TRESE
Twente Research & Education on Software Engineering

Detecting Mode Inconsistencies in Component-Based Embedded Software

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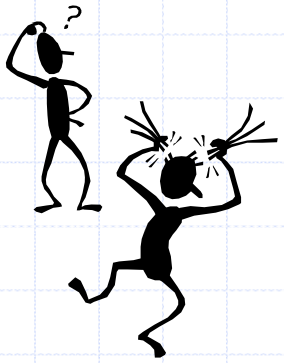
Outline

- The problem
  - Mode inconsistency
- The solution approach for error detection
- An implementation of the approach
- Discussion
  - Implementation issues
  - Integrating diagnosis and recovery
- Conclusion

The Mode Inconsistency Problem

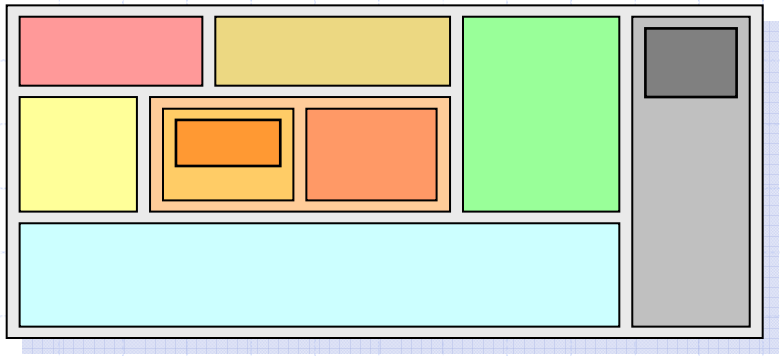
- An example:
  - system lock-up in TV



- User perspective:
  - TV screen is blanked out or frozen
  - No response to user actions
    - Teletext page cannot be changed

