Debugging Software Architectures

Kyungsoo Im and John D. McGregor
School of Computing
Clemson University
Clemson, SC 29634

Outline

- Motivation
- Related Work
- Research Approach
- Summary & Future Work

Motivation

- An incorrect software architecture can lead to problems during development
- Architecture descriptions are becoming larger and more detailed -> more possibility of bugs
  - Ex) Avionics Display System: 21,000 lines
- Expensive to correct the software architecture in later stages
- Goal: aid the software architect in locating known defects in software architectures

Motivation

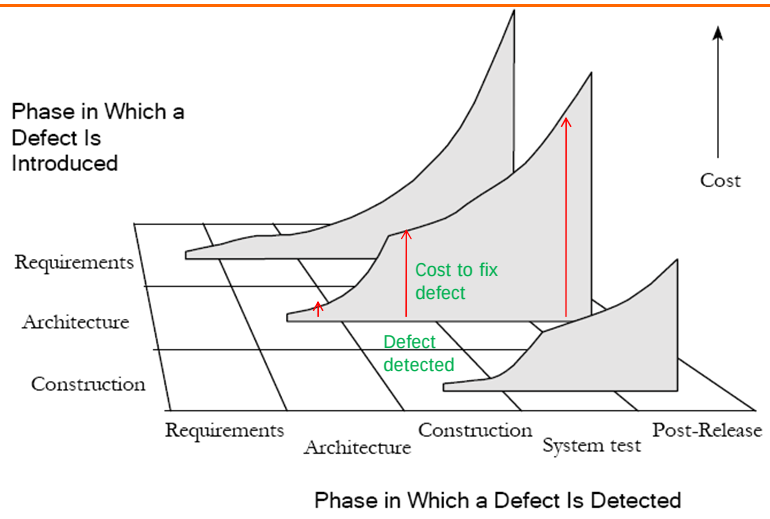


Image from *CodeComplete* 2nd edition by Steve McConnell

Related Work

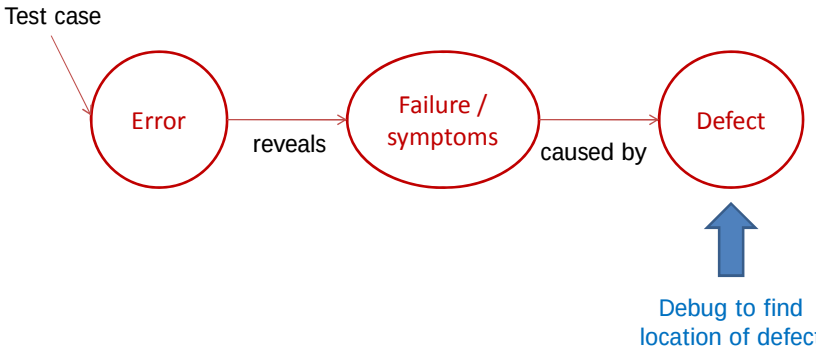
- Much work exists on software architecture analysis
  - Most only point out existence of defect and not its location
- Debugging UML Designs
- Little work on debugging software architectures
  - Visualization of event traces, Monitoring of events, Simulation
  - No clear definition, process, or method to debugging software architectures

Research Approach

- Define debugging at the architectural level
- Develop a classification of architectural defects
- Develop techniques for tracing a defect to its cause through debugging

Definitions

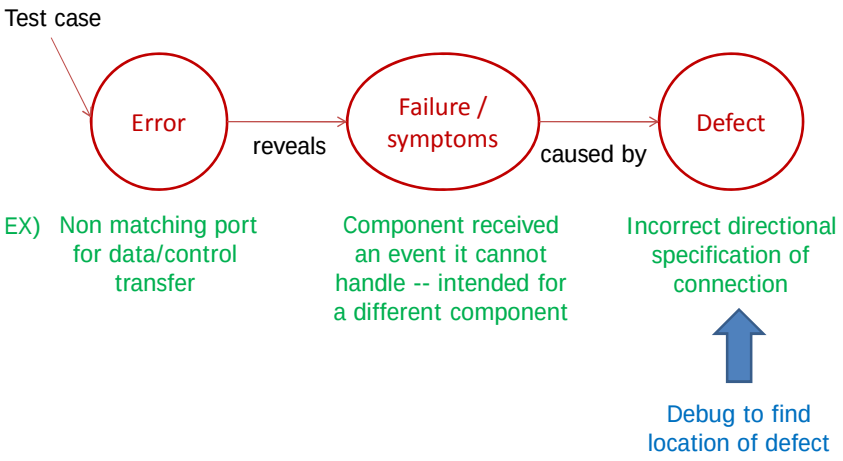
- Mirror debugging at program level



Definitions

- Software Architectural Error - Difference exist between actual and expected software architecture
- Software Architectural Failure - Inability of a software architecture to meet a functional or nonfunctional requirement
- Software Architectural Defect – Incorrect, incomplete, or inconsistent architectural specification, behavior, or design

