Spell: Streaming Parsing of System Event Logs

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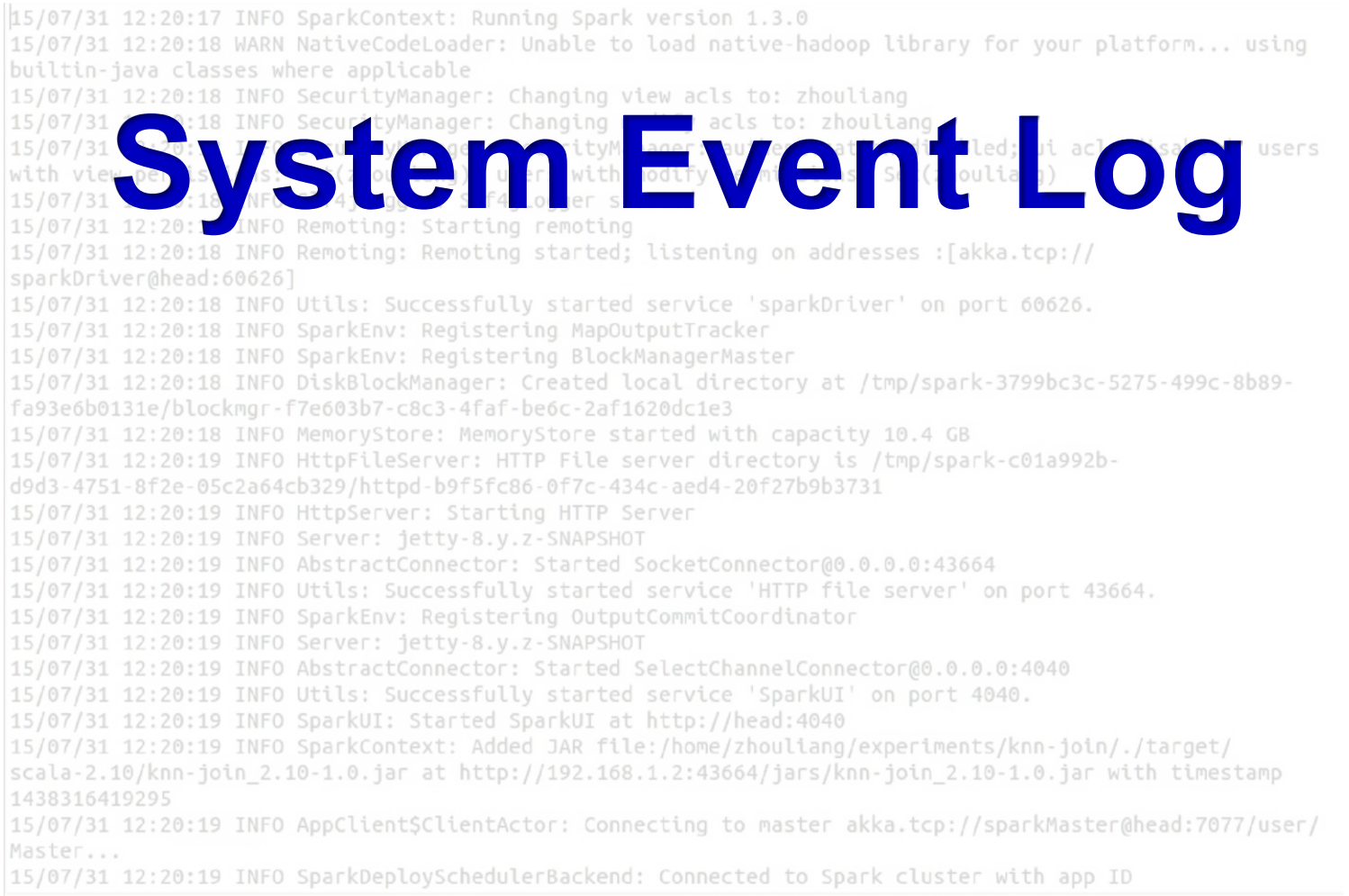
School of Computing,

