Automatic Reliability Testing for Cluster Management Controllers

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https://github.com/sieve-project/sieve

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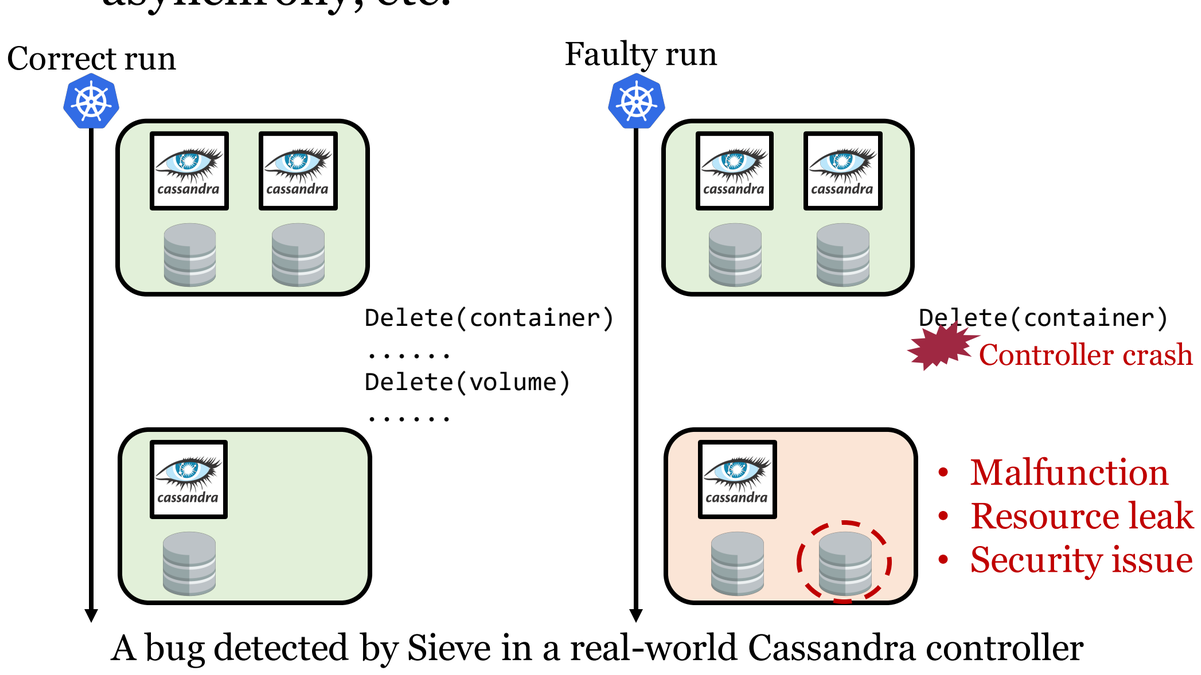
1. CONTRIBUTIONS

- Sieve: the *first* automatic reliability-testing tool for *unmodified* cluster management controllers
  - Perturbing the controller's view of the cluster state
  - Applying differential oracles to automatically flag buggy behavior
- Sieve has detected **46** *new* bugs (**35** confirmed and **22** fixed) in **10** popular controllers
  - Sieve can reliably reproduce the detected bugs

2. BACKGROUND & MOTIVATION

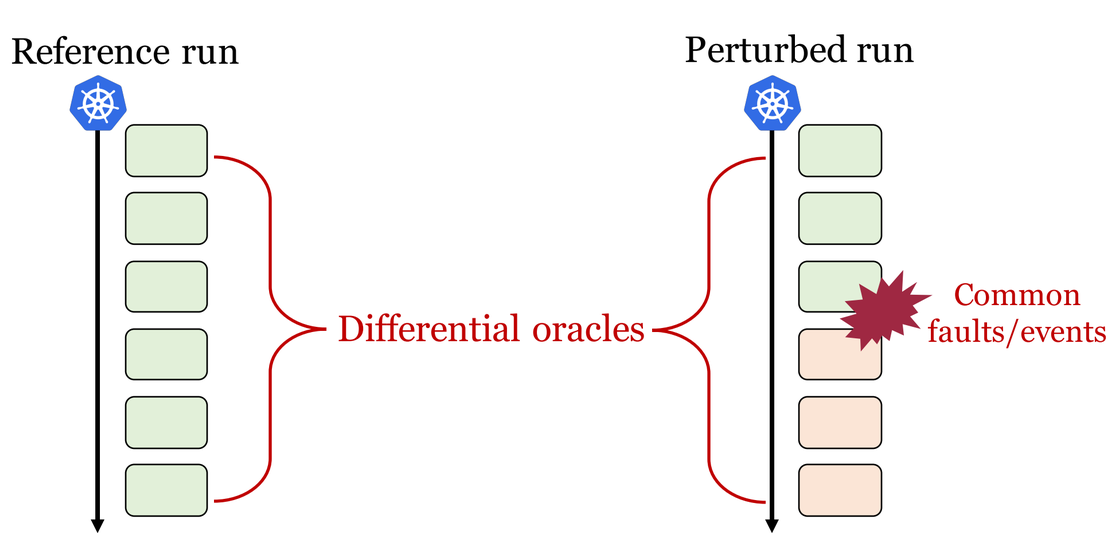
- Modern datacenter infrastructures are managed by cluster management controllers
  - Controllers implement **state reconciliation**
- Controller reliability is **critical** but **challenging**
  - Controllers run in distributed environments and need to tolerate unexpected faults, network issues, asynchrony, etc.



