Automated Debugging In Data Intensive Scalable Computing Systems

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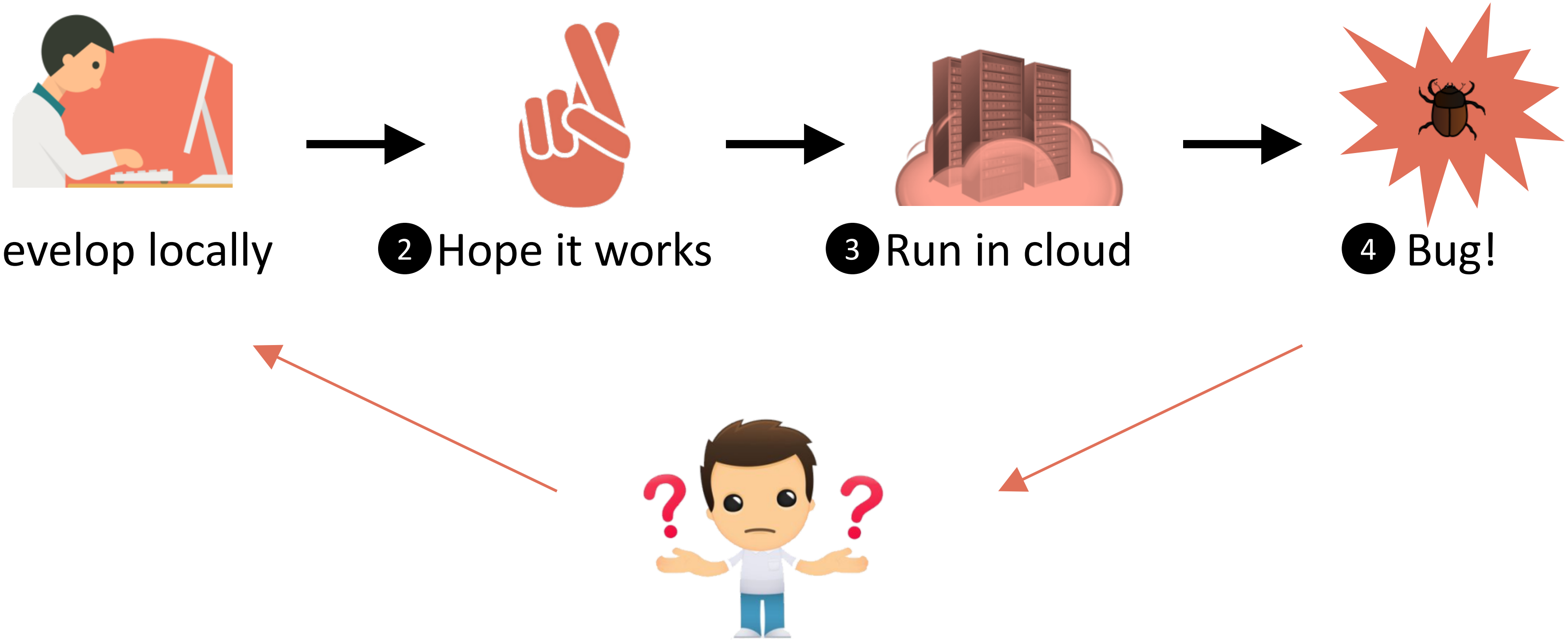
Big Data Debugging in the Dark



1 Develop locally

2 Hope it works

3 Run in cloud

4 Bug!

5 Guesswork

Google

Map Reduce

hadoop

Spark

HIVE

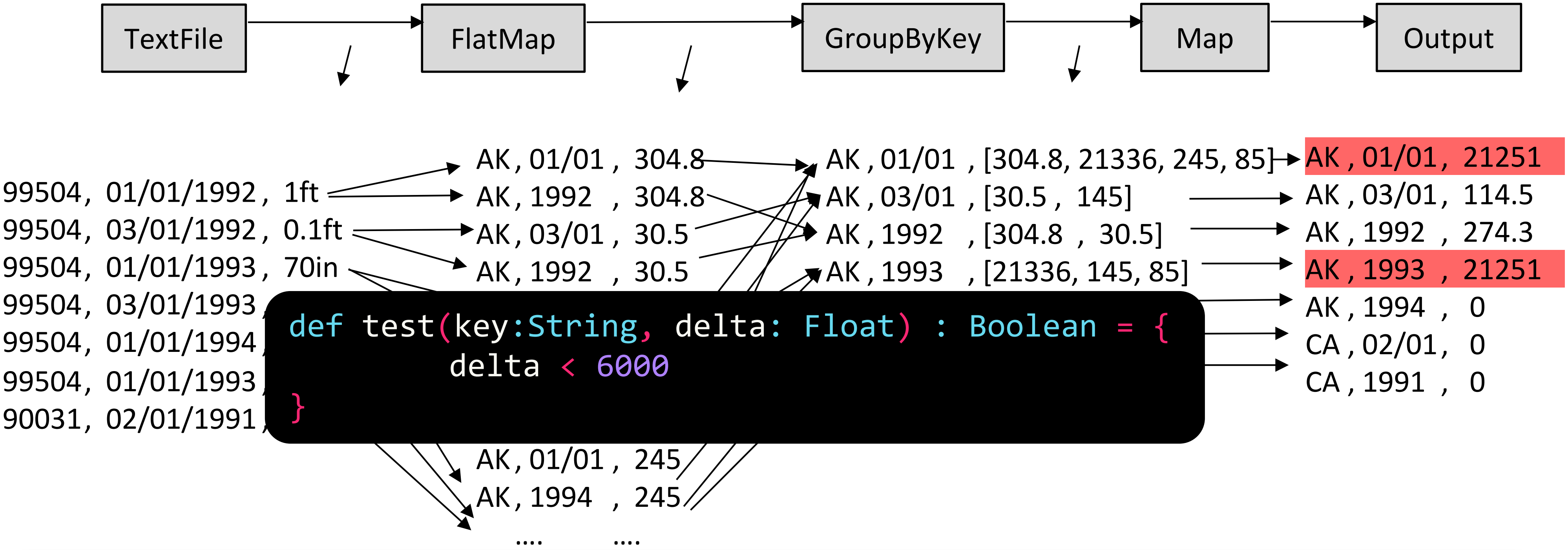
Motivating Example

- Alice writes a Spark program that identifies, **for each state** in the US, the **delta between the minimum and the maximum** snowfall reading for **each day of any year** and **for any particular year**.

