

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work

Brady J. Garvin* Myra B. Cohen Matthew B. Dwyer

University of Nebraska–Lincoln

September 4, 2011

Outline

Using Feature
Locality: Can We
Leverage History
to Avoid Failures
During
Reconfiguration?

ASAS 2011

- 1 Motivation
- 2 Failure Avoidance
- 3 Study
- 4 Results
- 5 Conclusions and Future Work

Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work



Adirondack, Spirit's first rock, whose investigation would be interrupted by a bout of insomnia, fever, and delirium.

Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work

What we Know from Testing Highly-Configurable Systems

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011

Motivation

Failure Avoidance

Study

Results

Conclusions and Future Work

- Spirit, a highly-configurable system, was exhibiting a configuration-dependent failure [Adler 2004].
- Highly-configurable systems tend to do this [Kuhn et al. 2004, Yilmaz et al. 2006, Qu et al. 2008].
- Configuration-dependence makes failures harder to find in testing, but easier to work around.

What we Know from Designing Autonomous Systems

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011

- Adaptations, including online reconfiguration, affect reliability.
- Reliability can be predicted fairly well from a few key parameters [Ahmed et al. 2010].
- But until the system has been running for a while under various configurations, we will have observed only a handful of discrete failures, which makes it difficult to build a reliability model and identify those parameters.

Motivation

Failure Avoidance

Study

Results

Conclusions and Future Work

What we Know from Fault Prediction

Using Feature
Locality: Can We
Leverage History
to Avoid Failures
During
Reconfiguration?

ASAS 2011

Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work

- Faults exhibit many forms of locality, both temporal and spacial [Hassan et al. 2005, Kim et al. 2007].
- In consequence, failures also show locality.

Hypothesis

Using Feature
Locality: Can We
Leverage History
to Avoid Failures
During
Reconfiguration?

ASAS 2011

- Reconfiguration workarounds effective against one failure tend to be effective against others.
- We call this phenomenon feature locality of failures.

Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work

Outline

Using Feature
Locality: Can We
Leverage History
to Avoid Failures
During
Reconfiguration?

ASAS 2011

- 1 Motivation
- 2 Failure Avoidance
- 3 Study
- 4 Results
- 5 Conclusions and Future Work

Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work

Configuration Space

Using Feature
Locality: Can We
Leverage History
to Avoid Failures
During
Reconfiguration?

ASAS 2011

Navigation	IDD	...
Blind	Stowed	...
Hazard Avoidance	APXS	...
Autonomous	MB	...
Wheel Wiggle	RAT	...

Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work

Configuration Space

Using Feature
Locality: Can We
Leverage History
to Avoid Failures
During
Reconfiguration?

ASAS 2011

Navigation	IDD	...
Blind	Stowed	...
Hazard Avoidance	APXS	...
Autonomous	MB	...
Wheel Wiggle	RAT	...

Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work

Configuration Space

Using Feature
Locality: Can We
Leverage History
to Avoid Failures
During
Reconfiguration?

ASAS 2011

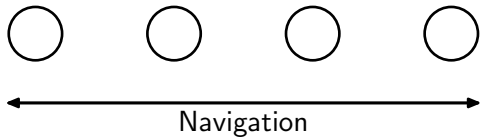
Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work



Configuration Space

Using Feature
Locality: Can We
Leverage History
to Avoid Failures
During
Reconfiguration?

ASAS 2011

Navigation	IDD	...
Blind	Stowed	...
Hazard Avoidance	APXS	...
Autonomous	MB	...
Wheel Wiggle	RAT	...

Motivation

Failure Avoidance

Study

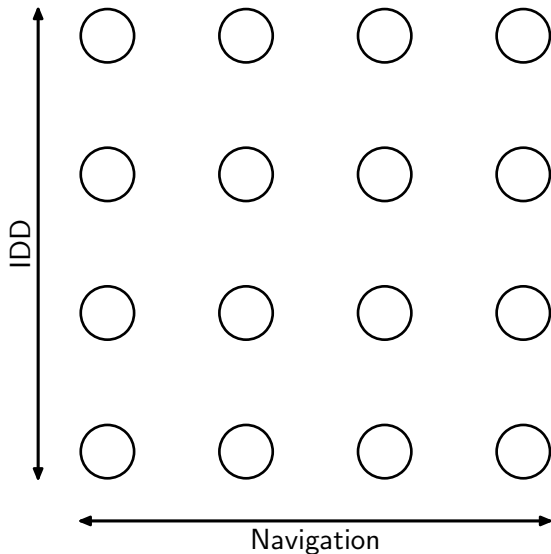
Results

Conclusions and
Future Work

Configuration Space

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

Results

Conclusions and Future Work

Configuration Space

Using Feature
Locality: Can We
Leverage History
to Avoid Failures
During
Reconfiguration?

