objects to be grouped into composites, or for it to be possible to iterate over a set of objects performing the same action for each. Actions for multiple objects may be implemented by the composite pattern [8] or the visitor pattern [8].

(Positive) relationships have been defined between the elements of the framework that link architectural sensitive usability patterns to usability properties and attributes. These relationships have been derived from our literature survey. The usability properties in the framework may be used as requirements during design. For example, if a requirements species, "the system must provide feedback", we use the framework to identify which usability patterns may be implemented to fulfill these properties by following the arrows in Figure 1. Our assessment technique uses this framework to analyze the architecture's support for usability.

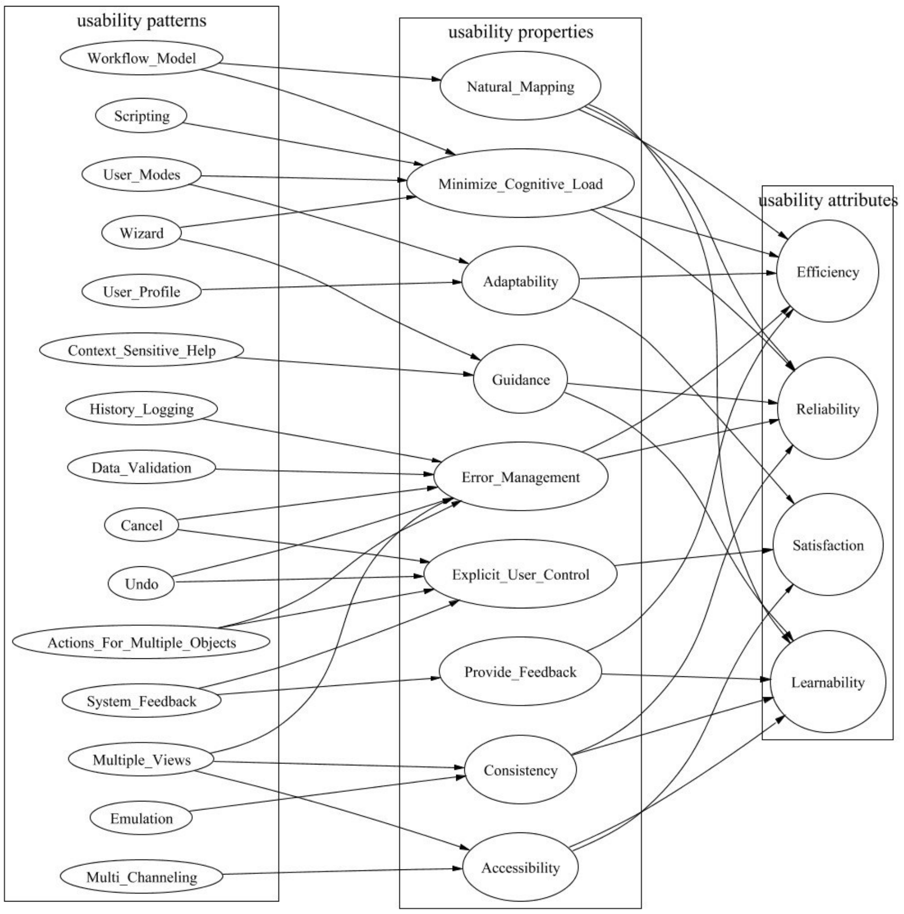


Fig. 1. Usability Framework

3 Software architecture assessment

The design and use of an explicitly defined software architecture has received increasing amounts of attention during the last decade. Generally, three arguments for defining an architecture are used [13]. First, it provides an artifact that allows discussion by the stakeholders very early in the design process. Second, it allows for early assessment of quality attributes [14,3]. Finally, the design decisions captured in the software architecture can be transferred to other systems.
Our work focuses on the second aspect: early assessment of usability. Most engineering disciplines provide techniques and methods that allow one to assess and test quality attributes of the system under design. For example for maintainability

assessment code metrics [15] have been developed. In [6] an overview is provided of usability evaluation techniques that can be used during software development. Some of the more popular techniques such as user testing [16], heuristic evaluation [17] and cognitive walkthroughs [18] can be used during several stages of development. Unfortunately, no usability assessment techniques exist that focus on assessment of software architectures. Without such techniques, architects may run the risk of designing a software architecture that fails to meet its usability requirements. To address to this problem we have defined a scenario based assessment technique (SALUTA).

The Software Architecture Analysis Method (SAAM) [19] was among the first to address the assessment of software architectures using scenarios. SAAM is stakeholder centric and does not focus on a specific quality attribute. From SAAM, ATAM [14] has evolved. ATAM also uses scenarios for identifying important quality attribute requirements for the system. Like SAAM, ATAM does not focus on a single quality attribute but rather on identifying tradeoffs between quality attributes. SALUTA can be integrated into these existing techniques.