Zip Code	Date	Snowfall
99504	01/01/1994	245mm
99504	01/01/1993	85mm
90031	02/01/1991	0mm
…	…	…

Problem Definition

- Using a test function, a user can specify incorrect results



TextFile → FlatMap → GroupByKey → Map → Output

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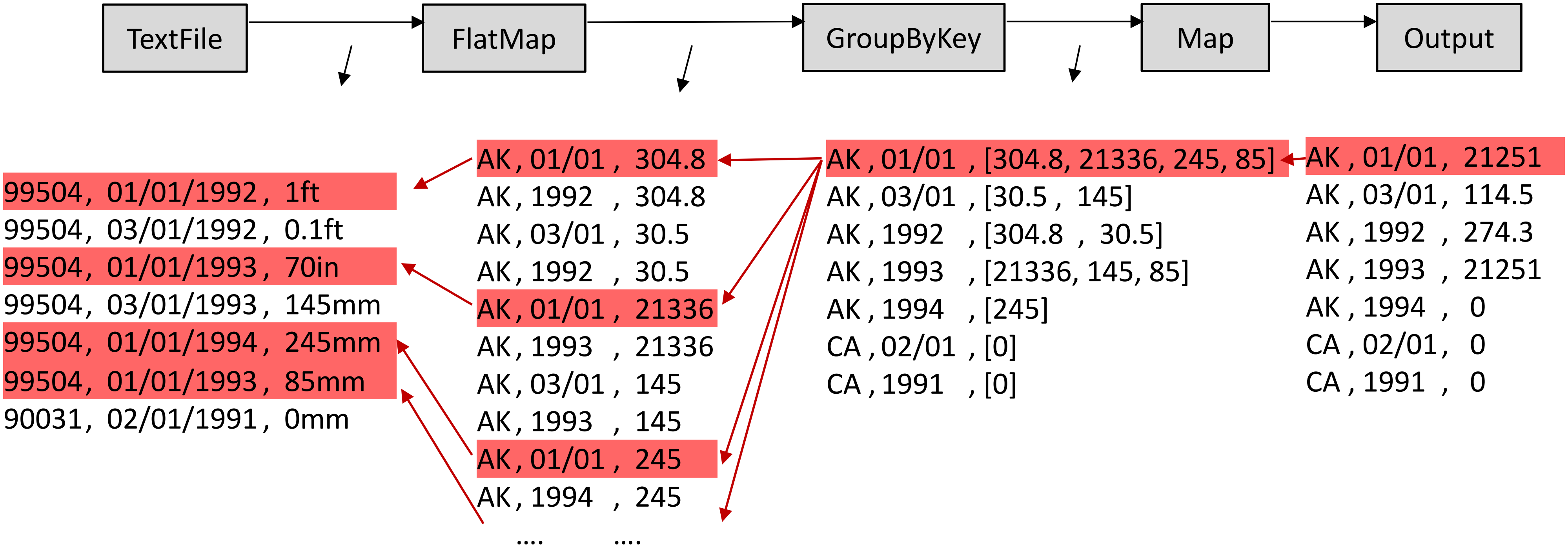
AK, 1992 , 274.3
AK, 1993 , 21251
AK, 1994 , 0
CA, 02/01, 0
CA, 1991 , 0

```
def test(key:String, delta: Float) : Boolean = {
          delta < 6000
}
```

Given a test function, the goal is to identify a minimum subset of the input that is able to reproduce the same test failure.

Existing Approach 1: Data Provenance for Spark



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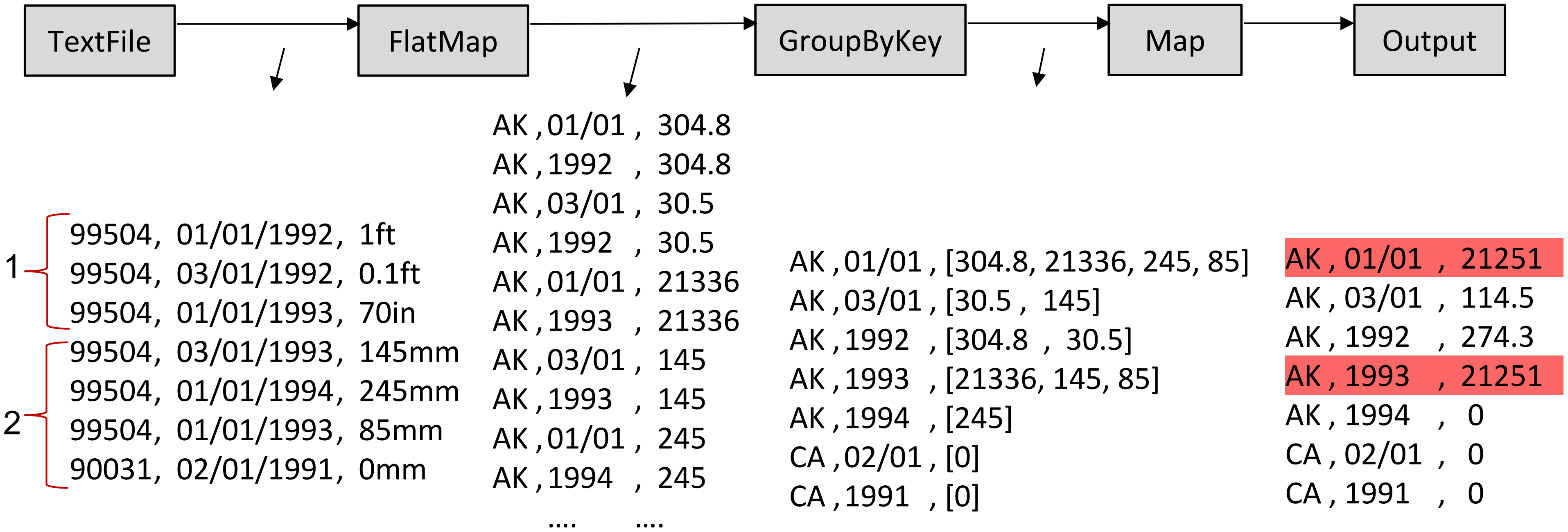
It over-approximates the scope of failure-inducing inputs *i.e.* records in the faulty key-group are all marked as faulty