University of Utah

Background

```
15/07/31 12:20:17 INFO SparkContext: Running Spark version 1.3.0
15/07/31 12:20:18 WARN NativeCodeLoader: Unable to load native-hadoop library for your platform... using
builtin-java classes where applicable
15/07/31 12:20:18 INFO SecurityManager: Changing view acls to: zhouliang
15/07/31 12:20:18 INFO SecurityManager: Changing modify acls to: zhouliang
15/07/31 12:20:18 INFO SecurityManager: SecurityManager: authentication disabled; ui acls disabled; users
with view permissions: Set(zhouliang); users with modify permissions: Set(zhouliang)
15/07/31 12:20:18 INFO Slf4jLogger: Slf4jLogger started
15/07/31 12:20:18 INFO Remoting: Starting remoting
15/07/31 12:20:18 INFO Remoting: Remoting started; listening on addresses :[akka.tcp://
sparkDriver@head:60626]
15/07/31 12:20:18 INFO Utils: Successfully started service 'sparkDriver' on port 60626.
15/07/31 12:20:18 INFO SparkEnv: Registering MapOutputTracker
15/07/31 12:20:18 INFO SparkEnv: Registering BlockManagerMaster
15/07/31 12:20:18 INFO DiskBlockManager: Created local directory at /tmp/spark-3799bc3c-5275-499c-8b89-
fa93e6b0131e/blockmgr-f7e603b7-c8c3-4faf-be6c-2af1620dc1e3
15/07/31 12:20:18 INFO MemoryStore: MemoryStore started with capacity 10.4 GB
15/07/31 12:20:19 INFO HttpFileServer: HTTP File server directory is /tmp/spark-c01a992b-
d9d3-4751-8f2e-05c2a64cb329/httpd-b9f5fc86-0f7c-434c-aed4-20f27b9b3731
15/07/31 12:20:19 INFO HttpServer: Starting HTTP Server
15/07/31 12:20:19 INFO Server: jetty-8.y.z-SNAPSHOT
15/07/31 12:20:19 INFO AbstractConnector: Started SocketConnector@0.0.0.0:43664
15/07/31 12:20:19 INFO Utils: Successfully started service 'HTTP file server' on port 43664.
15/07/31 12:20:19 INFO SparkEnv: Registering OutputCommitCoordinator
15/07/31 12:20:19 INFO Server: jetty-8.y.z-SNAPSHOT
15/07/31 12:20:19 INFO AbstractConnector: Started SelectChannelConnector@0.0.0.0:4040
15/07/31 12:20:19 INFO Utils: Successfully started service 'SparkUI' on port 4040.
15/07/31 12:20:19 INFO SparkUI: Started SparkUI at http://head:4040
15/07/31 12:20:19 INFO SparkContext: Added JAR file:/home/zhouliang/experiments/knn-join/./target/
scala-2.10/knn-join_2.10-1.0.jar at http://192.168.1.2:43664/jars/knn-join_2.10-1.0.jar with timestamp
1438316419295
15/07/31 12:20:19 INFO AppClient$ClientActor: Connecting to master akka.tcp://sparkMaster@head:7077/user/
Master...
15/07/31 12:20:19 INFO SparkDeploySchedulerBackend: Connected to Spark cluster with app ID
```

Background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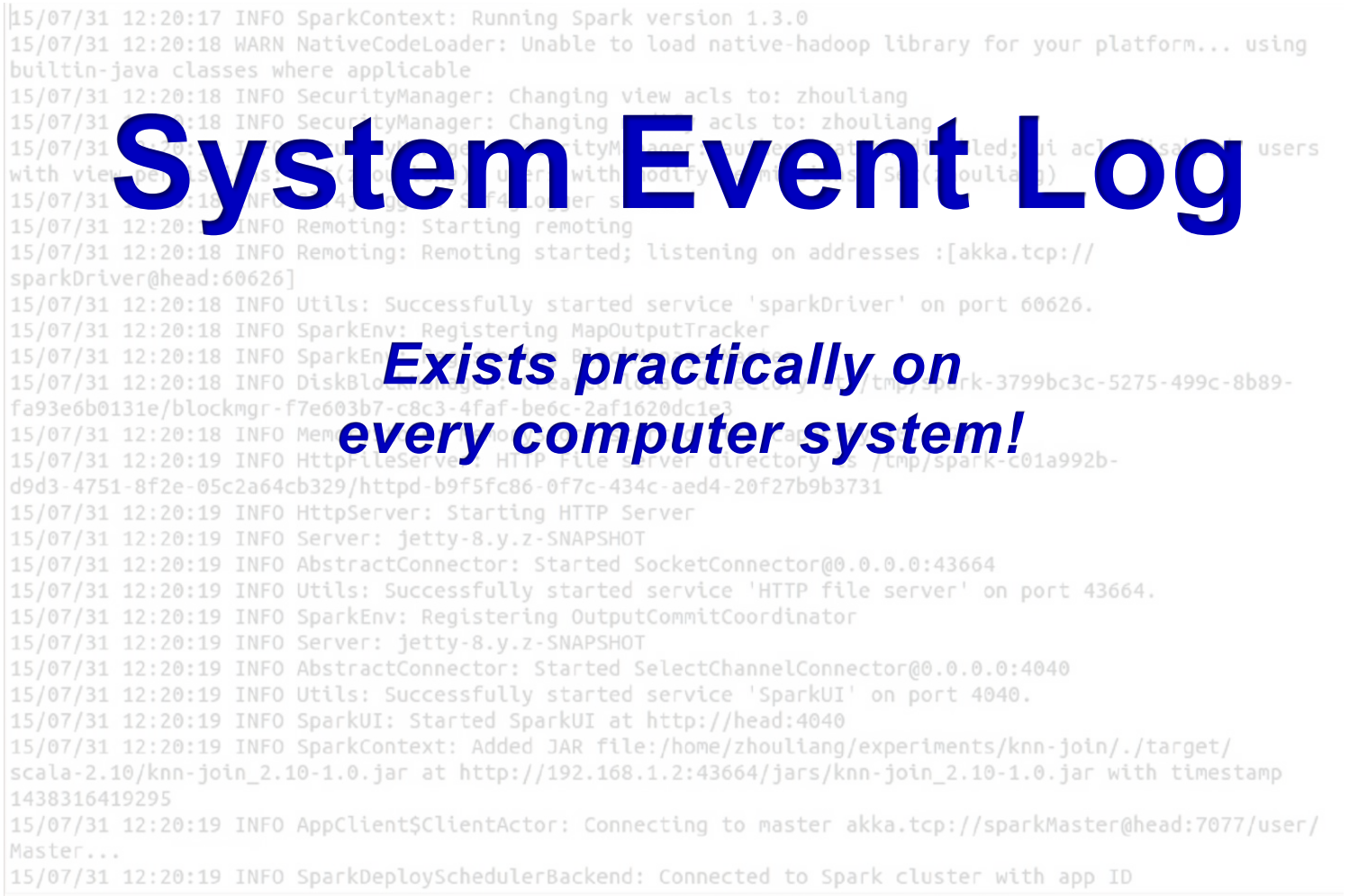

System Event Log

Exists practically on every computer system!

