

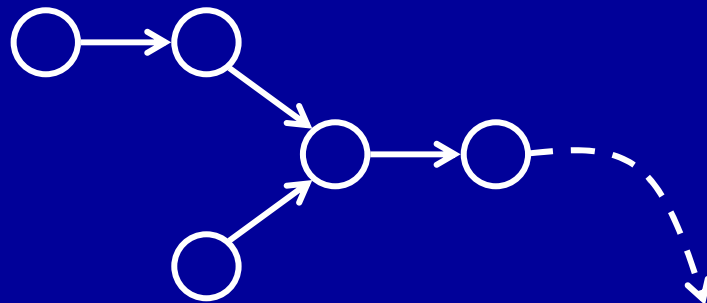
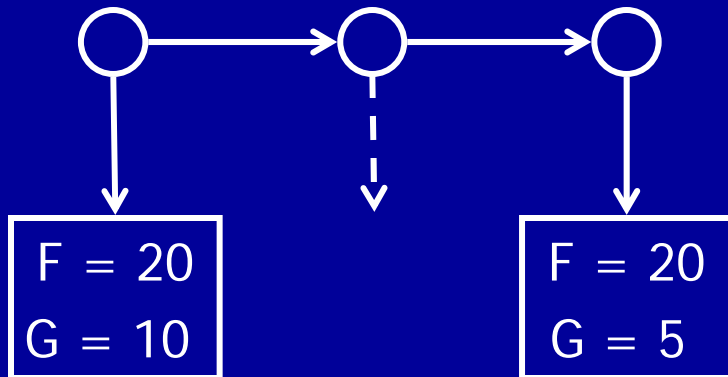
Learning, Monitoring and Repair in Application Communities

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Problem

Broken Data Structure



$I = 5$

$J = 2$



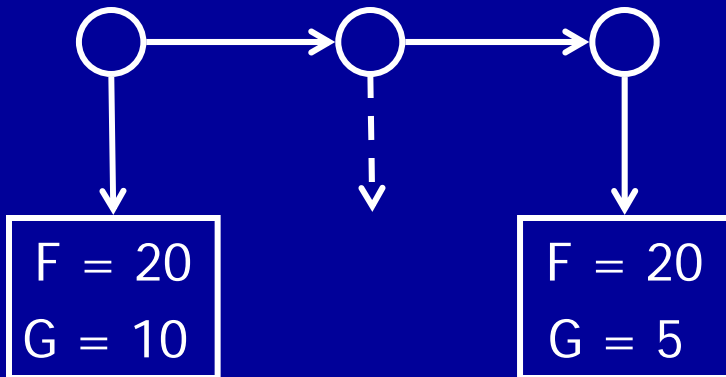
Errors

- Missing elements
- Inappropriate sharing
- Dangling references
- Out of bounds array indices
- Inconsistent values