Existing Approach 2: Delta Debugging

- Delta Debugging performs a systematic binary search-like procedure on the input dataset using a test oracle function



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It does not prune input records known to be irrelevant because of the lack of semantic understanding of data-flow operators

Existing Approach 2: Delta Debugging

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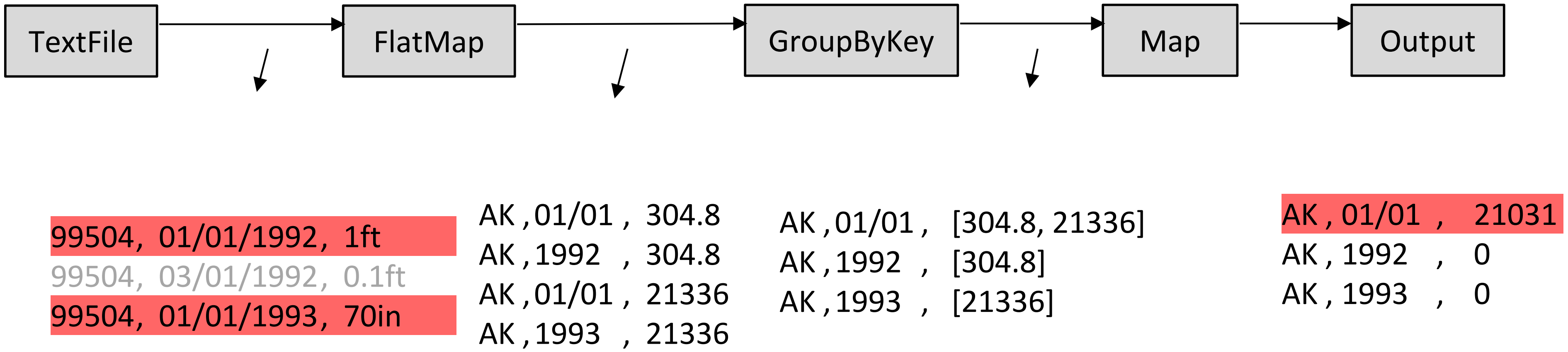

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AK , 01/01 , 21031
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AK , 1993 , 0

Run 9

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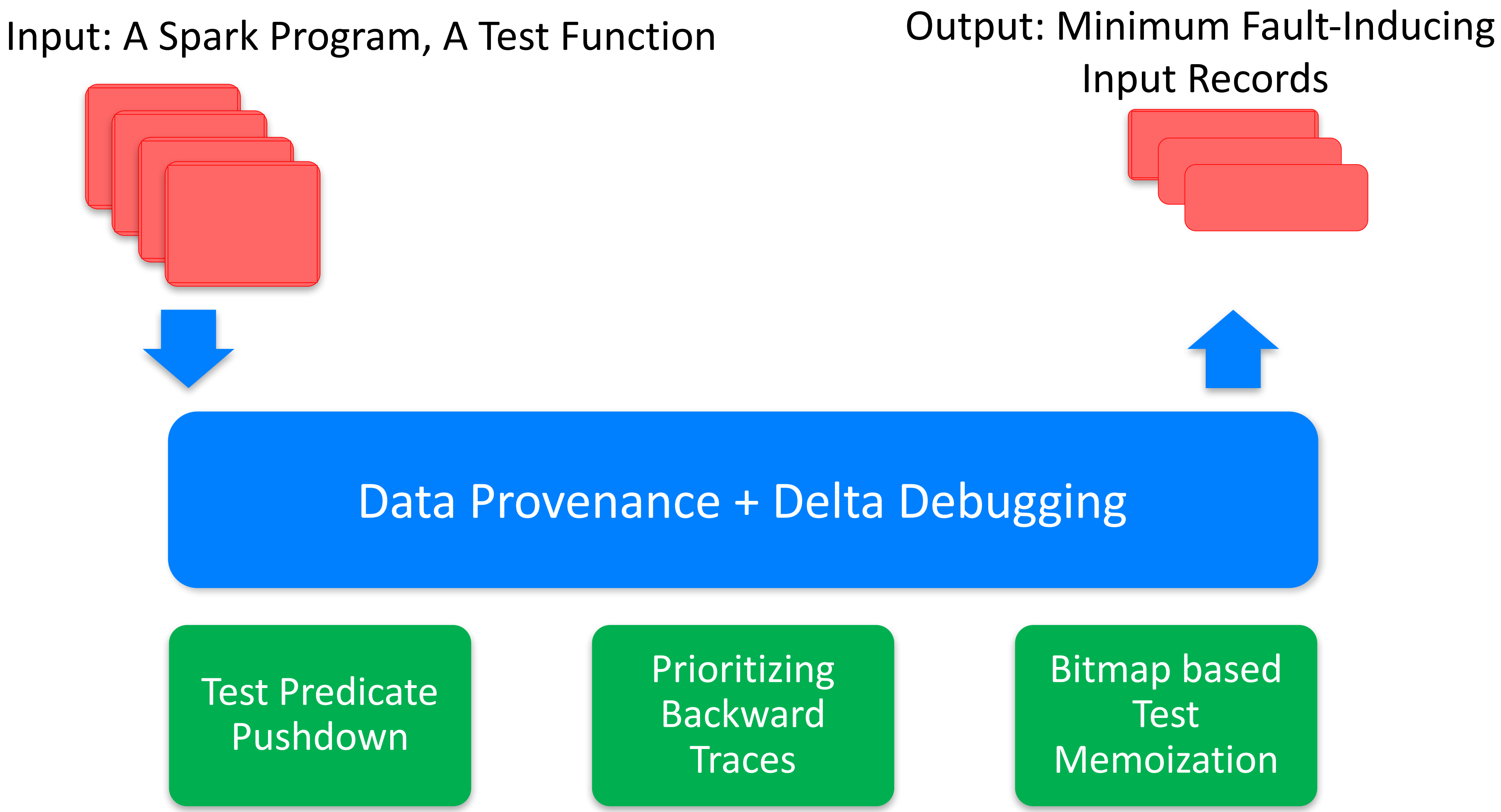
Automated Debugging in DISC with BigSift