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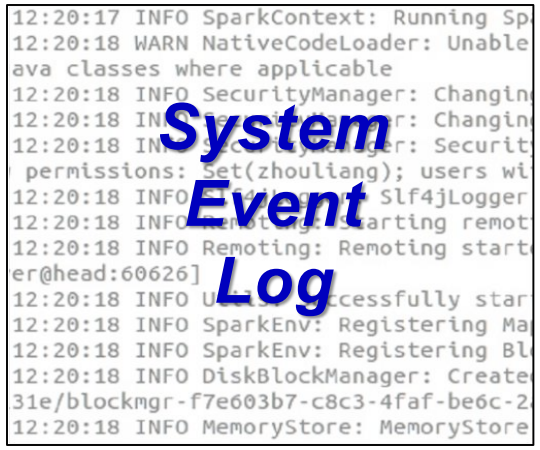
Automatic Analysis?

Background



Started service A on port 80

Started service B on port 90

Started service C on port 100

Executor updated: app-1 is now LOADING

Executor updated: app-2 is now LOADING

TaskSetManager: Starting task 0 in stage 2

TaskSetManager: Starting task 1 in stage 5

……

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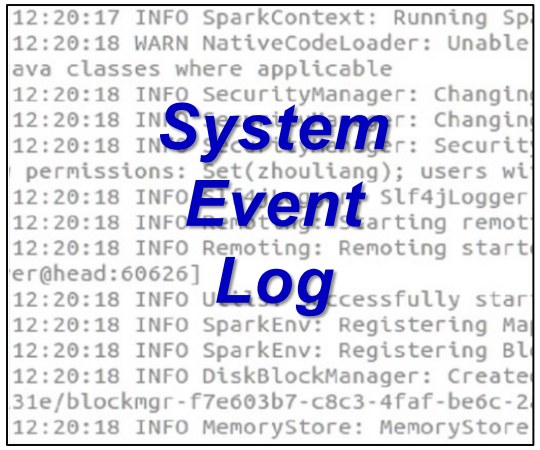

System Event Log

Structured Data

Message/Event type
Log key
……

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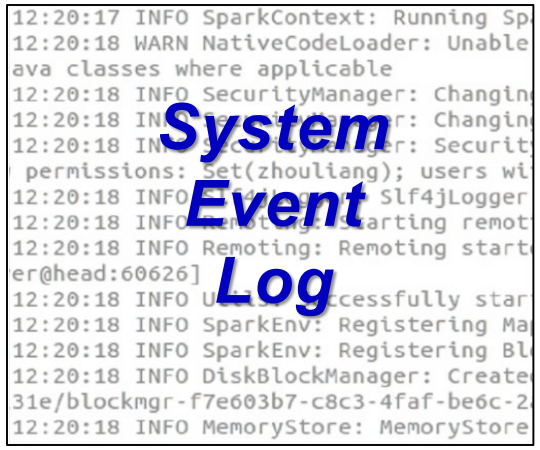

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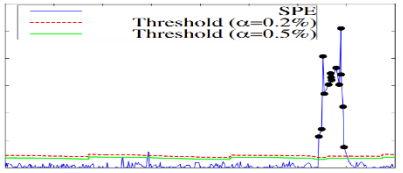

L O G A N A L Y S I S

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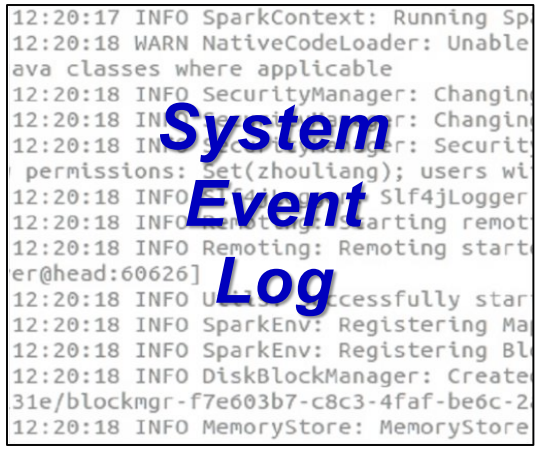

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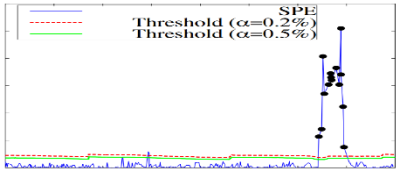

L O G A N A L Y S I S

- **Message count vector:**
  Xu'SOSP09, Lou'ATC10, Lin'ICSE16, etc.