Definitions



Architectural Defects

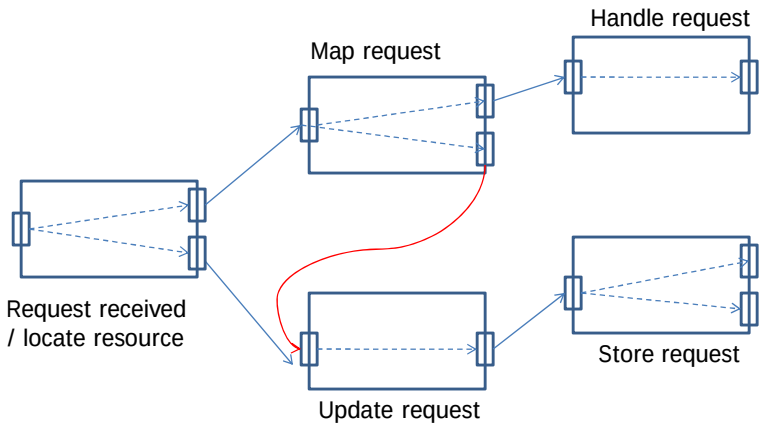
- Classification of software architectural defects
  - Helps understand possible types of defects
  - Depending on defect types, debugging methods will be different
- Defects can be found at 2 levels
  - Structural, Behavioral
- Defects regarding functional and non-functional requirements

Structural Defects

- Syntactic defects
- Directional defects on connections, flows
- Missing or unintended connections or flows
- Data type mismatches
- Unused components
- Not matching the architectural pattern used
- Too much / too little modularity
- Failure to meet nonfunctional requirements (ex: modifiability)

… …

Structural Defect Example



- Scenario cannot be fulfilled because of missing connection
- For structural defects, the failure usually defines region of interest to find defect

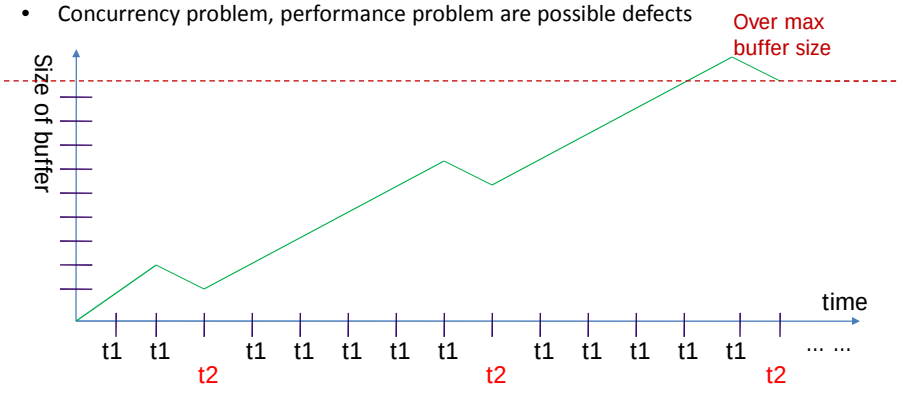
Behavioral Defects

- Receive unexpected event
- Expected event not sent
- Missing activity
- Extraneous activity
- Concurrency issues
- Execution on incorrect states
- Pre / Post conditions violations
- Failure to meet nonfunctional requirements (ex: performance)