Input: A Spark Program, A Test Function

Output: Minimum Fault-Inducing Input Records

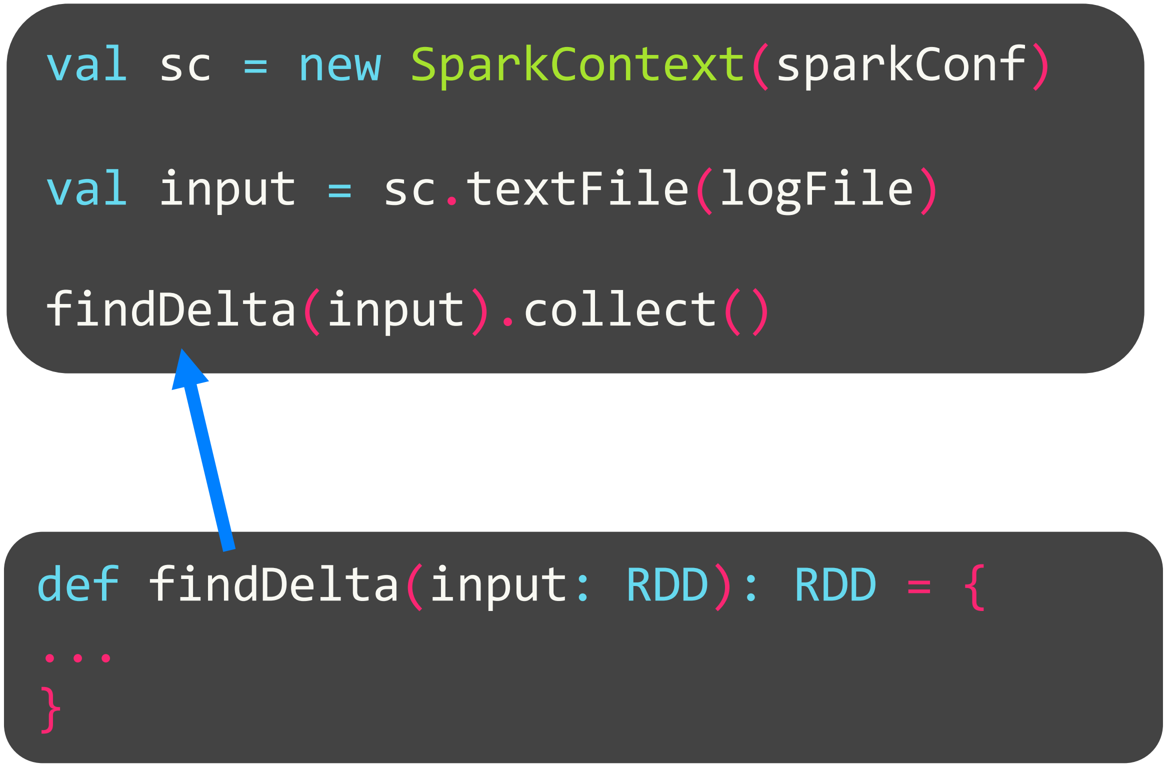
Data Provenance + Delta Debugging

Test Predicate Pushdown

Prioritizing Backward Traces

Bitmap based Test Memoization

A sample dataflow program



```
val sc = new SparkContext(sparkConf)

val input = sc.textFile(logFile)

findDelta(input).collect()
```

```
def findDelta(input: RDD): RDD = {
...
}
```

Invocation of dataflow program in Apache Spark

Dataflow program that returns the transformed input data

Invoking BigSift’s API

```
val sc= new SparkContext(sparkConf)

+ val bsift = new BigSift(sc, logFile)

+ bsift.runWithBigSift[_,_](findDelta)
```