ASAS 2011

Navigation	IDD	...
Blind	Stowed	...
Hazard Avoidance	APXS	...
Autonomous	MB	...
Wheel Wiggle	RAT	...

Motivation

Failure Avoidance

Study

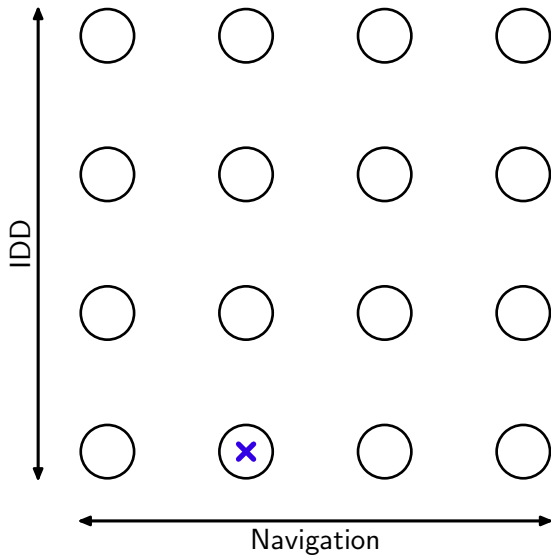
Results

Conclusions and
Future Work

Configuration Space

Using Feature
Locality: Can We
Leverage History
to Avoid Failures
During
Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

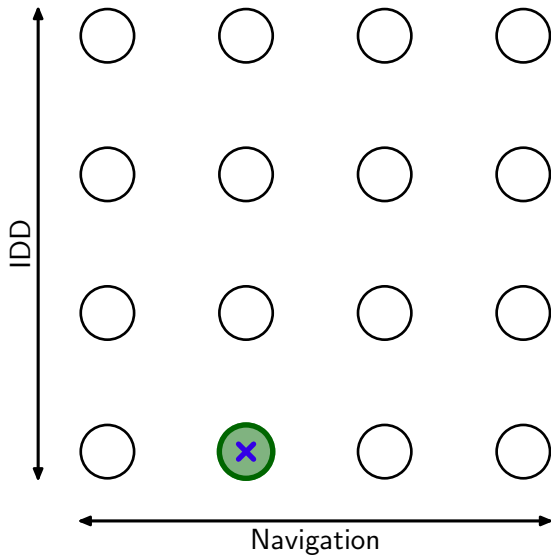
Results

Conclusions and
Future Work

Configuration Space

Using Feature
Locality: Can We
Leverage History
to Avoid Failures
During
Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

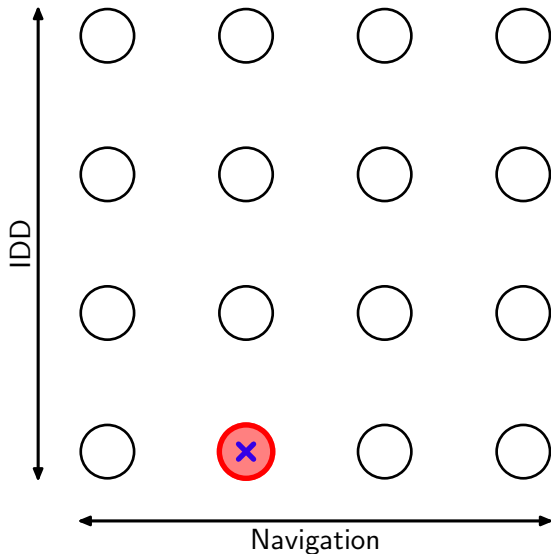
Results

Conclusions and
Future Work

Configuration Space

Using Feature
Locality: Can We
Leverage History
to Avoid Failures
During
Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work