3.1 Usability specification

Before a software architecture can be assessed for its support of usability, the required usability of the system needs to be determined. Several specification styles of usability have been identified [20]. One shortcoming of these techniques [17,21,22] is that they are poorly suited for architectural assessment.

- Usability requirements are often rather weakly specified: practitioners have great difficulties specifying usability requirements and often end up stating: “the system shall be usable” [20].
- Many usability requirements are performance based specified [20]. For example, such techniques might result in statements such as “customers must be able to withdraw cash within 4 minutes” or “80% of the customers must find the system pleasant”.

Given an implemented system, such statements may be verified by observing how users interact with the system. However, during architecture assessment such a system is not yet available. Interface prototypes may be analyzed for such requirements however we want to analyze the architecture for such requirements.

A technique that is used for specifying the required quality requirements and the assessment of software architectures for these requirements are scenario profiles [5]. Scenario profiles describe the semantics of software quality attributes by means of a set of scenarios. The primary advantage of using scenarios is that scenarios represent the actual meaning of a requirement. Consequently, scenarios are much more specific and fine-grained than abstract usability requirements. The software architecture may then be evaluated for its support for the scenarios in the scenario profile. Scenario profiles and traditional usability specification techniques are not interfering; scenarios are just a more concrete instance of these usability requirements.

3.2 Usage profiles

A usage profile represents the required usability of the system by means of a set of usage scenarios. Usability is not an intrinsic quality of the system. According to the ISO definition [23], usability depends on:

- The users - who is using the product? (system administrators, novice users)
- The tasks - what are the users trying to do with the product? (insert order, search for item X)
- The context of use - where and how is the product used? (helpdesk, training environment)

Usability may also depend on other variables, such as goals of use, etc. However in a usage scenario only the variables stated above are included. A usage scenario is defined as "an interaction (task) between users, the system in a specific context of use". A usage scenario specified in such a way does not yet specify anything about the required usability of the system. In order to do that, the usage scenario is related to the four usability attributes defined in our framework. For each usage scenario, numeric values are determined for each of these usability attributes. The numeric values are used to determine a prioritization between the usability attributes.

For some usability attributes, such as efficiency and learnability, tradeoffs have to be made. It is often impossible to design a system that has high scores on all attributes. A purpose of usability requirements is therefore to specify a necessary level for each attribute [20]. For example, if for a particular usage scenario learnability is considered to be of more importance than other usability attributes (maybe because of a requirement), then the usage scenario must reflect this difference in the priorities for the usability attributes. The analyst interprets the priority values during the analysis phase (section 4.3) to determine the level of support in the software architecture for the usage scenario.

4 SALUTA

In this section we present SALUTA (Scenario based Architecture Level UsabiliTy Analysis. SALUTA consists of the following four steps:

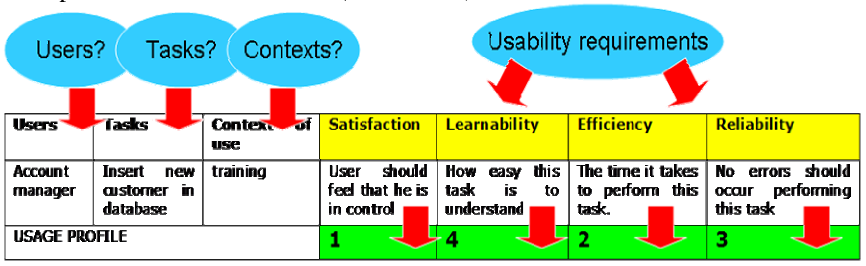
1. Create usage profile.
2. Describe provided usability.
3. Evaluate scenarios.
4. Interpret the results.

When performing an analysis the separation between these steps is not very strict and it is often necessary to iterate over various steps. In the next subsections, however the steps are presented as if they are performed in strict sequence.

4.1 Create usage profile

The steps that need to be taken for usage profile creation are the following:

1. Identify the users: rather than listing individual users, users that are representative for the use of the system should be categorized in types or groups (for example system administrators, end-users etc).
2. Identify the tasks: Instead of converting the complete functionality of the system into tasks, representative tasks are selected that highlight the important features of the system. For example, a task may be “find out where course computer vision is given”.
3. Identify the contexts of use: In this step, representative contexts of use are identified. (For example. Helpdesk context or disability context.) Deciding what users, tasks and contexts of use to include requires making tradeoffs between all sorts of factors. An important consideration is that the more scenarios are evaluated the more accurate the outcome of the assessment is, but the more expensive and time consuming it is to determine attribute values for these scenarios.
4. Determine attribute values: For each valid combination of user, task and context of use, usability attributes are quantified to express the required usability of the system, based on the usability requirements specification. Defining specific indicators for attributes may assist the analyst in interpreting usability requirements as will be illustrated in the case study in section 5. To reflect the difference in priority, numeric values between one and four have been assigned to the attributes for each scenario. Other techniques such as pair wise comparison may also be used to determine a prioritization between attributes.
5. Scenario selection & weighing: Evaluating all identified scenarios may be a costly and time-consuming process. Therefore, the goal of performing an assessment is not to evaluate all scenarios but only a representative subset. Different profiles may be defined depending on the goal of the analysis. For example, if the goal is to compare two different architectures, scenarios may be selected that highlight the differences between those architectures. If the goal is to predict the level of usability for an architecture, scenarios may be selected that are important to the users. To express differences between usage scenarios in the usage profile, properties may be assigned to scenarios, for example: priority or probability of use within a certain time. The result of the assessment may be influenced by weighing scenarios, if some scenarios are more important than others, weighing these scenarios reflect these differences. The usage profile that is created using these steps is summarized in a table (See Table 2).



Users	Tasks	Context of use	Satisfaction	Learnability	Efficiency	Reliability
Account manager	Insert new customer in database	training	User should feel that he is in control	How easy this task is to understand	The time it takes to perform this task.	No errors should occur performing this task
USAGE PROFILE			1	4	2	3

Fig. 2. Example usage profile

This step results in a set of usage scenarios that accurately express the required usability of the system. Usage profile creation is not intended to replace existing requirements engineering techniques. Rather it is intended to transform (existing) usability requirements into something that can be used for architecture assessment. Existing techniques such as such as interviews, group discussions or observations [17,22,24] typically already provide information such as representative tasks, users and contexts of use that are needed to create a usage profile. Close cooperation between the analyst and the person responsible for the usability requirements (such as a usability engineer) is required. The usability engineer may fill in the missing information on the usability requirements, because usability requirements are often not explicitly defined.

4.2 Describe provided usability

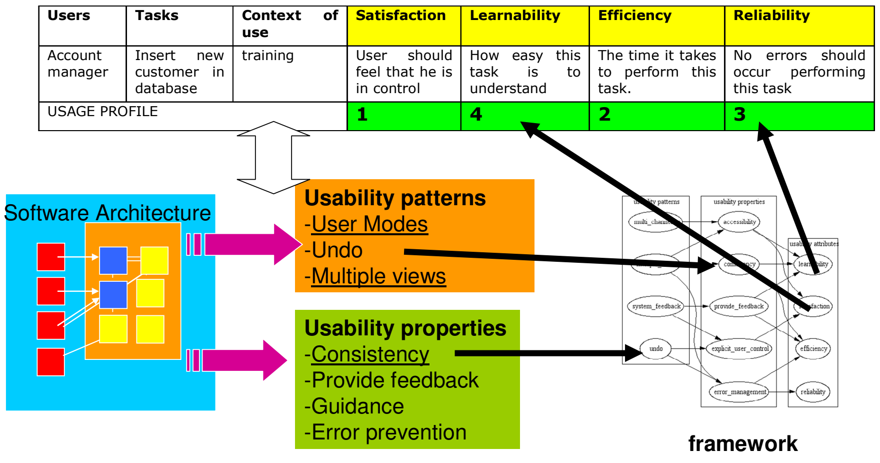
In the second step of SALUTA, the information about the software architecture is collected. Usability analysis requires architectural information that allows the analyst to determine the support for the usage scenarios. The process of identifying the support is similar to scenario impact analysis for maintainability assessment [5] but is different, because it focuses on identifying architectural elements that may support the scenario. Two types of analysis techniques are defined:

- Usability pattern based analysis: using the list of architectural sensitive usability patterns defined in our framework the architecture's support for usability is determined by the presence of these patterns in the architecture design.
- Usability property based analysis: The software architecture can be seen as the result of a series of design decisions [25]. Reconstructing this process and assessing the effect of such individual decisions with regard to usability attributes may provide additional information about the intended quality of the system. Using the list of usability properties defined in our framework, the architecture and the design decisions that lead to this architecture are analyzed for these properties.

The quality of the assessment very much depends on the amount of evidence for patterns and property support that is extracted from the architecture. Some usability properties such as error management may be implemented using architectural patterns such as undo, cancel or data validation. However, in addition to patterns there may be additional evidence in the form of other design decisions that were motivated by usability properties. The software architecture of a system has several aspects (such as design decisions and their rationale) that cannot easily be captured or expressed in a single model. Different views on the system [26] may be needed access such information. Initially the analysis is based on the information that is available, such as diagrams etc. However due to the non explicit nature of architecture design the analysis strongly depends on having access to both design documentation and software architects. The architect may fill in the missing information on the architecture. SALUTA does not address the problem of properly documenting software architectures and design decisions. The more effort is put into documenting the software architecture the more accurate the assessment is.