A bug detected by Sieve in a real-world Cassandra controller

3. KEY IDEAS

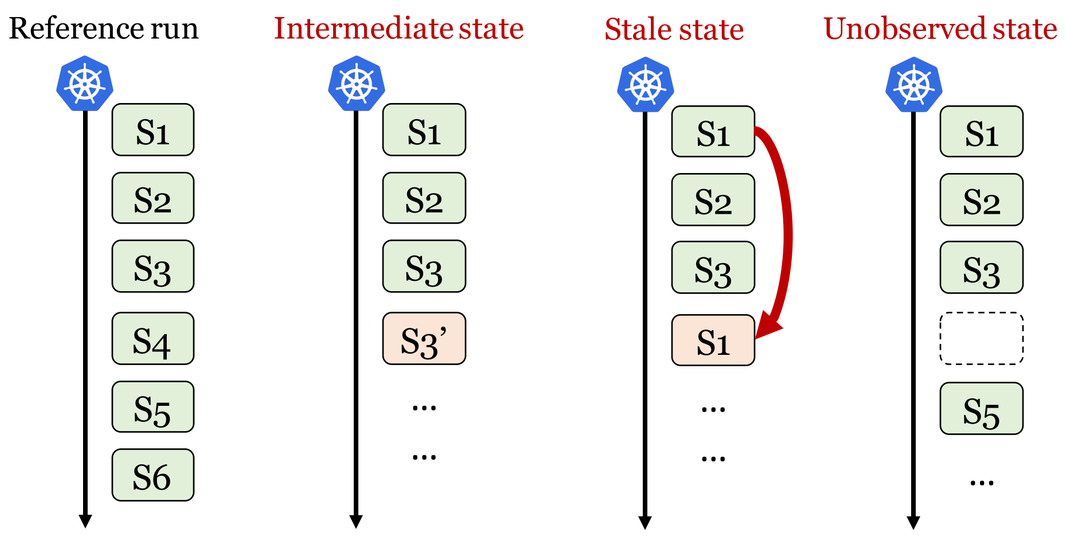
1. Perturbing the controller's view of the cluster state
   - Three perturbation patterns
   - Exhaustive perturbations for each pattern
   - Effective pruning of inefficient perturbations
2. Applying differential oracles to flag buggy behavior
   - Effective in flagging non-crashing symptoms
   - Checking both end states and state updates



- **Usability**: Applicable to unmodified controllers
- **Reproducibility**: Reliably reproduce detected bugs

4. PERTURBATION PATTERNS

- **Intermediate state:** crashing the controller in the middle of a reconciliation
- **Stale state:** making the controller operate on stale state by reconnecting it to a stale API server
- **Unobserved state:** making the controller miss a state by injecting delay to the controller



Generating tests to exhaustively cover all perturbations and pruning out ineffective perturbations.

5. EVALUATION

Applied Sieve to **10** popular Kubernetes controllers

Controller	Intermediate state bugs	Stale state bugs	Unobserved state bugs	Indirect bugs	Total
cass-operator	2	1	0	0	3
cassandra-operator	0	2	1	2	5
casskop	1	2	1	0	4
elastic-operator	0	2	0	0	2
mongodb-operator	2	3	1	3	9
nifikop	2	0	0	1	3
rabbitmq-operator	1	2	1	0	4
xtradb-operator	3	3	1	0	7
yugabyte-operator	0	2	1	2	5
zookeeper-operator	0	2	1	1	4
Total	**11**	**19**	**7**	**9**	**46**

- Found **46** new bugs (**35** confirmed; **22** fixed)
- Pruned out **46% - 99%** perturbations
- Tested each controller within a **nightly** run
- Low false-positive rate of **3.5%**