… …

Behavioral Defect Example

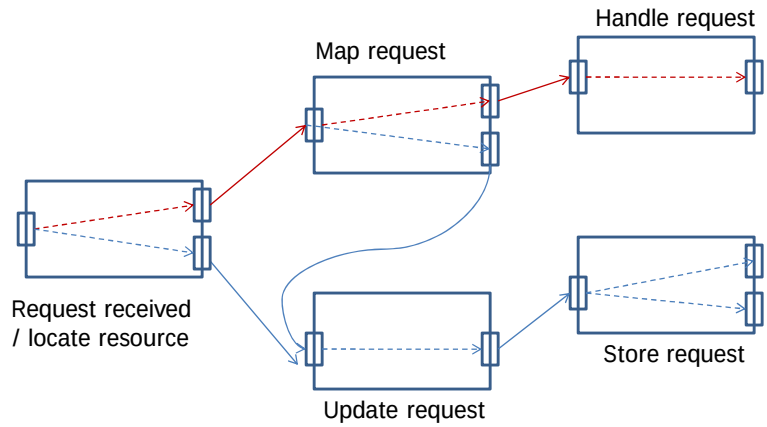
- Suppose there are two executing threads – one producing data (t1), one consuming data (t2)
- Assume t1 produces and t2 consumes the same size chunks
- Simulation shows the timestamps of the threads executing, where t2 lacks the speed of t1
- Concurrency problem, performance problem are possible defects



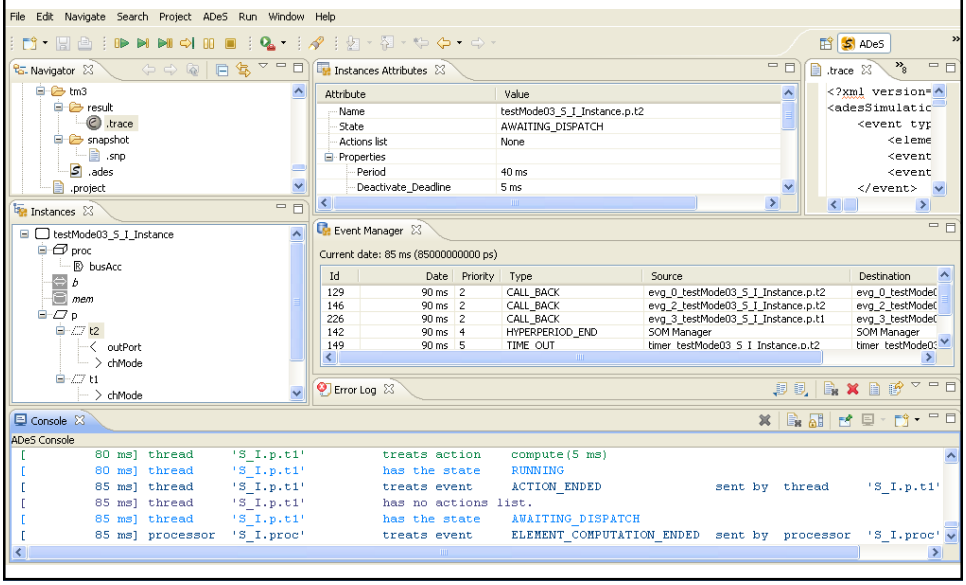
Debugging Approaches

- Our approach would be heterogeneous, including
  - Back trace a failed scenario
  - Localize defects through multiple runs of scenarios
    - Overlapping areas, divide and conquer
  - Apply software architecture slicing
  - Perform Simulation
  - Perform Model Checking
- In some cases, localizing a defect to a region in the architecture may be the correct result

Architecture Slicing



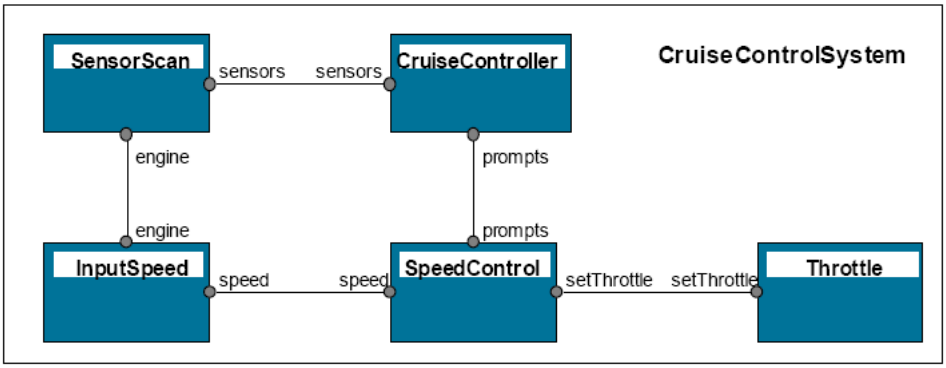
Simulation



Model Checking

- Used frequently to find design flaws
  - Deadlock, starvation, unreachability, constraint violations
- Same flaws exist in software architectures
- Provides a counter example/error trace when flaw is found

Example of Deadlock



- Example and image from "Exposing the Skeleton in the Coordination Closet" by J. Kramer, J. Magee
- This example used by author in classes for 3 years before finding this flaw.