4.3 Evaluate scenarios

SALUTA’s next step is to evaluate the support for each of the scenarios in the usage profile. For each scenario, it is analyzed by which usability patterns and properties, that have been identified in the previous step, it is affected. A technique we have used for identifying the provided usability in our cases is the usability framework approach. The relations defined in the framework are used to analyze how a particular pattern or property affects a specific usability attribute. For example if it has been identified that undo affects a certain scenario. Then the relationships of the undo pattern with usability are analyzed (see Figure 1) to determine the support for that particular scenario. Undo in this case may increase reliability and efficiency. This step is repeated for each pattern or property that affects the scenario. The analyst then determines the support of the usage scenario based on the acquired information. See Figure 2 for a snapshot assessment example.



Users	**Tasks**	**Context of use**	**Satisfaction**	**Learnability**	**Efficiency**	**Reliability**
Account manager	Insert new customer in database	training	User should feel that he is in control	How easy this task is to understand	The time it takes to perform this task.	No errors should occur performing this task
USAGE PROFILE			**1**	**4**	**2**	**3**

Fig. 3. Snapshot evaluation example

For each scenario, the results of the support analysis are expressed qualitatively using quantitative measures. For example the support may be expressed on a five level scale (++, +, +/-,-,--). The outcome of the overall analysis may be a simple binary answer (supported/unsupported) or a more elaborate answer (70% supported) depending on how much information is available and how much effort is being put in creating the usage profile.

4.4 Interpret the results

Finally, after scenario evaluation, the results need to be interpreted to draw conclusions concerning the software architecture. This interpretation depends on two factors: the goal of the analysis and the usability requirements. Based on the goal of the analysis, a certain usage profile is selected. If the goal of the analysis is to compare two or more candidate software architectures, the support for a particular usage scenario must be expressed on an ordinal scale to indicate a relation between the different candidates. (Which one has the better support?). If the analysis is sufficiently accurate the results may be quantified, however even without quantification the assessment can produce useful results. If the goal is to iteratively design an architecture, then if the architecture proves to have sufficient support for usability, the design process may be ended. Otherwise, architectural transformations need to be applied to improve usability. Qualitative information such as which scenarios are poorly supported and which usability properties or patterns have not been considered may guide the architect in applying particular transformations. The framework may then be used as an informative source for design and improvement of the architecture's support of usability.

5 Validation

In order to validate SALUTA it has been applied in three case studies:

- eSuite. A web based enterprise resource planning (ERP) system.
- Compressor. A web based e-commerce system.
- Webplatform. A web based content management system (CMS)

The goal of the case studies was twofold: first to conduct a software architecture analysis of usability on each of the three systems and to collect experiences. Our technique had initially only been applied at one case study and we needed more experiences to further refine our technique and make it generally applicable. Second, our goal was to gain a better understanding of the relationship between usability and software architecture. Our analysis technique depends on the framework we developed in [9]. Analyzing architectural designs in the case studies allowed us to further refine and validate the framework we developed. As a research method we used action research [27], we took upon our self the role of external analysts and actively participated in the analysis process and reflected on the process and the results.

These cases studies show that it is possible to use SALUTA to assess software architectures for their support of usability. Whether we have accurately predicted the architecture's support for usability is answered by comparing our analysis with the results of user tests that are conducted when the systems are implemented. These results are used to verify whether the usage profile we created actually matches the actual usage of the system and whether the results of the assessment fits results from the user tests For all three cases, the usage profile and architecture assessment phase is completed. In the case of the Webplatform, a user test has been performed recently. In this article, we limit ourselves to highlighting some examples from the Webplatform case study.

ECCOO develops software and services for one of the largest universities of the Netherlands (RuG). ECCOO has developed the Webplatform. Faculties, departments and organizations within the RuG are already present on the inter/intra/extra –net but because of the current wild growth of sites, concerning content, layout and design, the usability of the old system was quite poor. For the Webplatform usability was considered as an important design objective. Webplatform has successfully been deployed recently and the current version of the RuG website is powered by the Webplatform. As an input to the analysis of the Webplatform, we interviewed the software architect and usability engineer, examined the design documentation, and looked at the newly deployed RuG site. In the next few subsections, we will present the four SALUTA steps for the Webplatform.

5.1 Usage profile creation

In this step of the SALUTA, we have cooperated with the usability engineer to create the usage profile.

- Three types of users are defined in the functional requirements: end users, content administrators and CMS administrators.
- Several different tasks are specified in the functional requirements. An accurate description of what is understood for a particular task is an essential part of this step. For example, several tasks such as "create new portal medical sciences" or "create new course description" have been understood for the task "make object", because the Webplatform data structure is object based.
- No relevant contexts of use were identified for Webplatform. Issues such as bandwidth or helpdesk only affect a very small part of the user population.