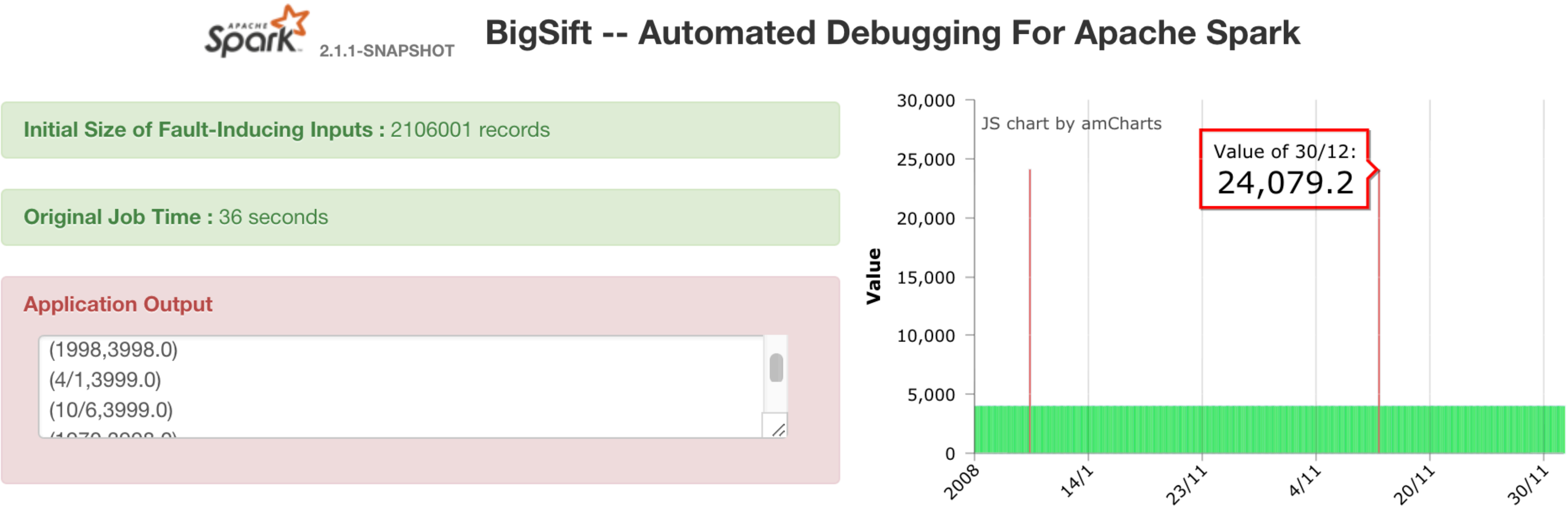
BigSift can used by initiating **BigSift** object and then invoking API **runWithBigSift** with the program method.

```
def findDelta(input: RDD): RDD = {
...
}
```

Dataflow program that returns the transformed input data

BigSift’s Interactive User Interface

- After invoking BigSift programmatically, a user can interact with BigSift’s UI at port 8989.
- When the program completes, BigSift visualizes the output and reports the execution time as well as input data size.



2.1.1-SNAPSHOT

BigSift -- Automated Debugging For Apache Spark

Initial Size of Fault-Inducing Inputs : 2106001 records

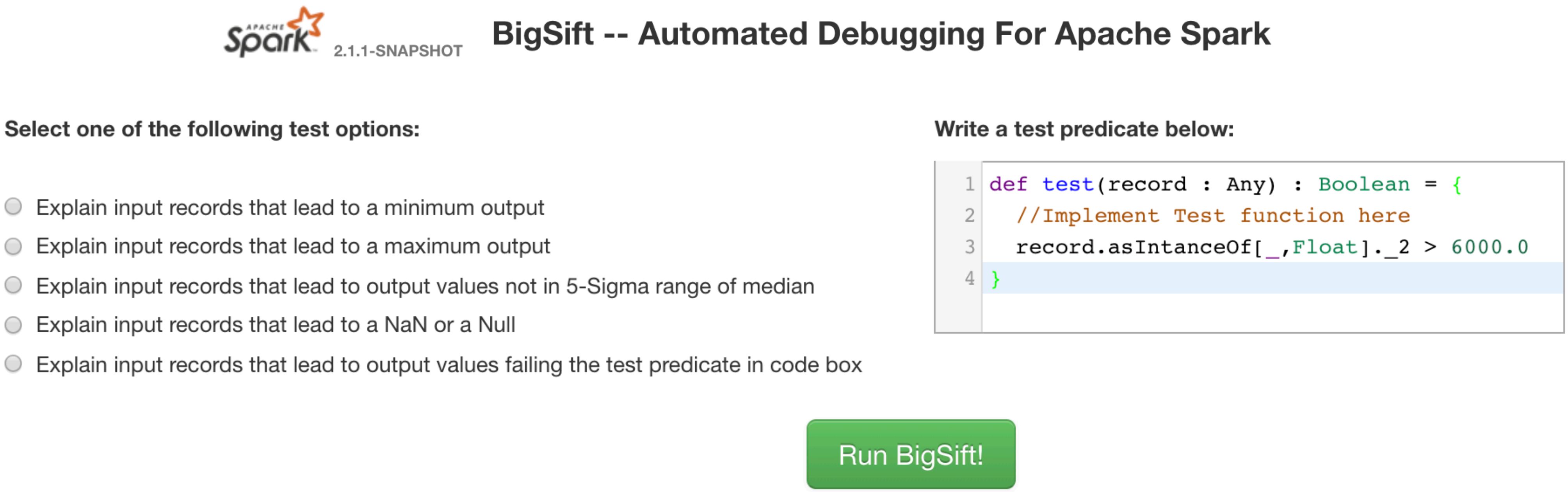
Original Job Time : 36 seconds

Application Output

```
(1998,3998.0)
(4/1,3999.0)
(10/6,3999.0)
```

Defining Test Oracle Function Interactively

- A user can write a predicate to be applied to each final output record to distinguish correct outputs from incorrect.
- BigSift also enables user to choose from a list of pre-defined test predicate functions