Motivation

Failure Avoidance

Study

Results

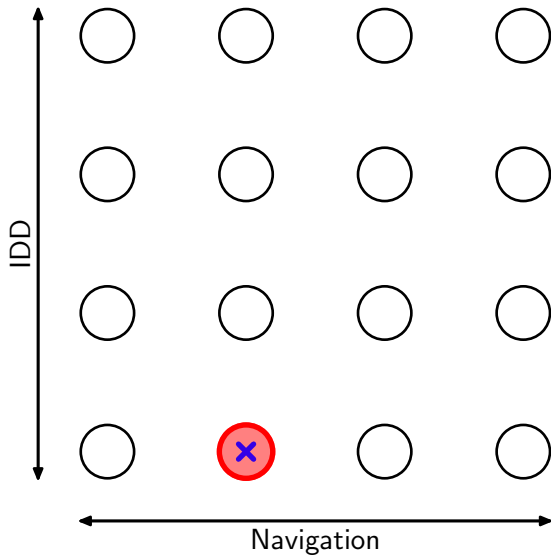
Conclusions and
Future Work

- 1 Analyze failures
- 2 Guard against dangerous configurations
- 3 Workaround new failures

Algorithm 1: Analyze

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

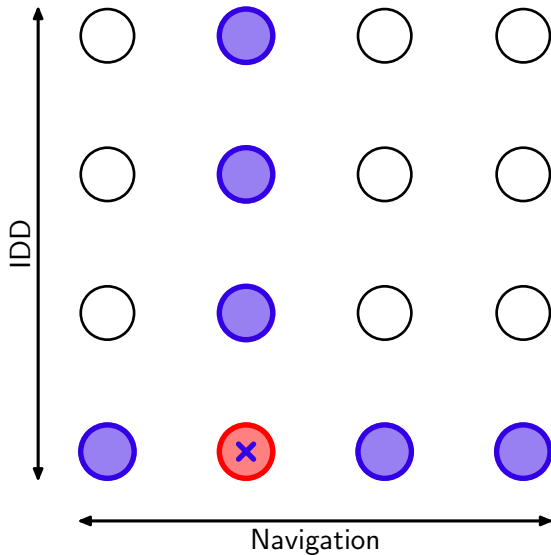
Results

Conclusions and Future Work

Algorithm 1: Analyze

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

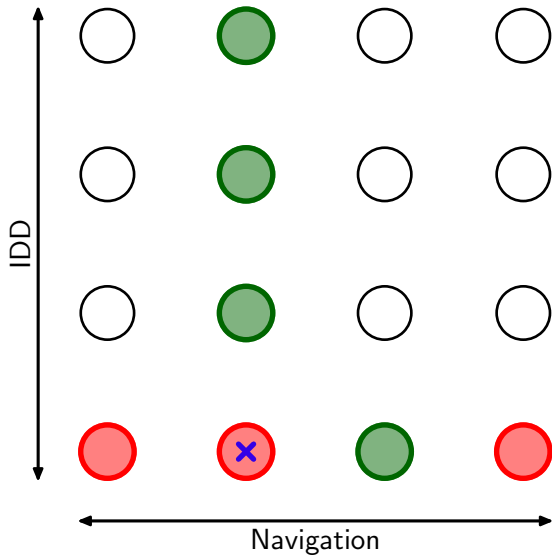
Results

Conclusions and Future Work

Algorithm 1: Analyze

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

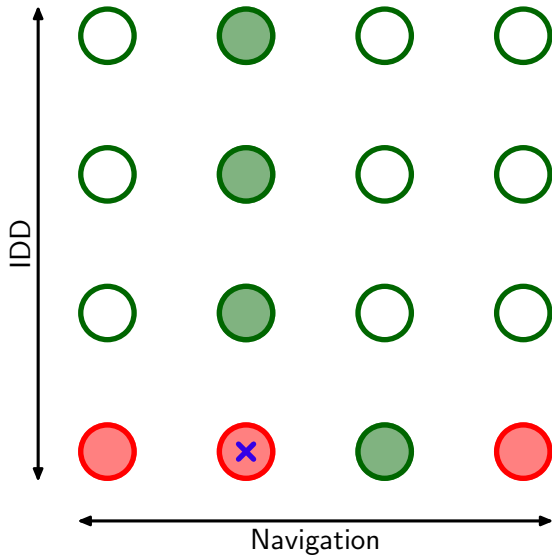
Results

Conclusions and Future Work

Algorithm 1: Analyze

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

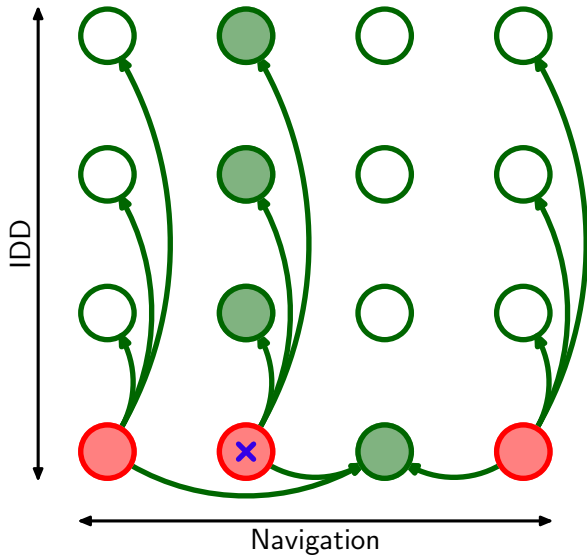
Results

Conclusions and Future Work

Algorithm 1: Analyze

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

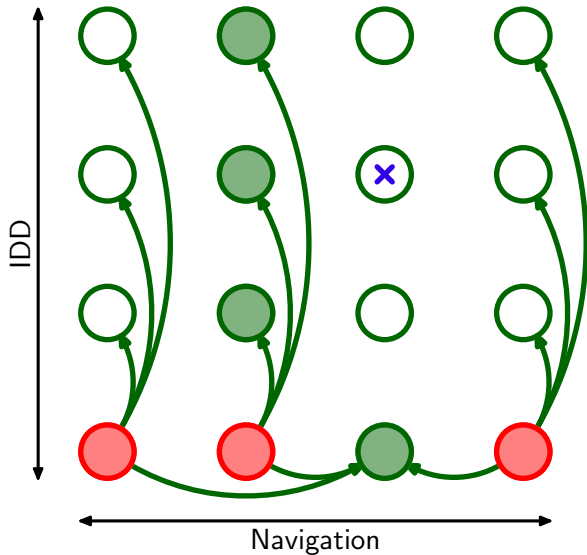
Results

Conclusions and Future Work

Algorithm 2: Guard

Using Feature
Locality: Can We
Leverage History to
Avoid Failures
During
Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