The result of the first three steps is summarized in Table 1.

Table 1. Summary of selected users, tasks for Webplatform

#	Users	Tasks	example
1	End-user	Quick search	Find course X
2	End-user	Navigate	Find employee X
3	Content Administrator	Edit object	Edit course description
4	Content Administrator	Make object	Create new course description
5	Content Administrator	Quick search	Find course X
6	Content Administrator	Navigate	Find phone number for person X
7	CMS Administrator	Edit object	Change layout of portal X
8	CMS Administrator	Make object	Create new portal medical sciences
9	CMS Administrator	Delete object	Delete teacher X
10	CMS Administrator	Quick search	Find all employees of section X
11	CMS Administrator	Navigate	Find section library

The next step is to determine attribute values for the scenarios. This has been done by consulting the usability requirements and by discussing these for each scenario with the usability engineer. In the functional requirements of the Webplatform only 30 guidelines based on Nielsen's heuristics [17] have been specified. Fortunately, the usability engineer in our case had a good understanding of the expected required usability of the system. As an example we explain how we determined attribute values for the usage scenario: "end user performing quick search".

First, we formally specified with the usability engineer what should be understood for each attribute of this task. We have associated reliability with the accuracy of search results; efficiency has been associated with response time of the quick search. Then the usability requirements were consulted. A usability requirement that affects this scenario states: “every page should feature a quick search which searches the whole portal and comes up with accurate search results”. In the requirements, it has not been specified that quick search should be performed quickly. However, in our discussions with the usability engineer we found that this is the most important aspect of usability for this task. Consequently, high values have been given to efficiency and reliability and low values to the other attributes. For each scenario, numeric values between one and four have been assigned to the usability attributes to express the difference in priority. Table 2 states the result of the quantification of the selected scenarios for Webplatform.

#	Users	Tasks	S	L	E	R
1	End-user	Quick search	2	1	4	3
2	End-user	Navigate	1	4	2	3
3	Content Administrator	Edit object	1	4	2	3
4	Content Administrator	Make object	1	4	2	3
5	Content Administrator	Quick search	2	1	4	3
6	Content Administrator	Navigate	1	4	2	4
7	CMS Administrator	Edit object	2	1	4	3
8	CMS Administrator	Make object	2	1	4	3
9	CMS Administrator	Delete object	2	1	4	3
10	CMS Administrator	Quick search	2	1	4	3
11	CMS Administrator	Navigate	1	2	3	4

Table 2. Attribute priority table for Webplatform

5.2 Architecture description

For scenario evaluation, a list of usability patterns and a list of usability properties that have been implemented in the system are required to determine the architecture’s support for usability. This information has been acquired, by analyzing the software architecture (see Figure 3), consulting the functional design documentation (some specific design decisions for usability had been documented) and interviewing the software architect using the list of patterns and properties defined in our framework.

One of the reasons to develop Webplatform was that the usability of the old system was quite poor; this was mainly caused by the fact that each “entity” within the RuG (Faculties, libraries, departments) used their own layout and their own way to present information and functionality to its users which turned out to be very confusing to users.

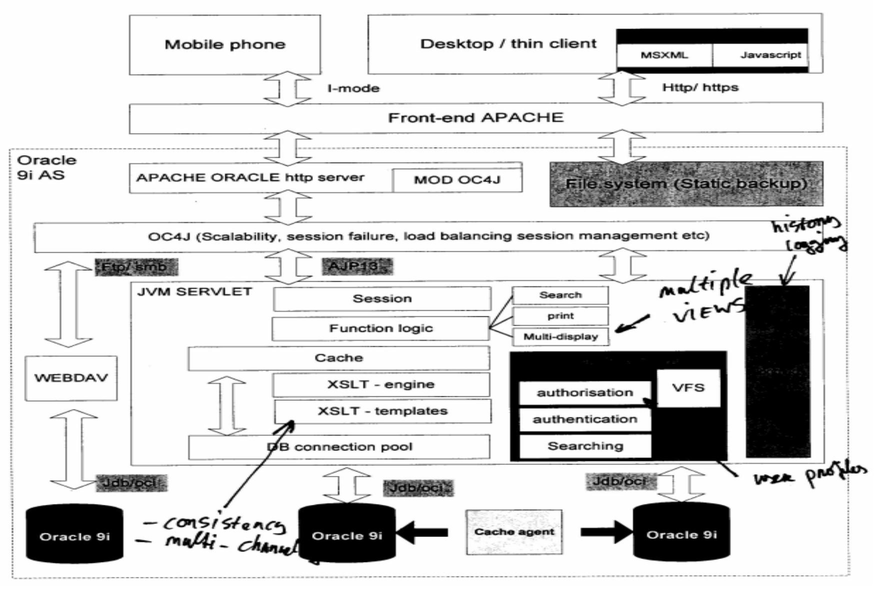
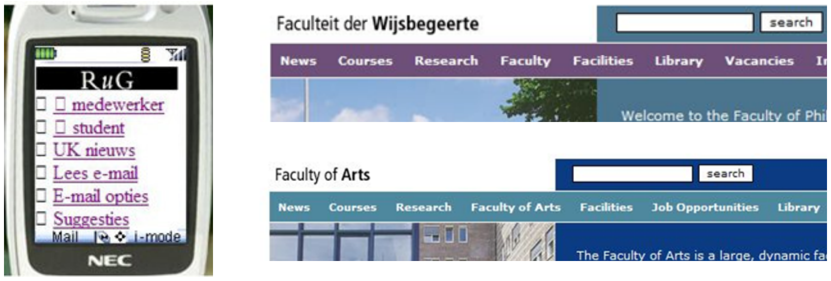