BigSift -- Automated Debugging For Apache Spark

Select one of the following test options:

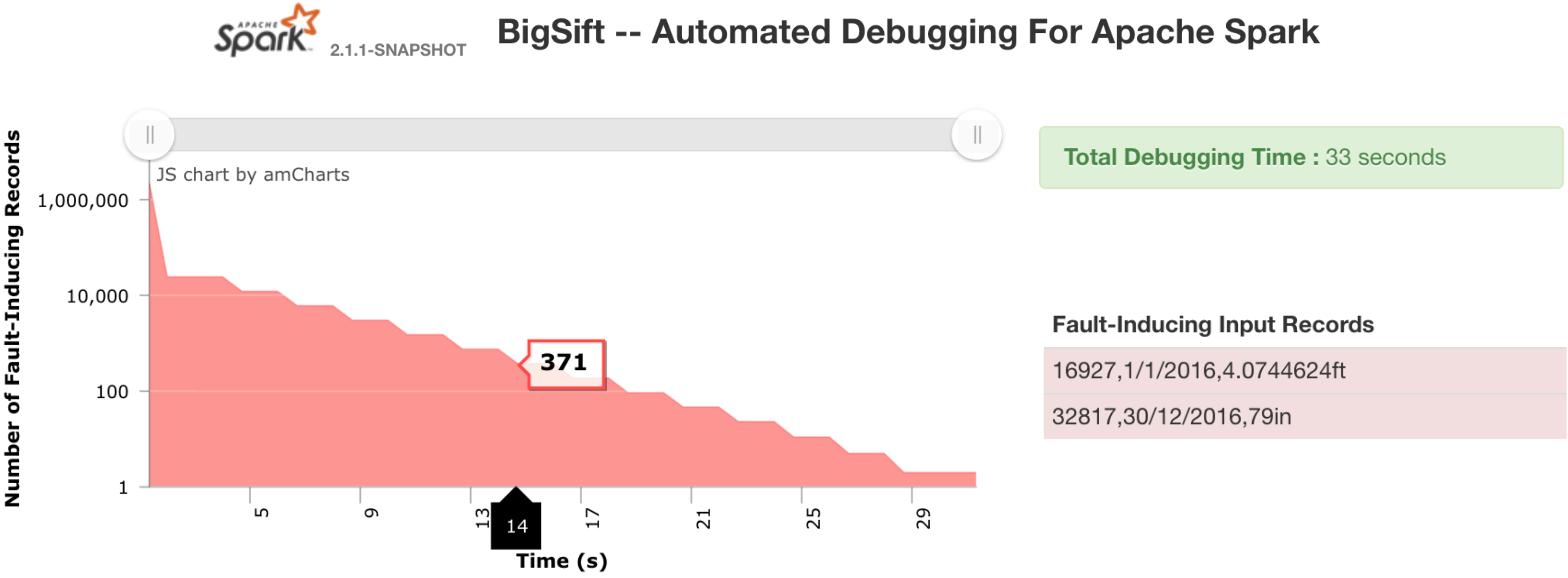
- ○ Explain input records that lead to a minimum output
- ○ Explain input records that lead to a maximum output
- ○ Explain input records that lead to output values not in 5-Sigma range of median
- ○ Explain input records that lead to a NaN or a Null
- ○ Explain input records that lead to output values failing the test predicate in code box

Write a test predicate below:

```
def test(record : Any) : Boolean = {
  //Implement Test function here
  record.asIntanceOf[_,Float]._2 > 6000.0
}
```

Real-time Automated Debugging

- When user submits test predicate, BigSift shows real-time area chart and stream debugging progress from the cloud.
- A user can click on any part of the chart to view sample fault-inducing input records at the selected time.



2.1.1-SNAPSHOT

BigSift -- Automated Debugging For Apache Spark

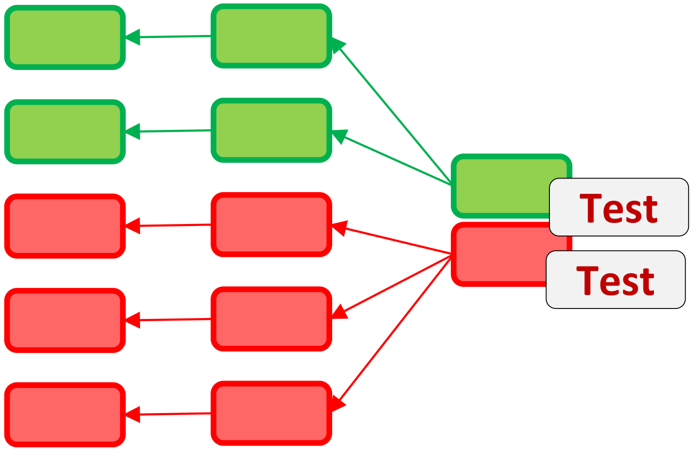
Total Debugging Time : 33 seconds

Fault-Inducing Input Records
16927,1/1/2016,4.0744624ft
32817,30/12/2016,79in

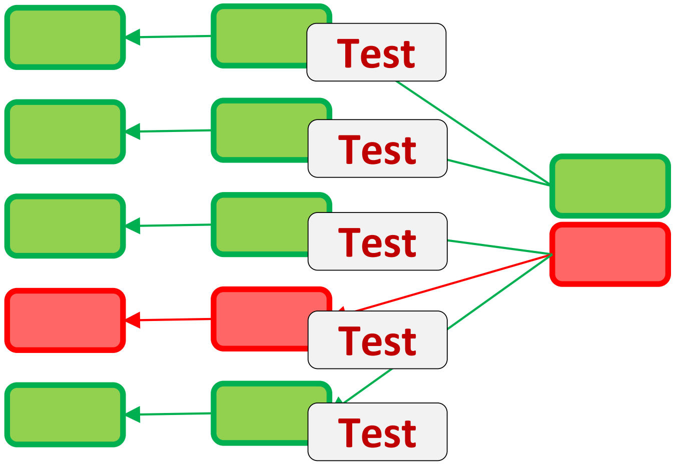
Live Demonstration

Optimization 1: Test Predicate Pushdown

- **Observation:** During backward tracing, data provenance traces through all partitions even though only a few partitions contain faulty intermediate data.