Example of Deadlock

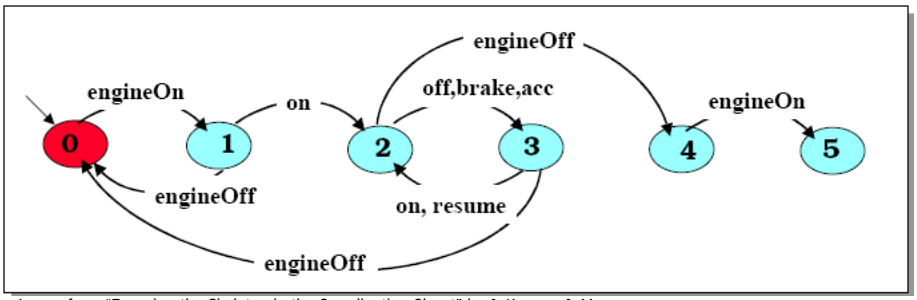
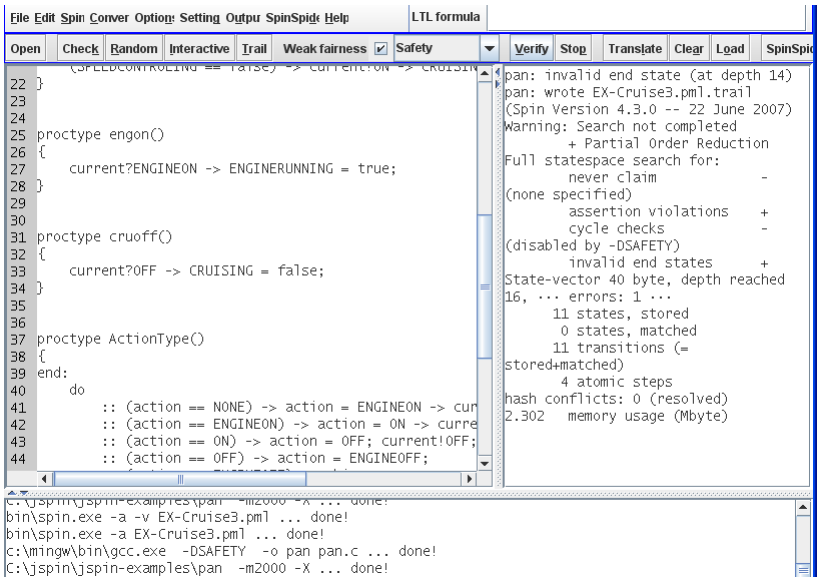


Image from "Exposing the Skeleton in the Coordination Closet" by J. Kramer, J. Magee

- Deadlock exists in the software architecture in the event of engineOn, cruiseControlOn, engineOff, and then engineOn again.
  - Reason: SpeedControl never disabled, leading to a deadlock state.

Model Checking with JSpin



Error Trace

```
 14:    proc  1 (ActionType) line  40 "pan_in" (state 14)       [((action==ENGINEON))]

 15:    proc  1 (ActionType) line  42 "pan_in" (state 5)        [action = ON]

spin: trail ends after 15 steps
#processes 5:
 15:    proc 0 (:init:)  line  58 (state  7)
                -end-
 15:    proc 1 (ActionType)  line  42 (state  6) (invalid end state)
                current!ON
 15:    proc 2 (engon)  line  30 (state  5)
                -end-
 15:    proc 3 (cruon)  line  21 (state  5) (invalid end state)
                ((SPEEDCONTROLING==0))
 15:    proc 4 (cruoff)  line  33 (state  3) (invalid end state)
                current?OFF
```

Summary & Future Work

- Outline of approach to debugging software architectures
- Overview of what is debugging at software architecture level & how to achieve it
- Debugging an architectural defect dependent on type of defect
- Extend debugging for all architectural defects
  - Especially, how to debug a quality attribute
- Implement the debugging techniques to be used as tools by the architect

Questions?