Fig. 4. Webplatform software architecture

A specific design decision that was taken which facilitates several patterns and properties in our framework was to use the internet file system (IFS):

- Multiple views [10]]: The IFS provides an interface that realizes the use of objects and relations as defined in XML. Using XML and XSLT templates the system can provide multiple views for different users and uses on the server side. CSS style sheets are used to provide different views on the client site, for example for providing a "print" layout view but also to allow each faculty their own "skin" as depicted in Figure 3.
- Consistency [10]: The use of XML/ XSLT is a means to enforce a strict separation of presentation from data. This design decision makes it easier to provide a consistent presentation of interface and function for all different objects of the same type such as portals. See for example Figure 6 where the menu layout, the menu items and the position of the quick search box is the same for the faculty of arts and the faculty of Philosophy.
- Multichanneling [8]: By providing different views & control mappings for different devices multichanneling is provided. The Webplatform can be accessed from an I-mode phone as well as from a desktop computer.

Next to the patterns and properties that are facilitated by the IFS several other patterns and properties were identified in the architecture. Sometimes even multiple instances of the same property (such as system feedback) have been identified. Some properties such as consistency have multiple aspects (visual/functional consistency). We need to analyze the architecture for its support of each element of such a property A result of such a detailed analysis for the property accessibility and the pattern history logging is displayed in Table 3.


RuG
medewerker
student
UK nieuws
Lees e-mail
E-mail opties
Suggesties
Mail i-mode
NEC
Faculteit der Wijsbegeerte
search
News Courses Research Faculty Facilities Library Vacancies
Welcome to the Faculty of Phi
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search
News Courses Research Faculty of Arts Facilities Job Opportunities Library
The Faculty of Arts is a large, dynamic fa

Fig. 5. Provide multiple views/ & Visual/Functional Consistency.

Table 3.

[pattern]- History Logging	- There is a component that logs every user action. It can be further augmented to also monitor system events (i.e. "the user failed to login 3 consecutive times"). History logging is especially helpful for speeding up the object manipulation process. - Cookies are used to prevent users from having to login again when a connection is lost. Cookies also serve as a backup mechanism on the client site. (To retrieve lost data).
[property] - Accessibility	
• Disabilities	×
• Multi channel	Multi channeling is provided by the web server which can provide a front end to I-Mode or other devices based on specified XLST templates.
• Internationalization	- Support for Dutch / English language, each xml object has different language attribute fields. - Java support Unicode

5.3. Evaluate scenarios

The next step is to evaluate the architecture's support for the usage scenarios in the usage profile. As an example, we analyze usage scenario #4 "content administrator makes object" from table 2. For this scenario it has been determined by which patterns and properties, that have been identified in the architecture it is affected. It is important to identify whether a scenario is affected by a pattern or property that has been implemented in the architecture because this is not always the case. The result of such an analysis is shown in a support matrix in Table 3 for two scenarios. A checkmark indicates that the scenario is affected by at least one or more patterns or properties. Some properties such as consistency have multiple aspects (visual/functional consistency). For a thorough evaluation we need to analyze each scenario for each element of such a property. The support matrix is used together with the relations in the framework to find out whether a usage profile is sufficiently supported by the architecture. The usage profile that we created shows that scenario #4 has high values for learnability (4) and reliability (3). Several patterns and properties positively contribute to the support of this scenario. For example, the property consistency and the pattern context sensitive help increases learnability as can be analyzed from Figure 1. By analyzing for each pattern and property, the effect on usability, the support for this scenario is determined. Due to the lack of formalized knowledge at the architecture level, this step is very much guided by tacit knowledge (i.e. the undocumented knowledge of experienced software architects and usability engineers). For usage scenario #4, we have concluded that the architecture provides weak support. Learnability is very important for this scenario and patterns such as a wizard or workflow modeling or different user modes to support novice users could increase the learnability of this scenario.