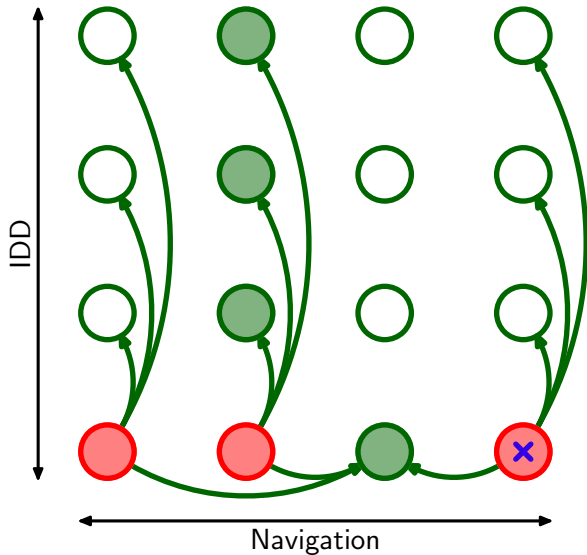
Results

Conclusions and
Future Work

Algorithm 2: Guard

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

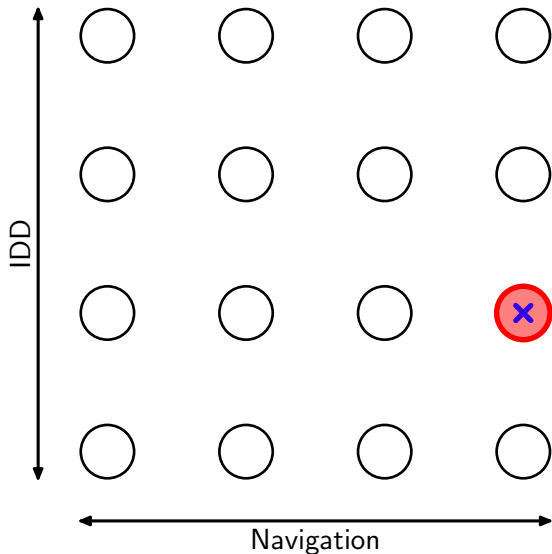
Results

Conclusions and Future Work

Algorithm 3: Reconfigure

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

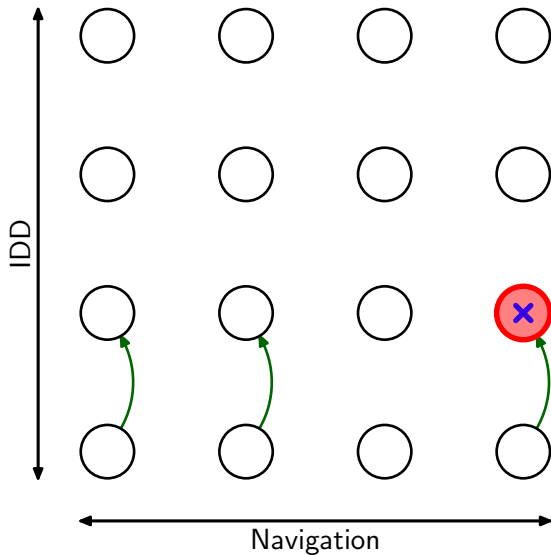
Results

Conclusions and Future Work

Algorithm 3: Reconfigure

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

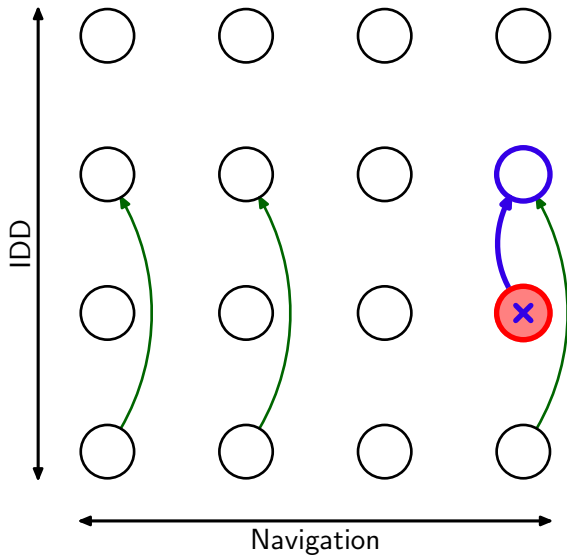
Results

Conclusions and Future Work