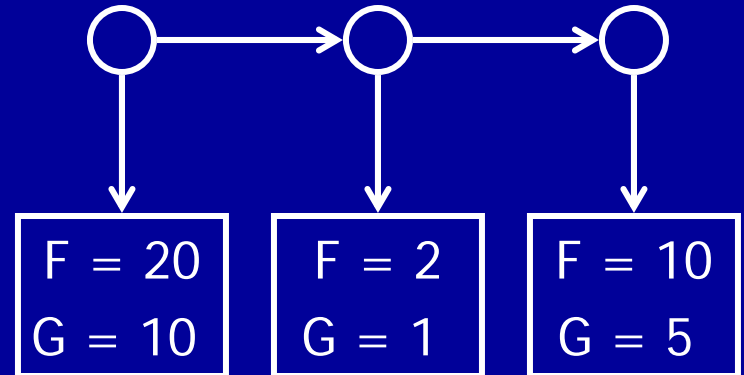
**Errors Cause
System to Fail!**

Ideal Solution

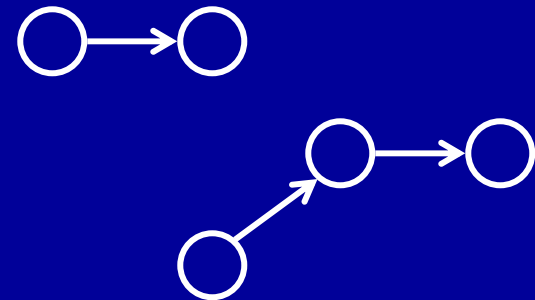
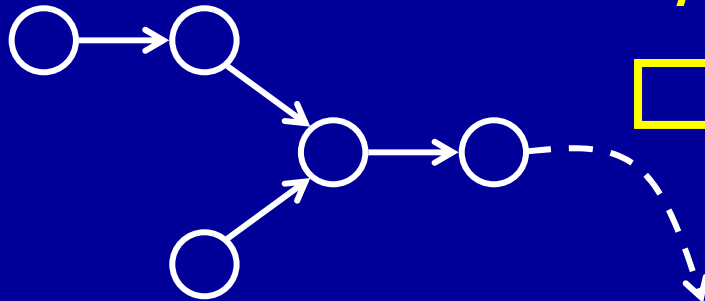
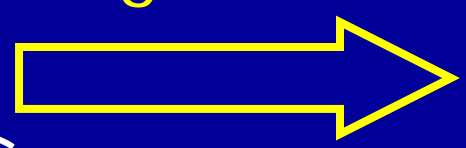
Broken Data Structure