Table 4. Architecture support matrix

Scenario number	**Usability patterns**															**Usability properties**								
	System Feedback	Actions for multiple obj.	Cancel	Data validation	History Logging	Scripting	Multiple views	Multi Channeling	Undo	User Modes	User Profiles	Wizard	Workflow model	Emulation	Context sensitive help	Provide feedback	Error management	Consistency	Adaptability	Guidance	Explicit user control	Natural mapping	Accessibility	Minimize cognitive load
1	✓	×	×	×	×	×	×	✓	×	×	×	×	✓	×	✓	✓	✓	✓	×	✓	×	✓	✓	×
4	✓	×	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×	✓	✓	✓	✓	×	✓	✓	✓	✓	×

5.4. Interpret the results

The result of the assessment of the Webplatform is that three scenarios are accepted, six are weakly accepted and that two scenarios are weakly rejected. The main cause for this is that we could not identify sufficient support for learnability for content administrators as was required by the usage profile. There is room for improvement; usability could be improved if provisions were made to facilitate patterns and properties that have not been considered. The usability requirement of consistency was one of the driving forces of design and our analysis shows that it has positive influence on the usability of the system. Apart from some general usability guidelines [17] stated in the functional requirements no clearly defined and verifiable usability requirements have been specified. Our conclusion concerning the assessment of the Webplatform is that the architecture provides sufficient support for the usage profile that we created. This does not necessarily guarantee that the final system will be usable since many other factors play a role in ensuring a system's usability. Our analysis shows however that these usability issues may be repaired without major changes to the software architecture thus preventing high costs incurring adaptive maintenance activities once the system has been implemented.

5.5. Validation

Whether the usage profile we created is fully representative for the required usability is open to dispute. However, the results from the user test that has recently been completed by the ECCOO is consistent with our findings. 65 test users (students, employees and graduate students) have tested 13 different portals. In the usability tests, the users had to perform specific tasks while being observed. The specific tasks that had to be performed are mostly related to the tasks navigation and quick search in our usage profile. After performing the tasks, users were interviewed about the relevance of the tasks they had to perform and the usability issues that were discovered. The main conclusions of the tests are:

- Most of the usability issues that were detected were related to navigation, structure and content. For example, users have difficulties finding particular information. Lack of hierarchy and structure is the main cause for this problem Although the architecture supports visual and functional consistency, organizations themselves are responsible for structuring their information.
- Searching does not generate accurate search results. This may be fixed by technical modifications. E.g. tuning the search function to generate more accurate search results. (This is also caused by that a lot of meta-information on the content in the system has not been provided yet).

The results of this usability tests fit the results of our analysis: the software architecture supports the right level of usability. Some usability issues came up that where not predicted during our architectural assessment. However, these do not appear to be caused by problems in the software architecture. Future usability tests will focus on analyzing the usability of the scenarios that involve content administrators. Preliminary results from these tests show that the system has a weak support for learnability as predicted from the architectural analysis.

7. Conclusions

In this paper, we have presented SALUTA, a scenario based assessment technique that assists software architects in designing a software architecture that supports usability. SALUTA consists of four major steps: First, the required usability of the system is expressed by means of a usage profile. The usage profile consists of a representative set of usage scenarios that express the required usability of the system. The following sub-steps are taken for creating a usage profile: identify the users, identify the tasks, identify the contexts of use, determine attribute values, scenario selection & weighing. In the second step, the information about the software architecture is collected using a framework that has been developed in earlier work. This framework consists of an integrated set of design solutions such as usability patterns and usability properties that have a positive effect on usability but are difficult to retrofit into applications because they have architectural impact. This framework is used to analyze the architecture for its support of usability. The next step is to evaluate the architecture's support of usage profile using the information extracted in the previous step. To do so, we perform support analysis for each of the scenarios in the set. The final step is then to interpret these results and to draw conclusions about the software architecture. The result of the assessment for example, which scenarios are poorly supported or which usability properties or patterns have not been considered, may guide the architect in applying particular transformations to improve the architecture's support of usability. We have elaborated the various steps in this paper, discussed the issues and techniques for each of the steps, and illustrated these by discussing some examples from a case study. The main contributions of this paper are:

- SALUTA is the first and currently the only technique that enables software architects to assess the level of usability supported by their architectures.
- Because usability requirements tend to change over time and may be discovered during deployment, SALUTA may assist a software architect to come up with a more usable first version of a software architecture that might allow for more "usability tuning" on the detailed design level. This prevents some of the high costs incurring adaptive maintenance activities once the system has been implemented.