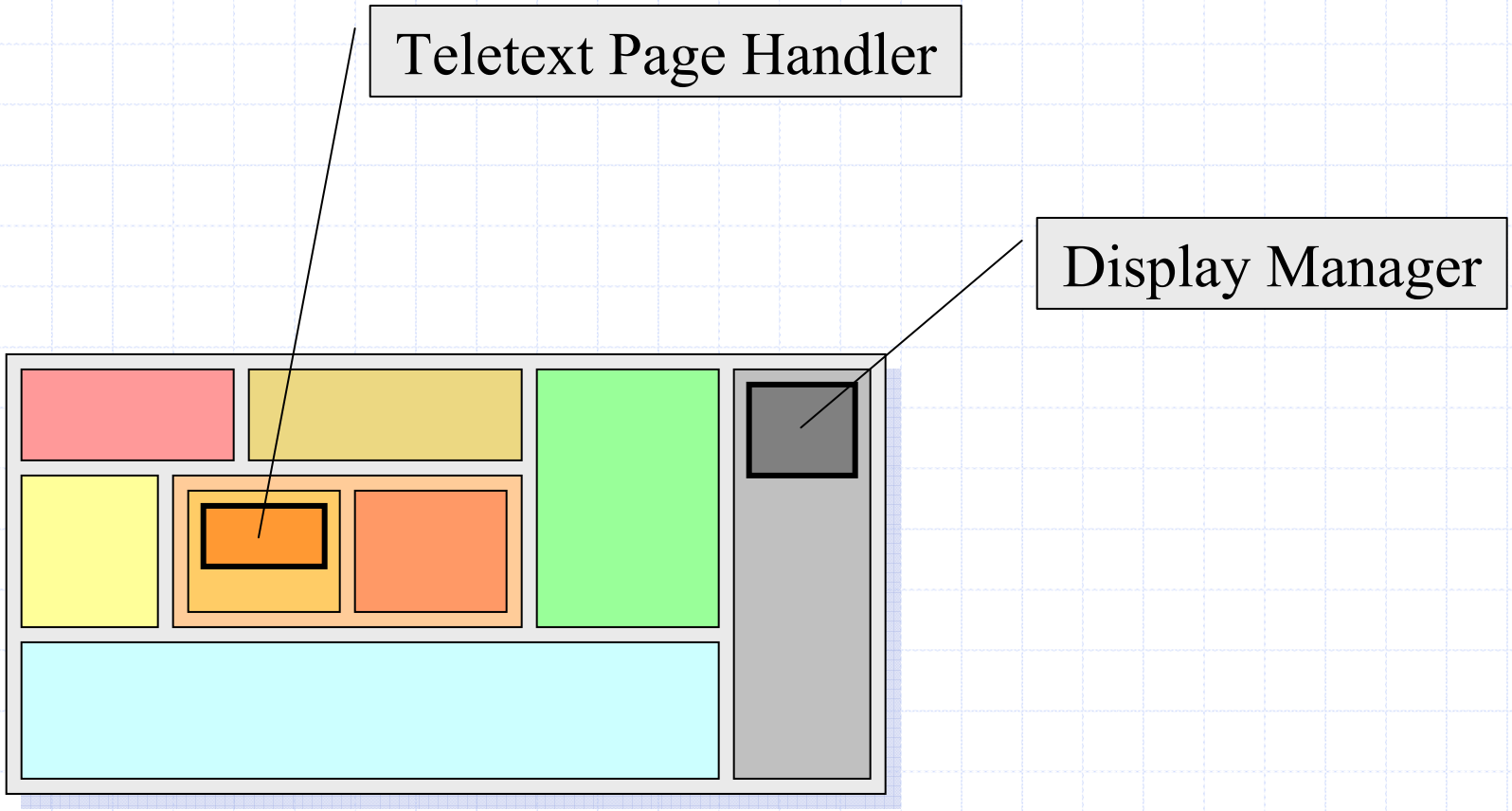
The Mode Inconsistency Problem

- An example:
  - system lock-up in TV