Consistent Data Structure



Repair
Algorithm



$I = 5$

$J = 2$



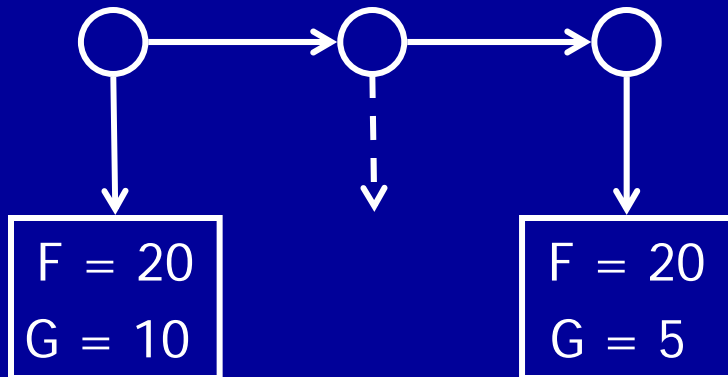
$I = 3$

$J = 2$



Our Solution

Broken Data Structure

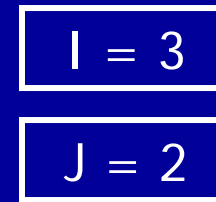
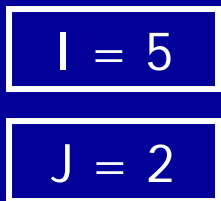
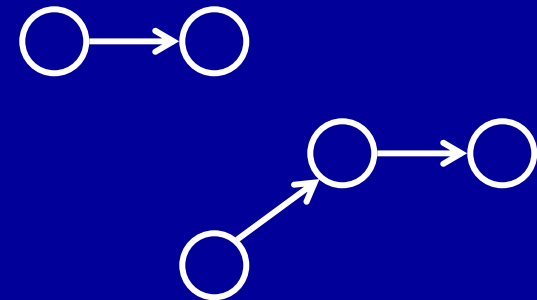
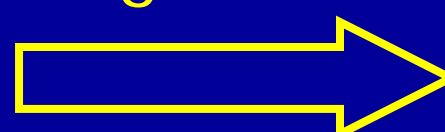
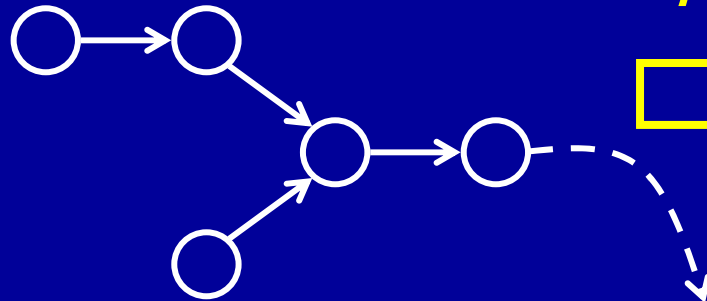
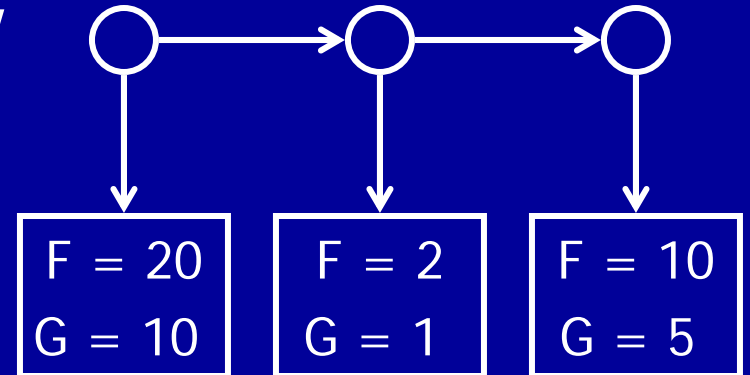