Algorithm 3: Reconfigure

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

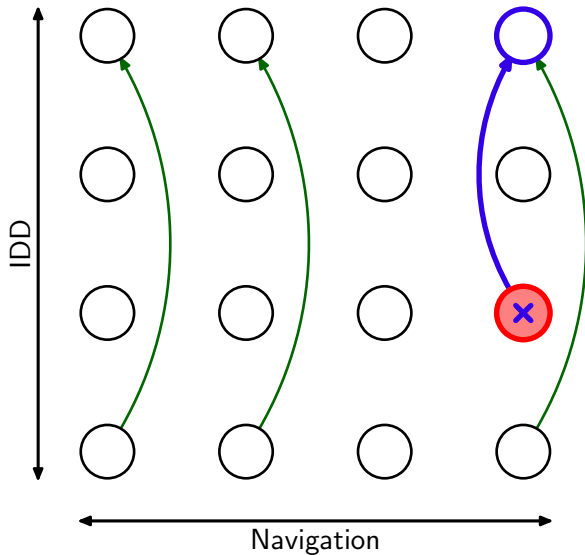
Results

Conclusions and Future Work

Algorithm 3: Reconfigure

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

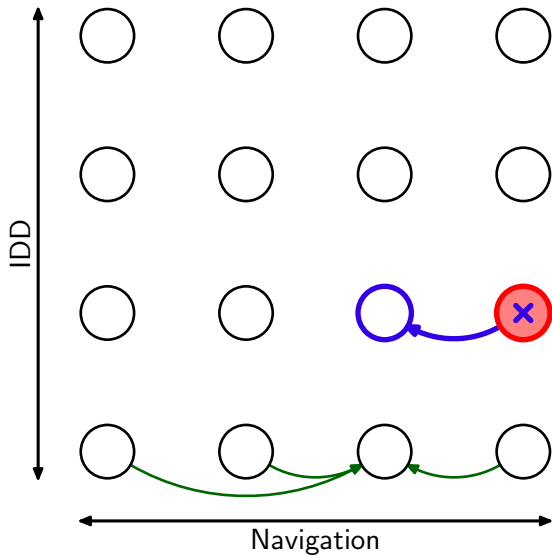
Results

Conclusions and Future Work

Algorithm 3: Reconfigure

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

Results

Conclusions and Future Work

Outline

Using Feature
Locality: Can We
Leverage History
to Avoid Failures
During
Reconfiguration?