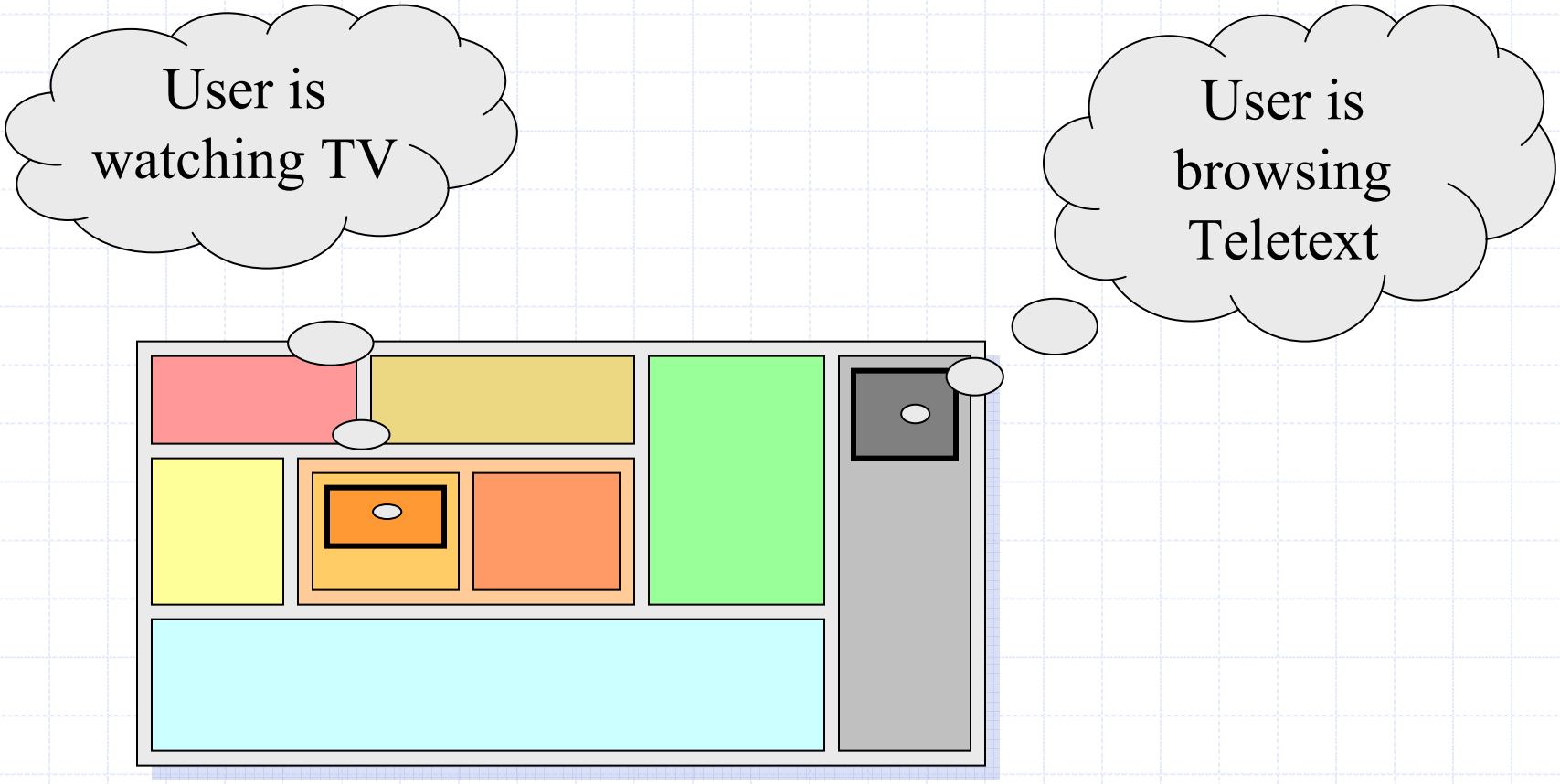


- System perspective:
  - Each sub-system seems to work fine
  - Synchronization is lost