Future work shall focus on finalizing the case studies, refining the usability framework and validating our claims we make. Preliminary experiences with these three case studies shows the results from the assessment seem reasonable and do not conflict with the user tests. In the future, we will not only focus on assessing with SALUTA but also on using the framework for iteratively designing software architectures with SALUTA.

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References

[1] R. S. Pressman, *Software Engineering: A Practitioner's Approach*, McGraw-Hill, NY, 1992.

[2] T. K. Landauer, *The Trouble with Computers: Usefulness, Usability and Productivity.*, MIT Press., Cambridge, 1995.

[3] J. Bosch, *Design and use of Software Architectures: Adopting and evolving a product line approach*, Pearson Education (Addison-Wesley and ACM Press), Harlow, 2000.

[4] IEEE, IEEE Architecture Working Group. Recommended practice for architectural description. Draft IEEE Standard P1471/D4.1, IEEE, 1998.

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[5] N. Lassing, P. O. Bengtsson, H. van Vliet, and J. Bosch, *Experiences with ALMA: Architecture-Level Modifiability Analysis*, Journal of systems and software, Elsevier, 2002, pp. 47-57.

[6] E. Folmer and J. Bosch, *Architecting for usability; a survey*, Journal of systems and software, Elsevier, 2002, pp. 61-78.

[7] F. Buschmann, R. Meunier, H. Rohnert, P. Sommerlad, and M. Stal, *Pattern-Oriented Software Architecture: A System of Patterns*, John Wiley and Son Ltd, New York, 1996.

[8] E. Gamma, R. Helm, R. Johnson, and J. Vlissides, *Design patterns elements of reusable object-orientated software.*, Addison -Wesley, 1995.

[9] L. Bass, J. Kates, and B. E. John, Achieving Usability through software architecture, 1-3-2001.

[10] E. Folmer, J. v. Gurp, and J. Bosch, *Investigating the Relationship between Usability and Software Architecture* , Software process improvement and practice, Wiley, 2003, pp. 0-0.

[11] J. Tidwell, Interaction Design Patterns, *Conference on Pattern Languages of Programming 1998*, 1998.

[12] Brighton, *The Brighton Usability Pattern Collection.* http://www.cmis.brighton.ac.uk/research/patterns/home.html

[13] L. Bass, P. Clements, and R. Kazman, *Software Architecture in Practice*, Addison Wesley Longman, Reading MA, 1998.

[14] R. Kazman, M. Klein, M. Barbacci, T. Longstaff, H. Lipson, and J. Carriere, The Architecture Tradeoff Analysis Method, *Proceedings of ICECCS'98*, 8-1-1998.

[15] W. Li and S. Henry, *OO Metrics that Predict Maintainability*, Journal of systems and software, Elsevier, 1993, pp. 111-122.

[16] J. Nielsen, *Heuristic Evaluation.*, in Usability Inspection Methods., Nielsen, J. and Mack, R. L., John Wiley and Sons, New York, NY., 1994.

[17] J. Nielsen, *Usability Engineering*, Academic Press, Inc, Boston, MA., 1993.

[18] C. Wharton, J. Rieman, C. H. Lewis, and P. G. Polson, *The Cognitive Walkthrough: A practitioner's guide.*, in Usability Inspection Methods, Nielsen, Jacob and Mack, R. L., John Wiley and Sons, New York, NY., 1994.

[19] R. Kazman, G. Abowd, and M. Webb, SAAM: A Method for Analyzing the Properties of Software Architectures, *Proceedings of the 16th International Conference on Software Engineering*, 1994.

[20] S. Lauesen and H. Younessi, Six styles for usability requirements, *Proceedings of REFSQ'98*, 1998.

[21] J. Preece, Y. Rogers, H. Sharp, D. Benyon, S. Holland, and T. Carey, *Human-Computer Interaction*, Addison Wesley, 1994.

[22] D. Hix and H. R. Hartson, *Developing User Interfaces: Ensuring Usability Through Product and Process.*, John Wiley and Sons, 1993.

[23] ISO, ISO 9241-11 Ergonomic requirements for office work with visual display terminals (VDTs) -- Part 11: Guidance on usability., 1994.

[24] B. Shneiderman, *Designing the User Interface: Strategies for Effective Human-Computer Interaction*, Addison-Wesley, Reading, MA, 1998.

[25] J. v. Gurp and J. Bosch, *Design Erosion: Problems and Causes*, Journal of systems and software, Elsevier, 3-1-2002, pp. 105-119.

[26] P. B. Kruchten, The 4+1 View Model of Architecture, IEEE Software, 1995.

[27] C. Argyris, R. Putnam, and D. Smith, *Action Science: Concepts, methods and skills for research and intervention*, Jossey-Bass, San Francisco, 1985.