Consistency Constraints

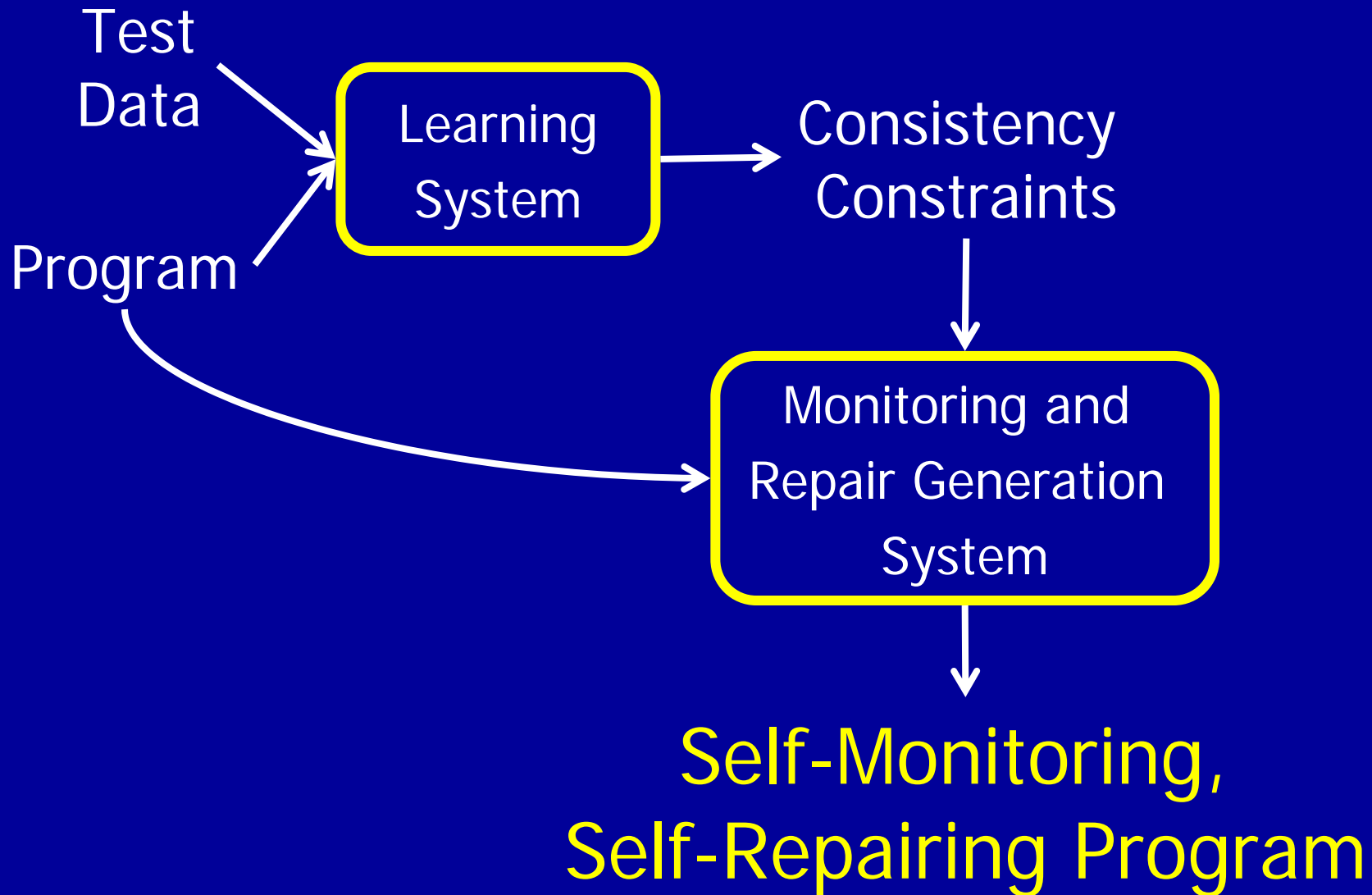


Repair Algorithm

Consistent Data Structure



Learning Consistency Constraints



Issues

- How accurate are learned constraints?
 - Hold in all observed executions
 - But may be overly restrictive
- Which repair choices give best result?
 - Shorter repairs preferred
 - Repairs that preserve information preferred
 - But may miss best (or even good) repair

How Can Application Communities Help?

- Key capabilities
 - Lots of participants exercising software
 - Communicating shared experiences
- Better learning
- Better attack detection
- Better repair

Better Learning



Better Learning



Violated
Constraint!