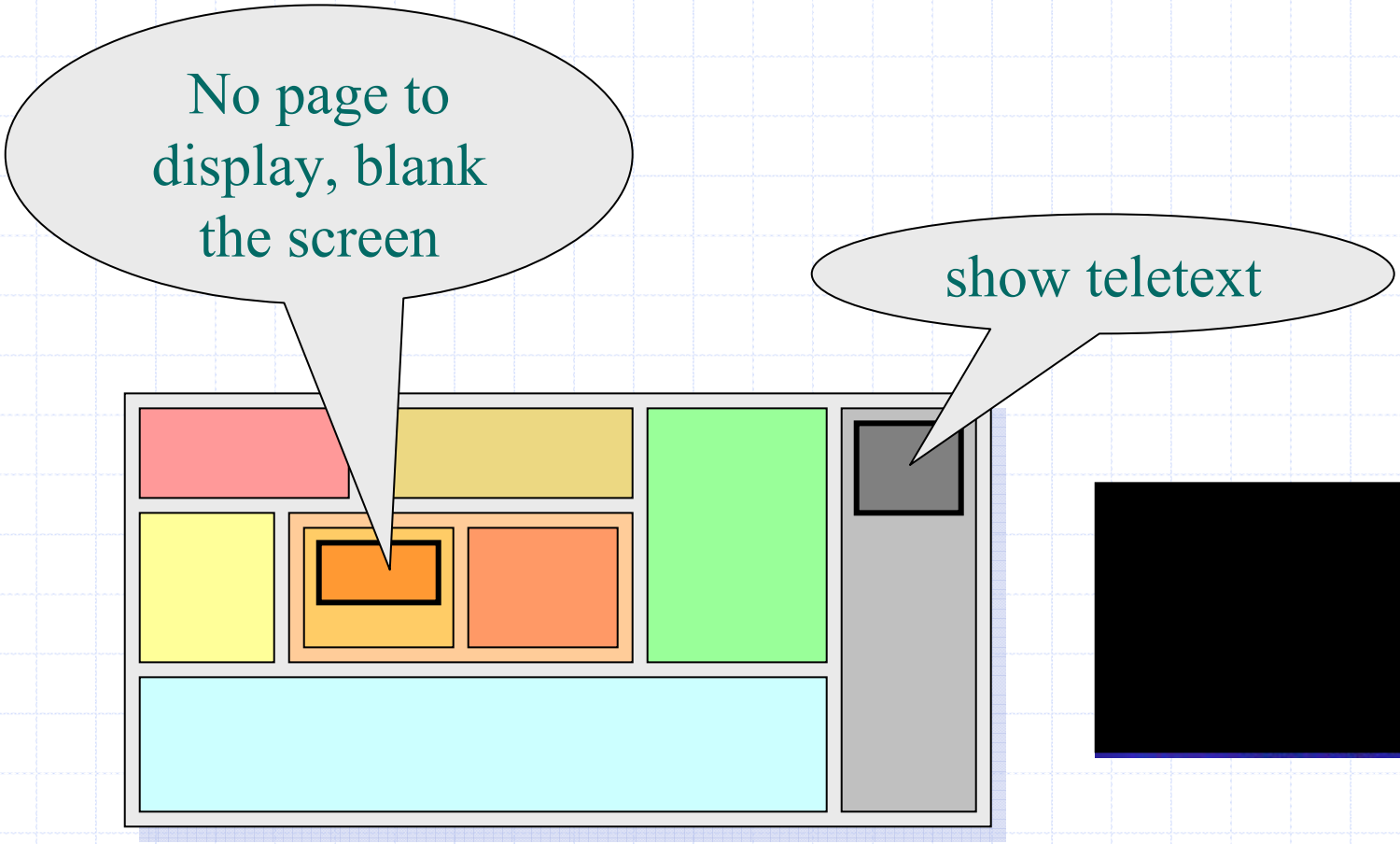
The Mode Inconsistency Problem



The Mode Inconsistency Problem



The Mode Inconsistency Problem



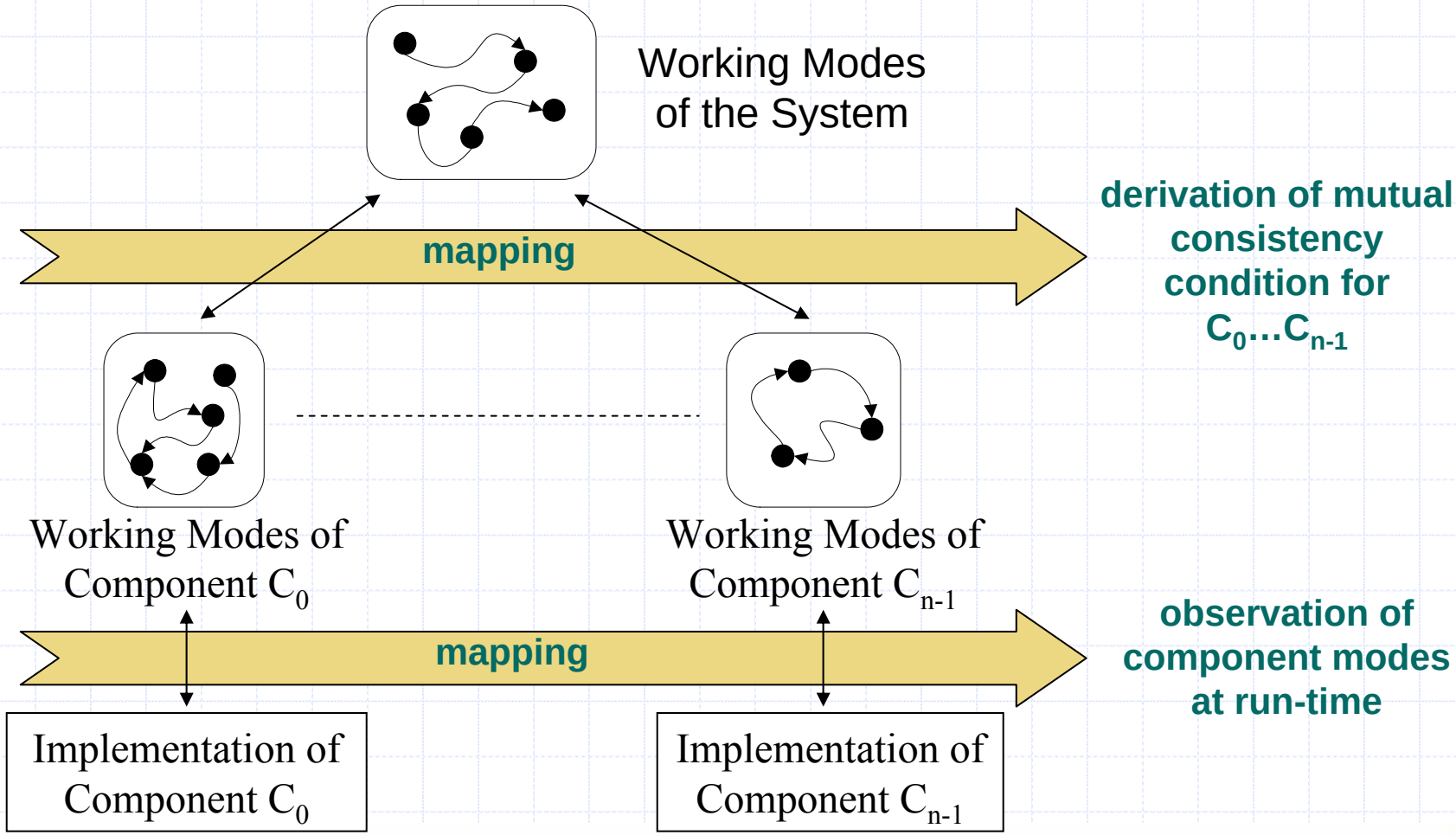
The Mode Inconsistency Problem

- system lock-up in TV: Observations
  - system is **unaware**
  - Existing error detection mechanisms are too low level
    - Stack overflow, memory corruption, ...