ASAS 2011

- 1 Motivation
- 2 Failure Avoidance
- 3 Study**
- 4 Results
- 5 Conclusions and Future Work

Motivation

Failure Avoidance

Study

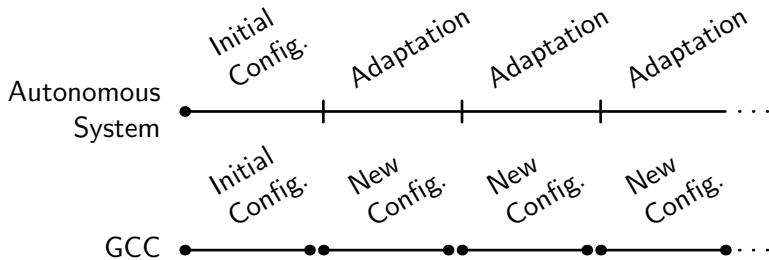
Results

Conclusions and
Future Work

A First Approximation of an Autonomous System

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

Results

Conclusions and Future Work

GCC also has a large configuration space, an open bug database, and a broad and active user community whose members tend to write good bug reports.

- Versions 4.4.0–4.4.2
- Features:
 - Command-line options that, when toggled, neither require changes to the input nor alter the semantics of the output
 - 339 in 168 groups, with 132 clauses to encode feature constraints

Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work

Reported	360
<hr/>	
Incomplete	7
Platform-Dependent	92
Require Alternate Bootstrap Options	3
Nonfunctional	13
Nondeterministic	8
<hr/>	
Remaining	237
Fixed before Release	109
<hr/>	
Reproducible on Releases	128

Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work

- RQ1: Can failures be avoided by reconfiguration?
- RQ2: To what extent do failures depend on similar combinations of features?
- RQ3: Can feature locality be exploited to avoid failures?

Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work

Outline

Using Feature
Locality: Can We
Leverage History
to Avoid Failures
During
Reconfiguration?

ASAS 2011

- 1 Motivation
- 2 Failure Avoidance
- 3 Study
- 4 Results
- 5 Conclusions and Future Work

Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work

RQ1: High-Priority Failures Tend to have Reconfiguration Workarounds

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011

Motivation

Failure Avoidance

Study

Results

Conclusions and Future Work

	4.4.0	4.4.1	4.4.2
P1	3 of 5 (60%)	3 of 4 (75%)	2 of 3 (67%)
P2	7 of 23 (30%)	7 of 19 (36%)	5 of 17 (29%)
P3	21 of 84 (25%)	20 of 80 (25%)	18 of 75 (24%)
P4	0 of 11 (0%)	0 of 11 (0%)	0 of 8 (0%)
P5	0 of 3 (0%)	0 of 3 (0%)	0 of 2 (0%)
Total	31 of 126 (25%)	30 of 117 (26%)	25 of 105 (24%)

RQ1: High-Priority Failures Tend to have Reconfiguration Workarounds

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011

Motivation

Failure Avoidance

Study

Results

Conclusions and Future Work

	4.4.0	4.4.1	4.4.2
P1	3 of 5 (60%)	3 of 4 (75%)	2 of 3 (67%)
P2	7 of 23 (30%)	7 of 19 (36%)	5 of 17 (29%)
P3	21 of 84 (25%)	20 of 80 (25%)	18 of 75 (24%)
P4	0 of 11 (0%)	0 of 11 (0%)	0 of 8 (0%)
P5	0 of 3 (0%)	0 of 3 (0%)	0 of 2 (0%)
Total	31 of 126 (25%)	30 of 117 (26%)	25 of 105 (24%)

RQ1: High-Priority Failures Tend to have Reconfiguration Workarounds

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011

Motivation

Failure Avoidance

Study

Results

Conclusions and Future Work

	4.4.0	4.4.1	4.4.2
P1	3 of 5 (60%)	3 of 4 (75%)	2 of 3 (67%)
P2	7 of 23 (30%)	7 of 19 (36%)	5 of 17 (29%)
P3	21 of 84 (25%)	20 of 80 (25%)	18 of 75 (24%)
P4	0 of 11 (0%)	0 of 11 (0%)	0 of 8 (0%)
P5	0 of 3 (0%)	0 of 3 (0%)	0 of 2 (0%)
Total	31 of 126 (25%)	30 of 117 (26%)	25 of 105 (24%)