Better Learning

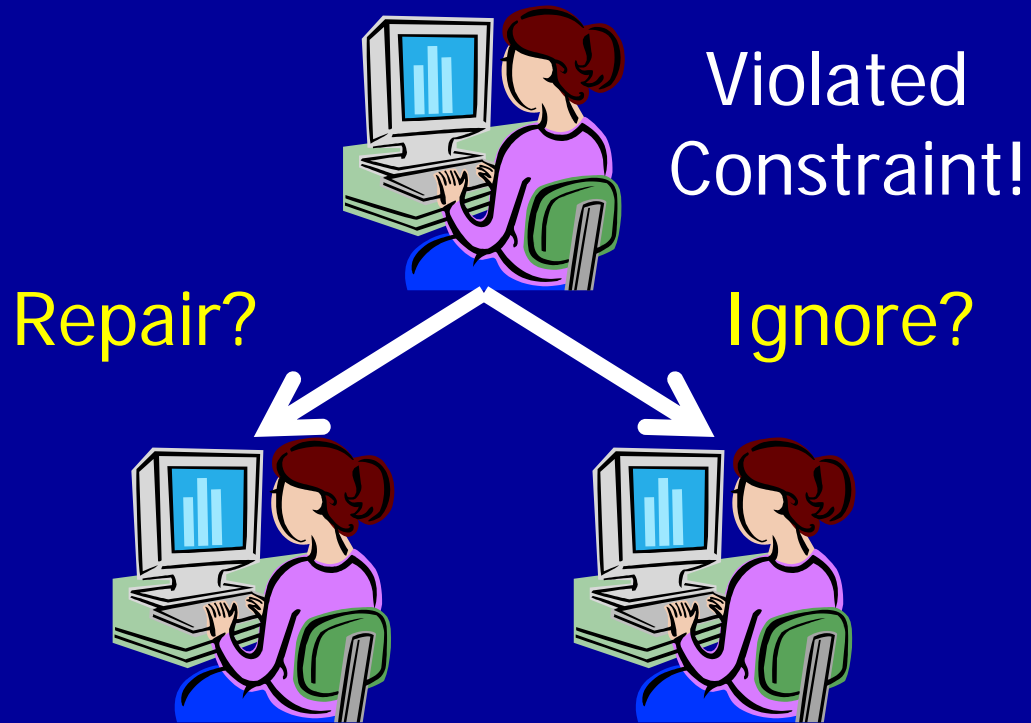


Violated
Constraint!

Repair?



Better Learning



Better Learning



Violated
Constraint!

Repair?

Ignore?

Choose Randomly!



Better Learning



Violated
Constraint!

Repair?

Ignore?

Choose Randomly!



Observe
Outcome

Better Learning



Violated
Constraint!

Repair?

Ignore?

Choose Randomly!

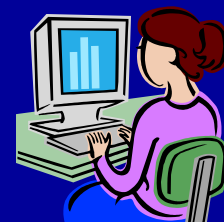


Observe
Outcome



Communicate Outcome
Others Observe and Learn

Better Attack Detection



Better Attack Detection



Violated
Constraint!



Violated
Constraint!



Violated
Constraint!



Violated
Constraint!



Violated
Constraint!



Violated
Constraint!

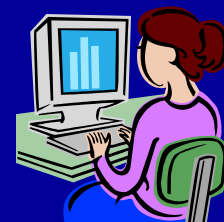
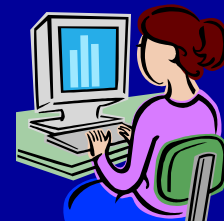


Violated
Constraint!



Violated
Constraint!

Better Attack Detection



Better Attack Detection



Violated
Constraint!



Better Repair



Better Repair



Violated
Constraint!

Better Repair



Violated
Constraint!

Repair A?



Better Repair



Violated
Constraint!

Repair A?

Repair B?



Better Repair



Violated
Constraint!

Repair A?

Repair B?

Choose Randomly!



Better Repair



Violated
Constraint!

Repair A?

Repair B?

Choose Randomly!



Observe
Outcome

Better Repair

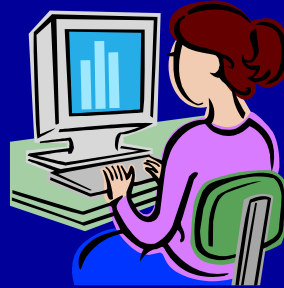


Violated
Constraint!

Repair A?

Repair B?

Choose Randomly!



Observe
Outcome



Communicate Outcome
Others Observe and Learn

Bottom Line

- Leverage experiences of individual members of the application community to
 - Distinguish valid versus overly restrictive learned constraints
 - Recognize attacks
 - Choose best repair options
- Community learns as a whole
 - Some few may experience bad outcomes
 - Others learn and avoid bad outcomes

Better Learning

- Observe violated constraint
- Options
 - Repair violation (appropriate if constraint valid)
 - Ignore violation and continue
(appropriate if constraint overly restrictive)
- Application community approach
 - Choose to repair or ignore randomly
 - Observe outcome, communicate to participants
 - Outcomes bias future repair or ignore choices
 - Learn as a community, not as individual

Better Attack Detection

- Consistency violation may indicate attack
- Observe violation frequency and signature
- Lots of similar violations all at once?
Probably an attack!
- Isolated violations?
Probably a bug!

Better Repair

- May have multiple repair options
- Application communities approach
 - Randomly choose one option
 - Observe and communicate outcome
 - Outcomes bias future repair choices
 - Learn as a community, not as individual

Bottom Line

- Leverage experiences of individuals to
 - Distinguish valid versus overly restrictive learned constraints
 - Recognize attacks
 - Choose best repair options
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