Error Detection: Solution Approach

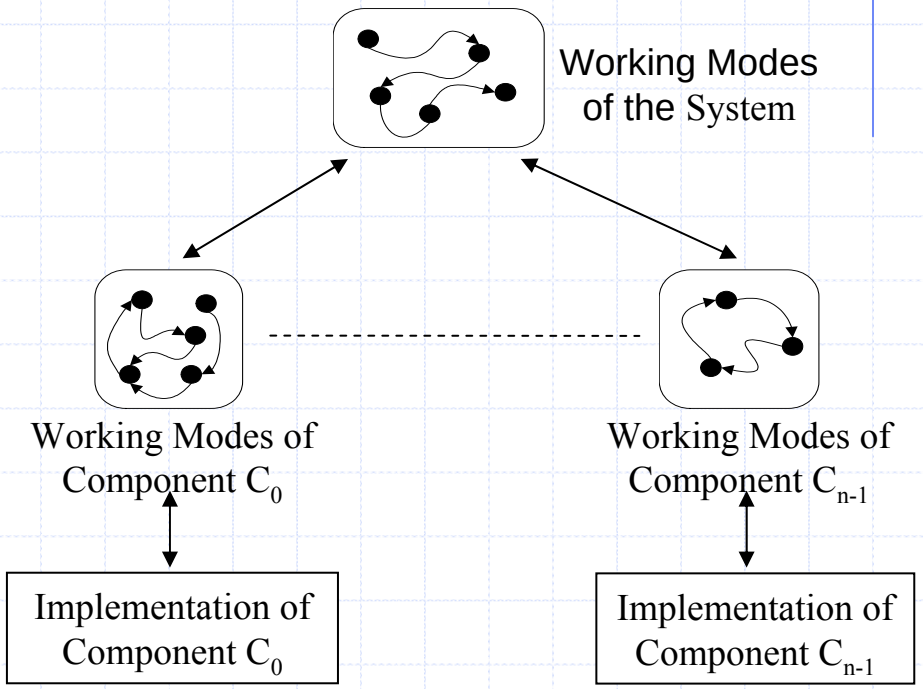
- Model the working modes of each **component**
- Model the working modes of the **system**
- Define links among **three levels of abstraction**:
  - Specification of the system working modes
  - Specification of the working modes of components
  - Run-time behavior of components (implementation)