RQ1: High-Priority Failures Tend to have Reconfiguration Workarounds

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011

Motivation

Failure Avoidance

Study

Results

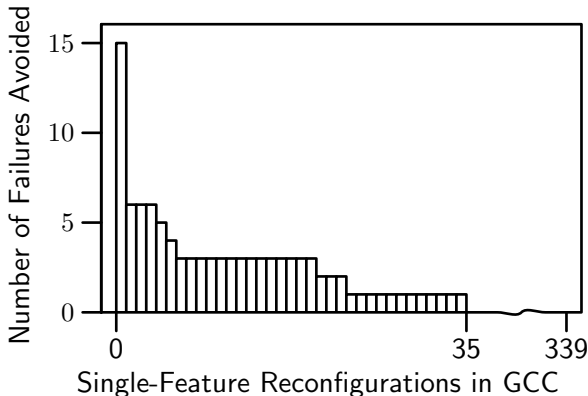
Conclusions and Future Work

	4.4.0	4.4.1	4.4.2
P1	3 of 5 (60%)	3 of 4 (75%)	2 of 3 (67%)
P2	7 of 23 (30%)	7 of 19 (36%)	5 of 17 (29%)
P3	21 of 84 (25%)	20 of 80 (25%)	18 of 75 (24%)
P4	0 of 11 (0%)	0 of 11 (0%)	0 of 8 (0%)
P5	0 of 3 (0%)	0 of 3 (0%)	0 of 2 (0%)
Total	31 of 126 (25%)	30 of 117 (26%)	25 of 105 (24%)

RQ2: Reconfiguration Workarounds Tend to Avoid Multiple Failures

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

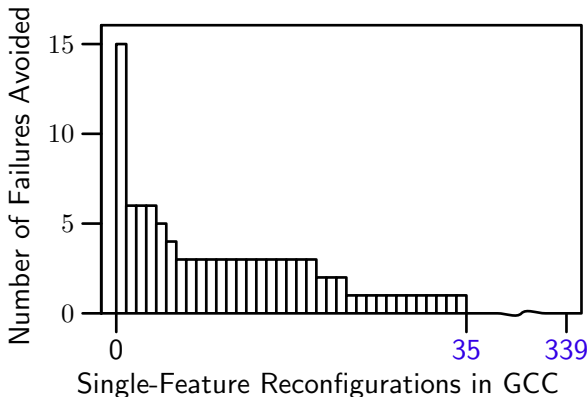
Results

Conclusions and Future Work

RQ2: Reconfiguration Workarounds Tend to Avoid Multiple Failures

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Motivation

Failure Avoidance

Study

Results

Conclusions and Future Work

RQ3: Biased Random Reconfiguration as an Alternative to Algorithm 3

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011

Motivation

Failure Avoidance

Study

Results

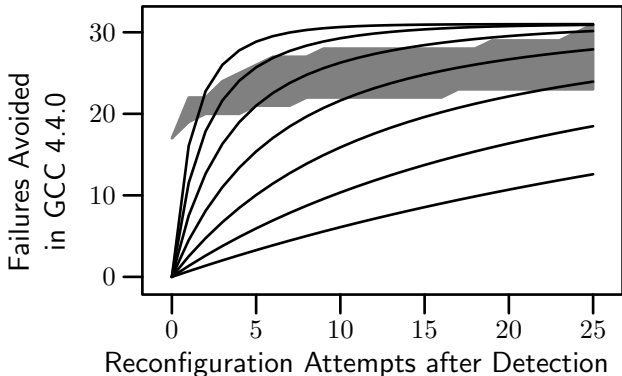
Conclusions and Future Work

- Choose a single-feature reconfiguration randomly, reconfigurations that will fail with probability p and reconfigurations that will succeed with probability q

RQ3: Failure History Tends to Suggest Effective Reconfiguration Workarounds

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Our Technique



Average Case, Biased Random Reconfiguration
with $q/p = 1, 2, 4, 8, 16, 32, 64$

Motivation

Failure Avoidance

Study

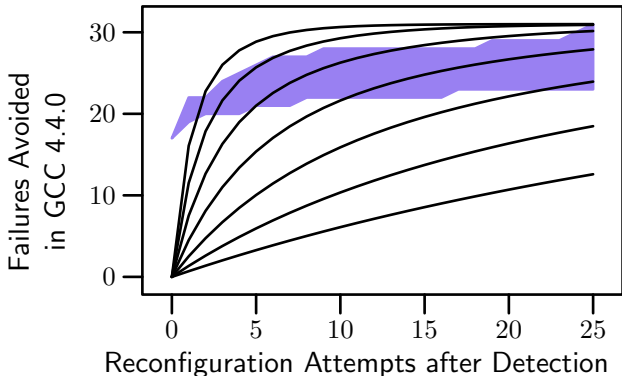
Results

Conclusions and
Future Work

RQ3: Failure History Tends to Suggest Effective Reconfiguration Workarounds

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



■ Our Technique

— Average Case, Biased Random Reconfiguration
with $q/p = 1, 2, 4, 8, 16, 32, 64$