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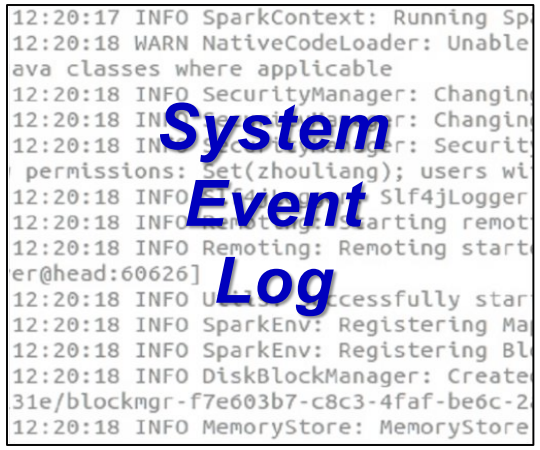

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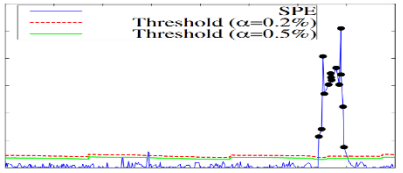

L O G A N A L Y S I S

- **Message count vector:**
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- **Build workflow model:**
  Lou'KDD10, Beschastnikh'ICSE14, Yu'ASPLOS16, etc.

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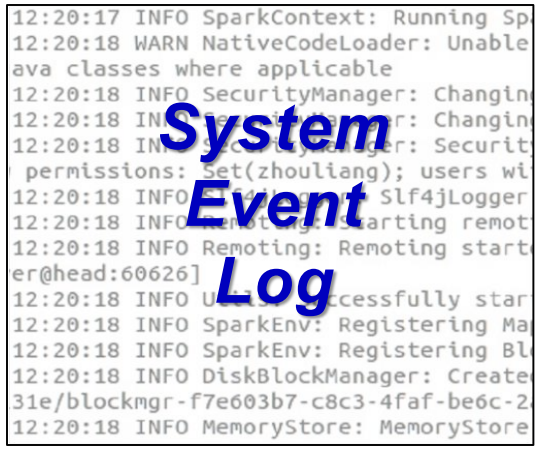

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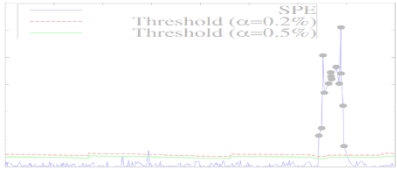

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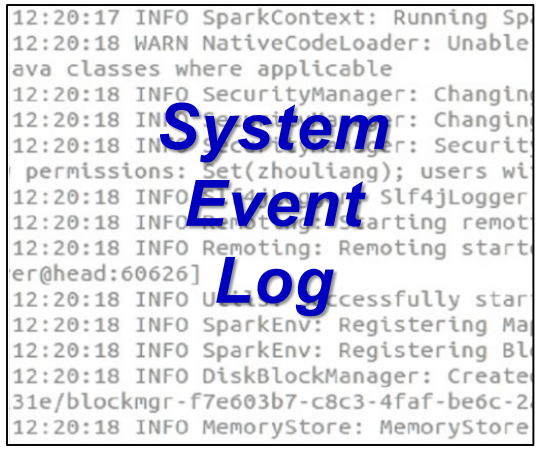

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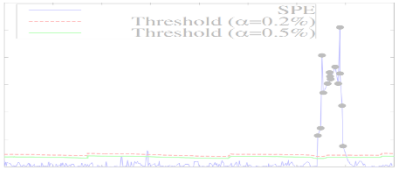

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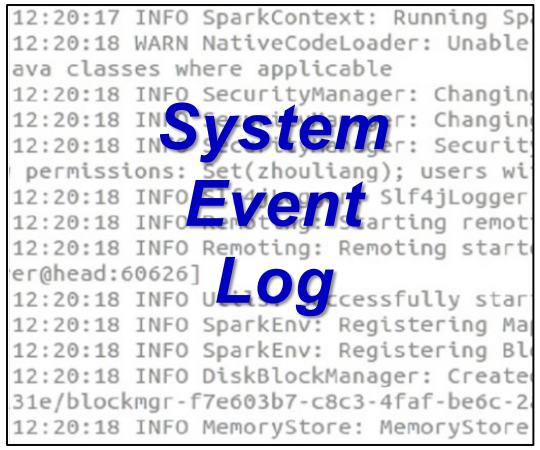

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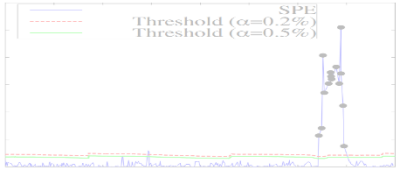

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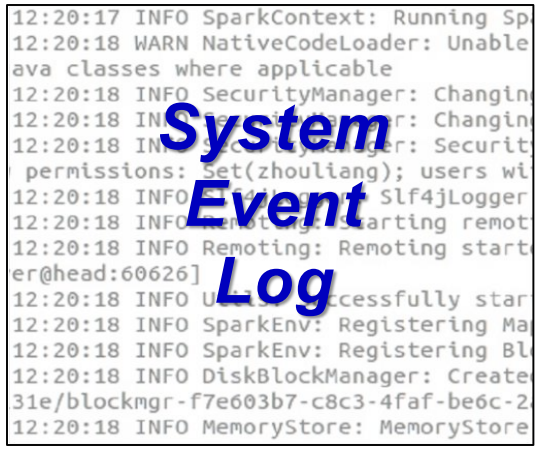