Error Detection: Solution Approach



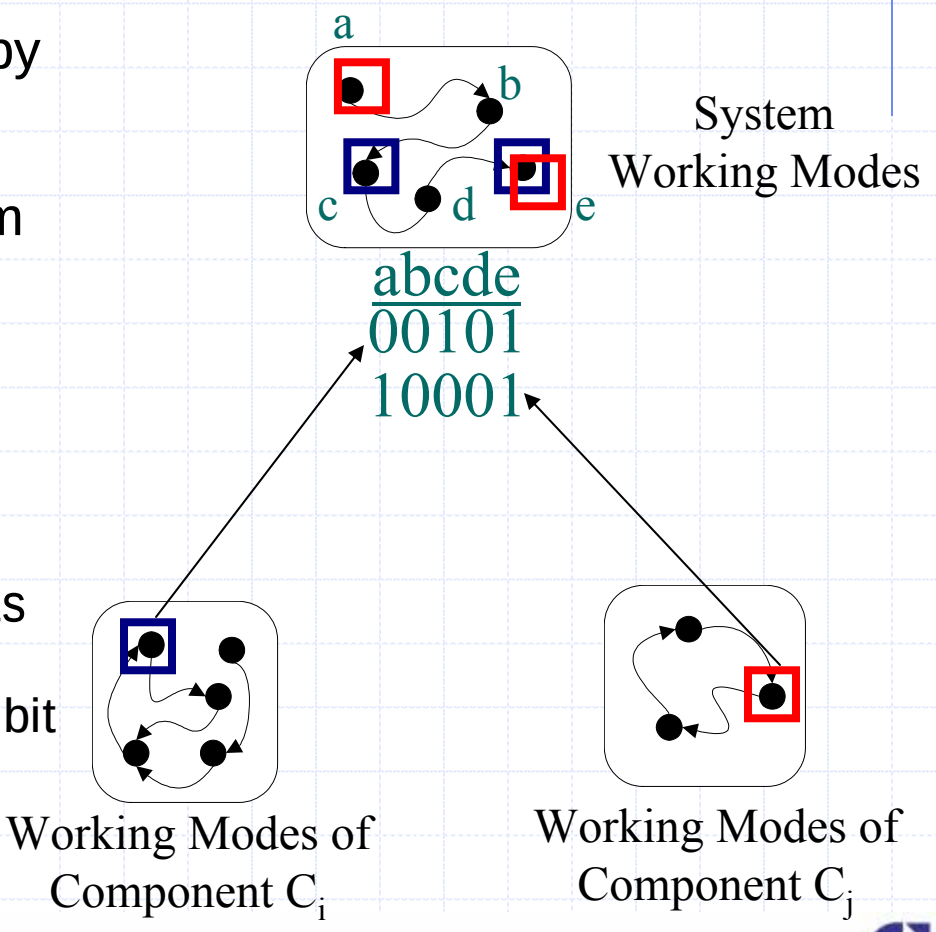
Error Detection: Solution Approach

- Implementation of the approach
  - How to model the working modes?
  - How to map the models to each other?
  - How to use the mappings to detect errors?



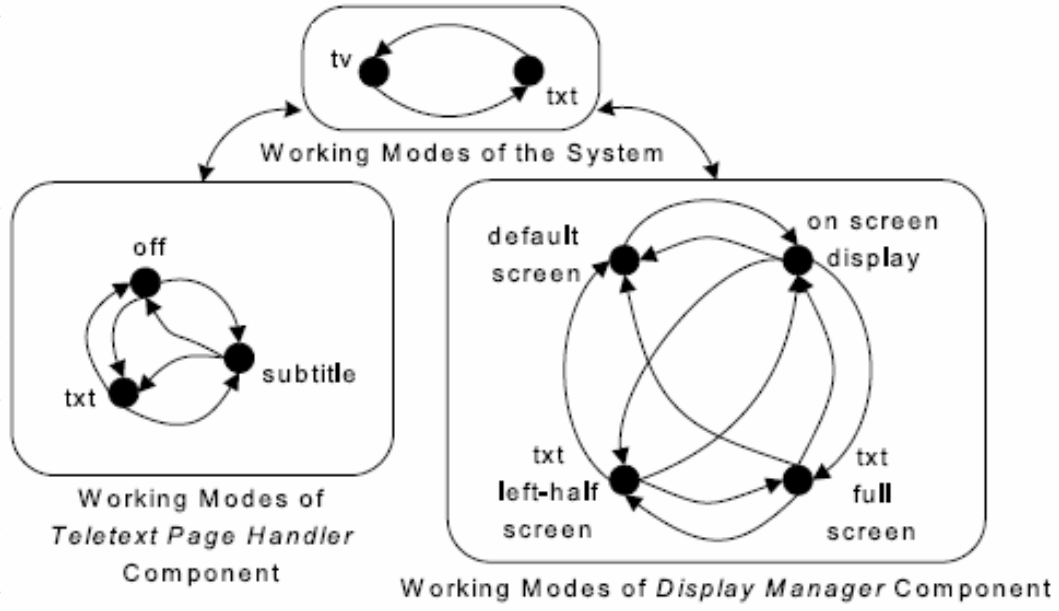
An Implementation of the Approach

- Each working mode **s** of a component **C** is represented by a bit vector
- Each bit corresponds to a working mode **g** of the system
- Each bit is set to
  - 0 if **C** can not be in working mode **s** while system is in working mode **g**
  - 1 otherwise
- There is an error if current working modes of components are not consistent
  - bit vectors have no common bit with value 1