Motivation

Failure Avoidance

Study

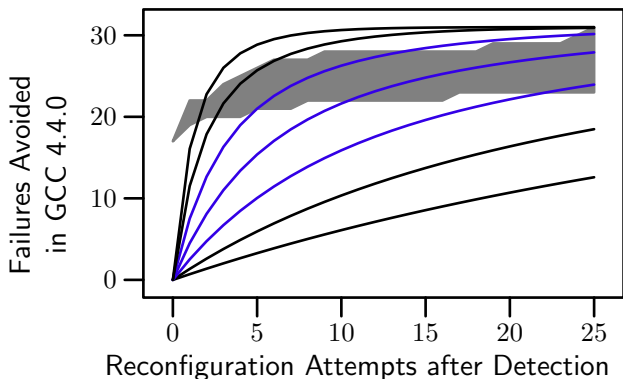
Results

Conclusions and
Future Work

RQ3: Failure History Tends to Suggest Effective Reconfiguration Workarounds

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Our Technique

Average Case, Biased Random Reconfiguration with $q/p = 1, 2, 4, 8, 16, 32, 64$

Motivation

Failure Avoidance

Study

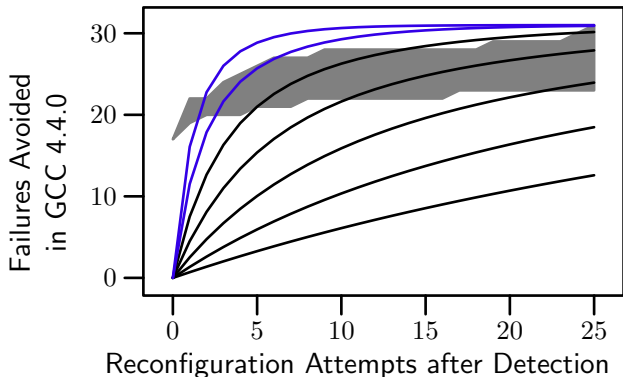
Results

Conclusions and Future Work

RQ3: Failure History Tends to Suggest Effective Reconfiguration Workarounds

Using Feature Locality: Can We Leverage History to Avoid Failures During Reconfiguration?

ASAS 2011



Our Technique

Average Case, Biased Random Reconfiguration with $q/p = 1, 2, 4, 8, 16, 32, 64$

Motivation

Failure Avoidance

Study

Results

Conclusions and Future Work

Outline

Using Feature
Locality: Can We
Leverage History
to Avoid Failures
During
Reconfiguration?

ASAS 2011

- 1 Motivation
- 2 Failure Avoidance
- 3 Study
- 4 Results
- 5 Conclusions and Future Work

Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work

- In systems like GCC, where we can
 - recreate failures,
 - reasonably run test cases under several configurations,
 - and change configuration in the field,feature locality allows us to avoid failures.

Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work

- The next step is to try extending these results to autonomous systems, by
 - identifying autonomous systems with which we can experiment,
 - generalizing the approach to accommodate those systems,
 - and incorporating our algorithms into the utility function that drives adaptation.

Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work

- This work is supported in part by the National Science Foundation through awards CNS-0720654, CCF-0747009, CCF-0915526, and CFDA-47.076, by the Air Force Office of Scientific Research through awards FA9550-09-1-0129 and FA9550-09-1-0687, the National Aeronautics and Space Administration under grant number NNX08AV20A.
- Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the position or policy of NSF, AFOSR, or NASA.

Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work

Jump to Slide (1-52)

Using Feature
Locality: Can We
Leverage History
to Avoid Failures
During
Reconfiguration?

ASAS 2011

Slide 1

Slide 2

Slide 3

Slide 4

Slide 5

Slide 6

Slide 7

Slide 8

Slide 9

Slide 10

Slide 11

Slide 12

Slide 13

Slide 14

Slide 15

Slide 16

Slide 17

Slide 18

Slide 19

Slide 20

Slide 21

Slide 22

Slide 23

Slide 24

Slide 25

Slide 26

Slide 27

Slide 28

Slide 29

Slide 30

Slide 31

Slide 32

Slide 33

Slide 34

Slide 35

Slide 36

Slide 37

Slide 38

Slide 39

Slide 40

Slide 41

Slide 42

Slide 43

Slide 44

Slide 45

Slide 46

Slide 47

Slide 48

Slide 49

Slide 50

Slide 51

Slide 52

Motivation

Failure Avoidance

Study

Results

Conclusions and
Future Work