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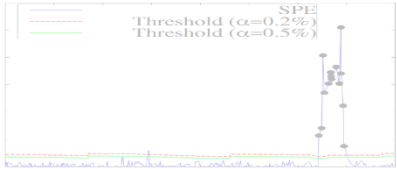

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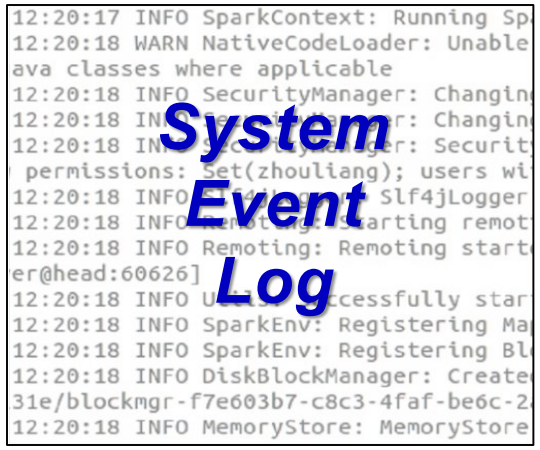

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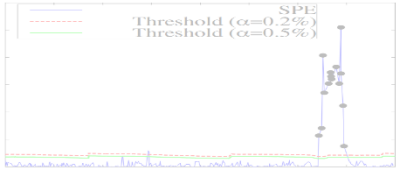

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  Problem: Offline batched processing, some very slow.

Our approach

Spell, **a structured *S*treaming *P*arser for *E*vent *L*ogs using an *L*CS (longest common subsequence) based approach.**

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Two log entries:

Temperature (41C) exceeds warning threshold
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LCS:

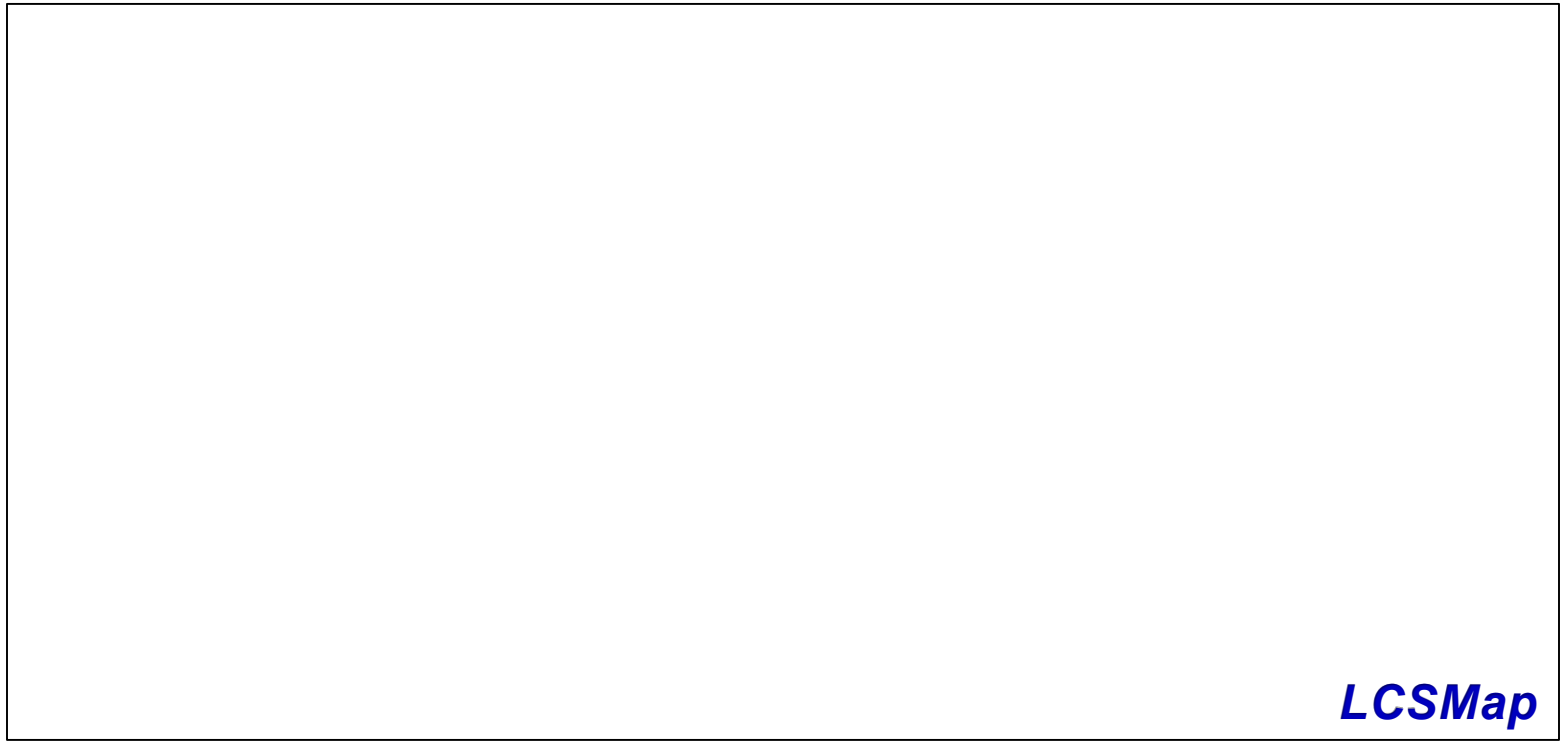
*Temperature * exceeds warning threshold*