Working Example: Error Detection

Txt. Page Handler	map	Display Mgr.	map
off	10	*default screen*	10
txt	01	*on screen display*	10
subtitle	11	*txt left-half screen*	01
		txt full screen	01



$10 \wedge 01 = 0 \rightarrow$ error

Properties of the Detection Mechanism

- The model of the system working modes is independent of its internal decomposition
- Components do not have to know about the working modes of the other components
- The mechanism can be incrementally introduced
- Low-cost
  - *effort to map the working modes*:
    - Developers have to set the bits to 0 or 1 based on consistency
  - *space complexity*:
    - (number of components) x (number of system working modes)
  - *time complexity*:
    - Error checking can be done with a single *AND* operation over bit-vector representations of component working modes

Implementation Issues

- When to check for consistency?
  - If there is no transaction concept in the system
- Current implementation: Periodic Error checking at a separate, lowest priority, preemptive task
  - Checking at a stable system state
  - Does not interfere with the other system functions
    - External observer
  - Does not degrade the system performance

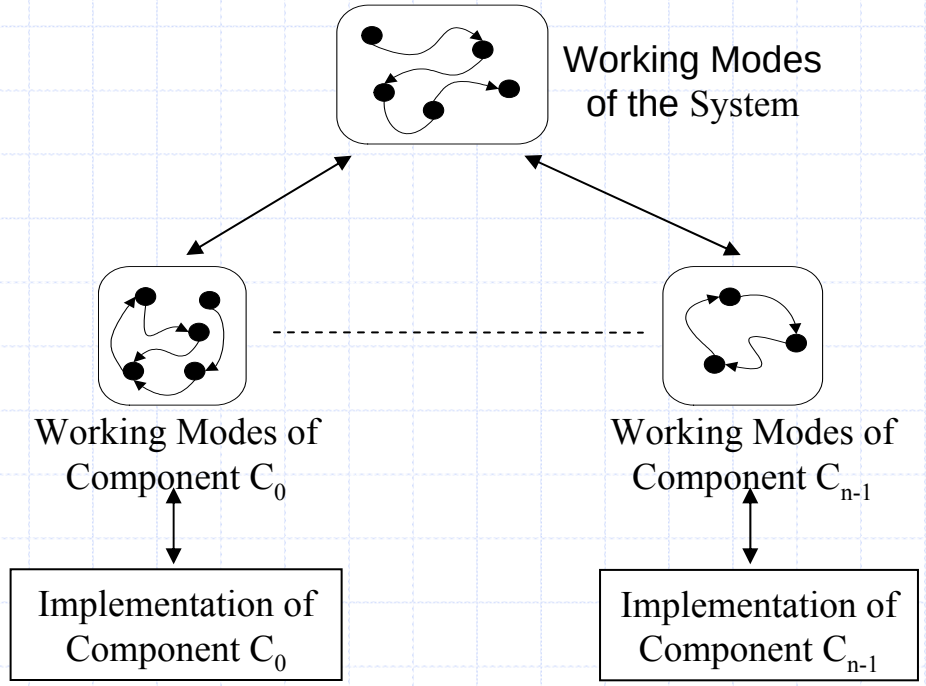
Integration of Recovery & Diagnosis

- Recovery
  - Backward recovery
    - Check-pointing consistent states and roll-back
  - Cheap/Simple solution: restart the system
  - Local-recovery (e.g. microreboot)
    - Does the system support?
    - How to localize the error? (**Diagnosis**)
- Diagnosis
  - Voting Based
    - Is there a consensus on the global system state?
    - Who does not agree?

Conclusion

- Mode Inconsistency
  - Can lead to serious failures
  - Such errors should be detected for fault tolerance
  - Existing error detection mechanisms are too low-level and fall short to detect such errors
- A simple, lightweight solution for error detection
  - Specifying the consistency of component working modes with respect to system working modes
  - Monitoring component working modes at run-time
  - Checking the mutual consistency of monitored working modes that are represented by bit-vectors

Questions


Working Modes of the System
Working Modes of Component C_0
Working Modes of Component C_{n-1}
Implementation of Component C_0
Implementation of Component C_{n-1}