Without Test Pushdown

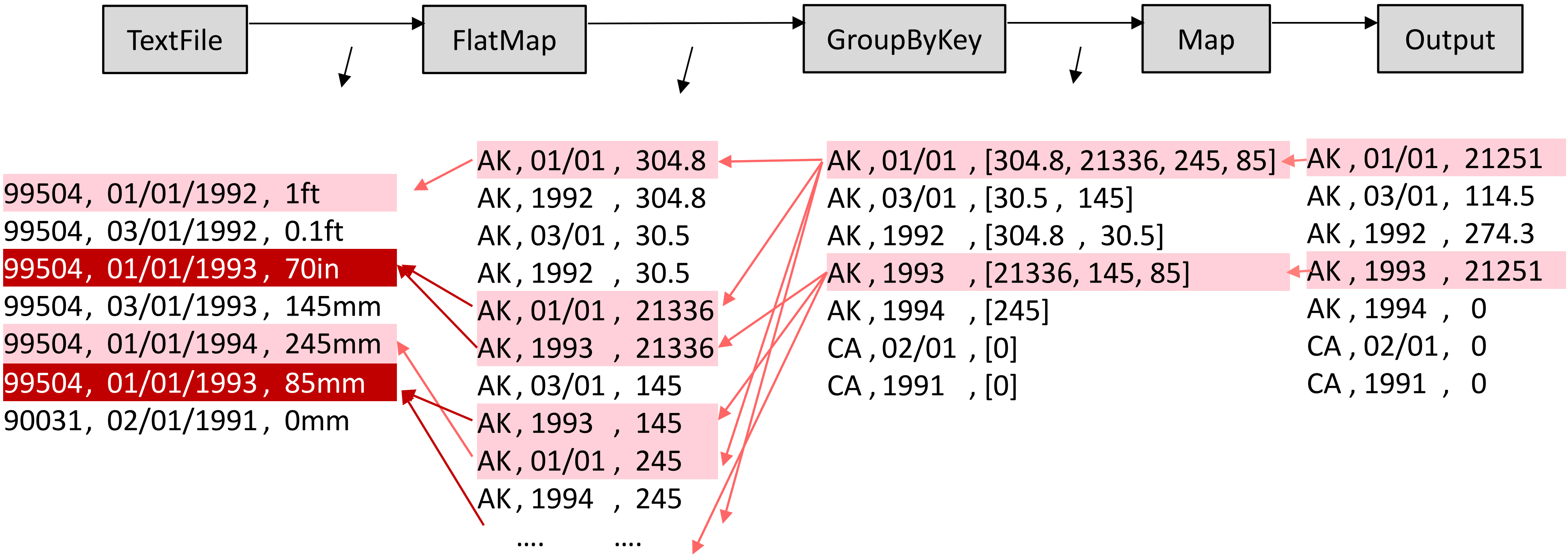


With Test Pushdown

If applicable, BigSift pushes down the test function to test the output of combiners in order to isolate the faulty partitions.

Optimization 2: Prioritizing Backward Traces

- **Observation:** The same faulty input record may contribute to multiple faulty output due to operators such as Join or Flatmap



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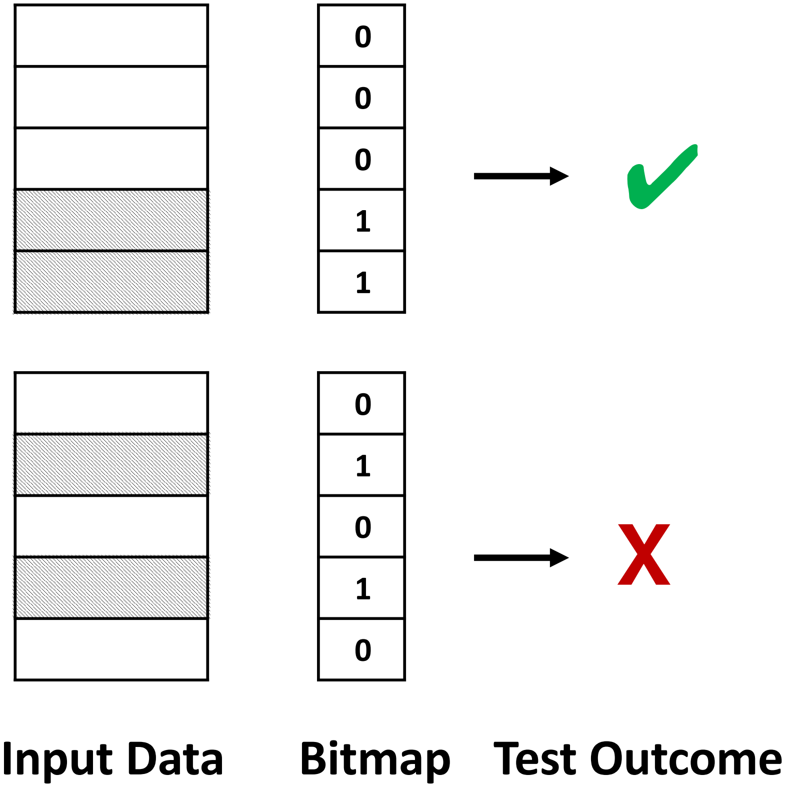
In case of multiple faulty outputs, BigSift overlaps two backward traces to minimize the scope of fault-inducing input records

Optimization 3: Bitmap Based Test Memoization

- **Observation:** Delta debugging may try running a program on the same subset of input redundantly.
- BigSift leverages bitmap to compactly encode the offsets of original input to refer to an input subset



We use a bitmap based test memoization technique to avoid redundant testing of the same input dataset.