Naturally a message type!

printf("Temperature %s exceeds warning threshold")

SPELL – Basic workflow

Add new log entry into LCSMap in a streaming fashion, update existing message type if *length(LCS) > 0.5 * length(new log entry)*



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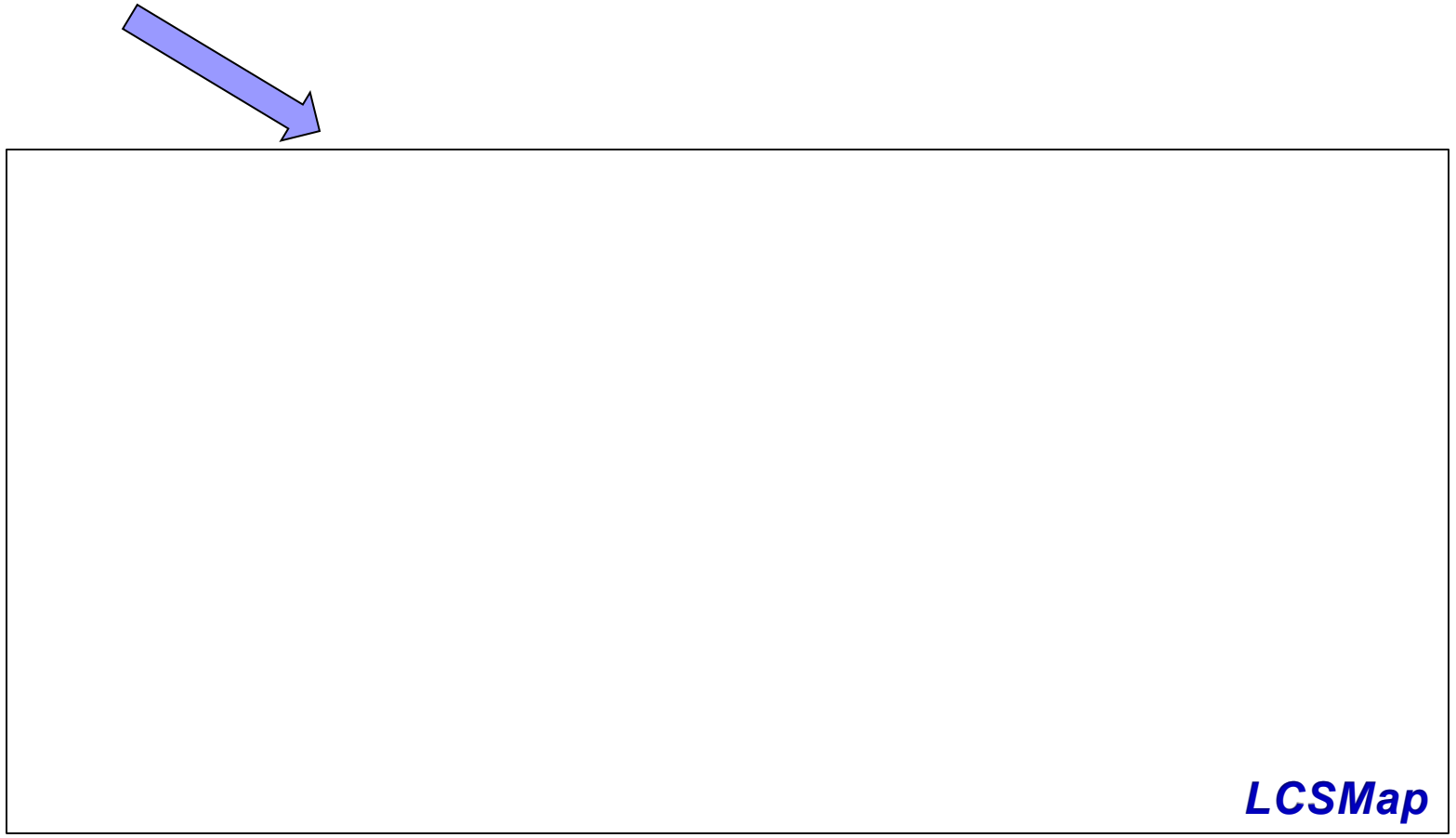