Evaluation: Performance Improvement

Subject Program		Running Time (sec)	Debugging Time (sec)		
Subject Program	Fault	Original Job	DD	BigSift	Improvement
Movie Histogram	Code	56.2	232.8	17.3	13.5X
Inverted Index	Code	107.7	584.2	13.4	43.6X
Rating Histogram	Code	40.3	263.4	16.6	15.9X
Sequence Count	Code	356.0	13772.1	208.8	66.0X
Rating Frequency	Code	77.5	437.9	14.9	29.5X
College Student	Data	53.1	235.3	31.8	7.4X
Weather Analysis	Data	238.5	999.1	89.9	11.1X
Transit Analysis	Code	45.5	375.8	20.2	18.6X

BigSift provides up to a 66X speed up in isolating the precise fault-inducing input records, in comparison to the baseline DD

Evaluation: Debugging Time vs. Original Job Time

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On average, BigSift takes 62% less time to debug a single faulty output than the time taken for a single run on the entire data.

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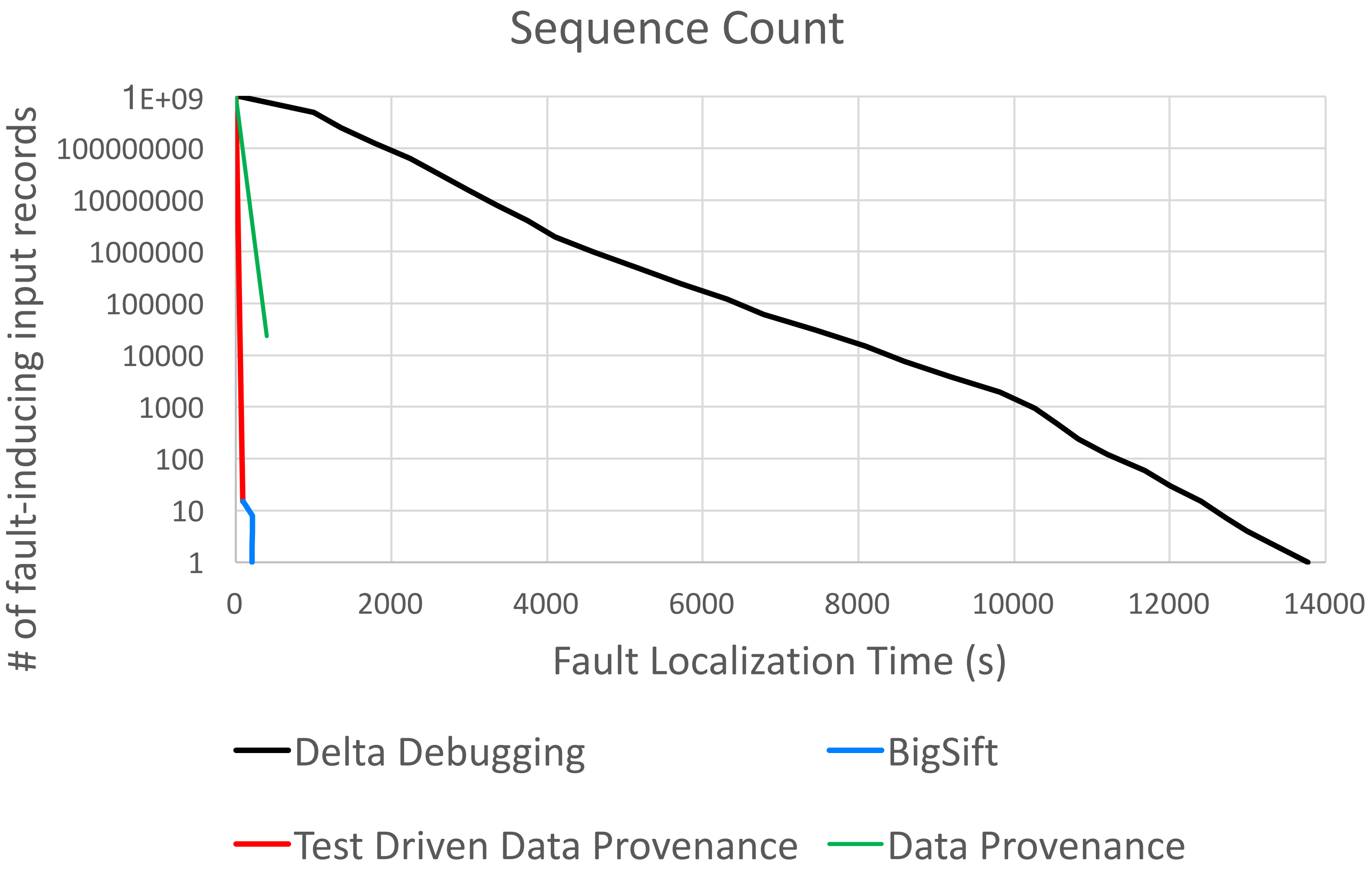

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Conclusion

- BigSift is the first piece of work in automated debugging of big data analytics in DISC.
- It provides up to **66X speed up** in debugging time over baseline Delta Debugging.
- In our evaluation we have observed that, on average, BigSift finds the faulty input in **62% less** than the original job execution time.

Questions?