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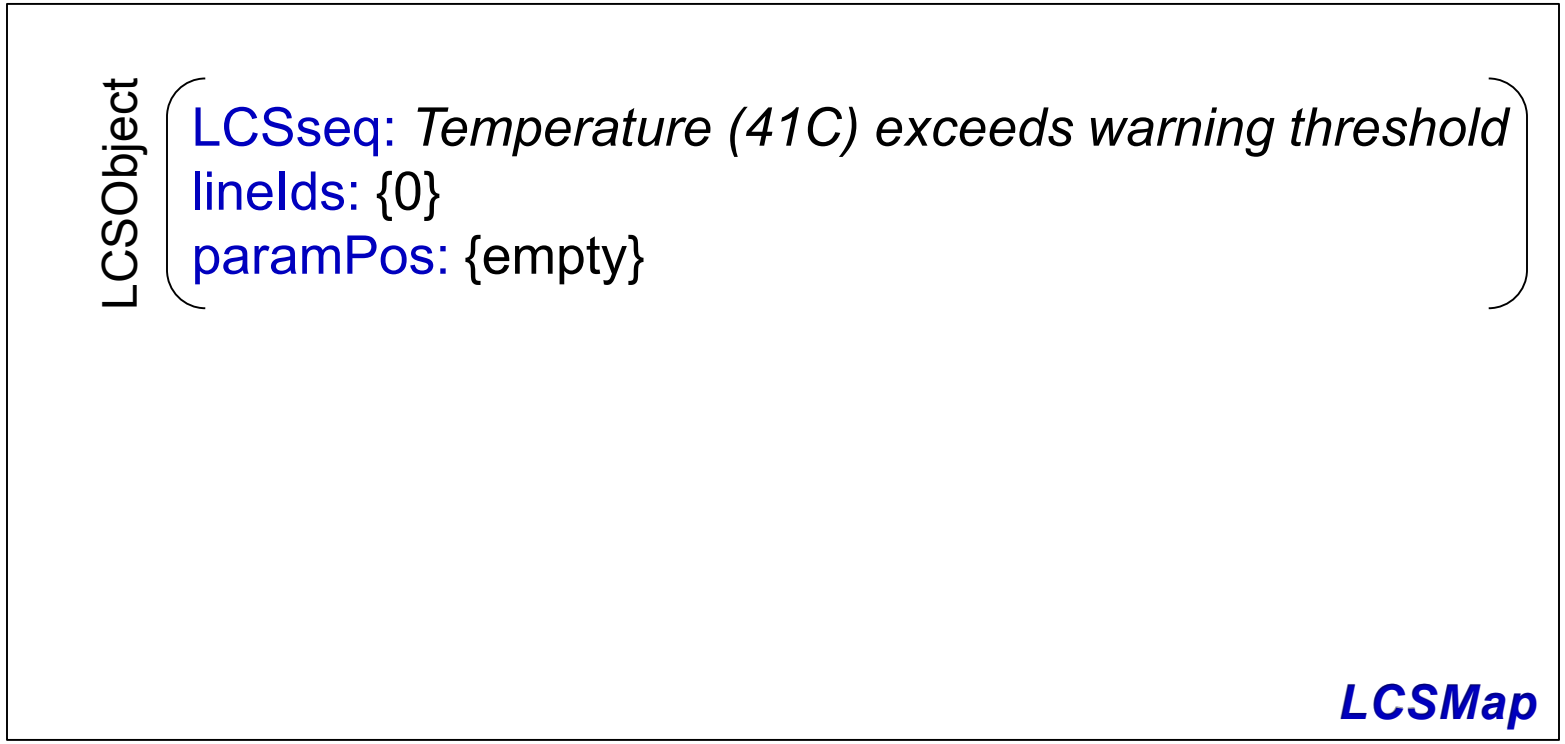

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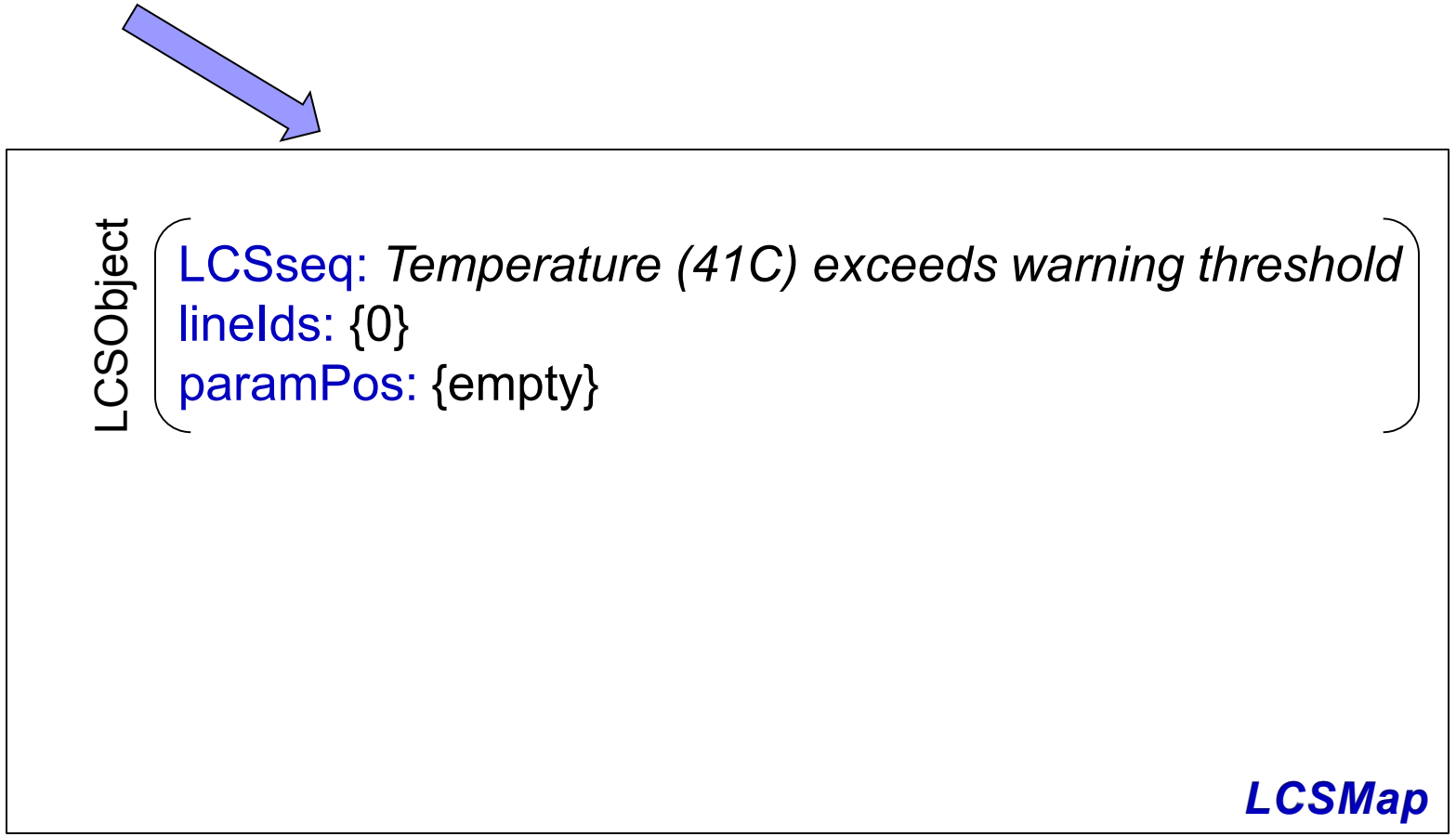
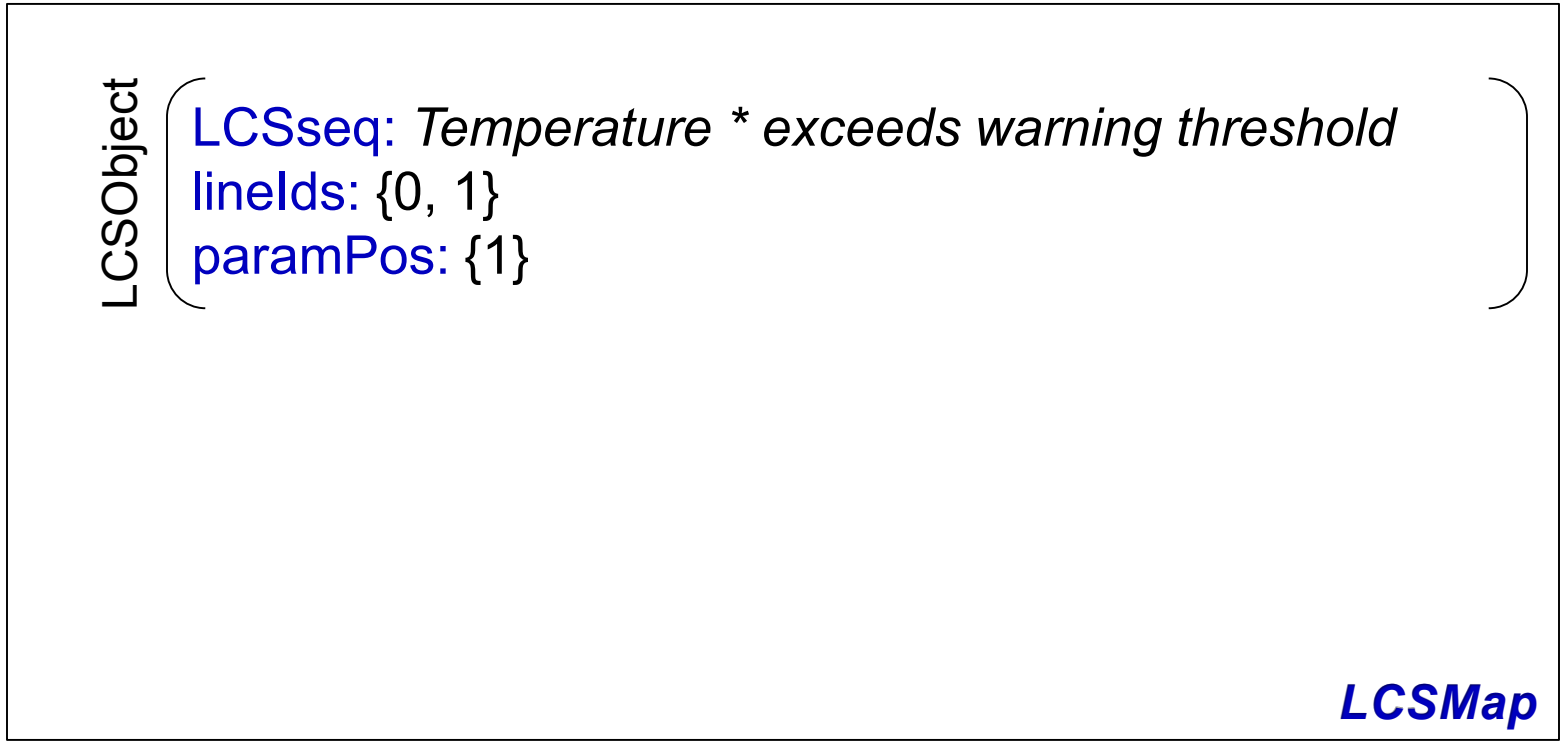
new log entry: *Temperature (43C) exceeds warning threshold*



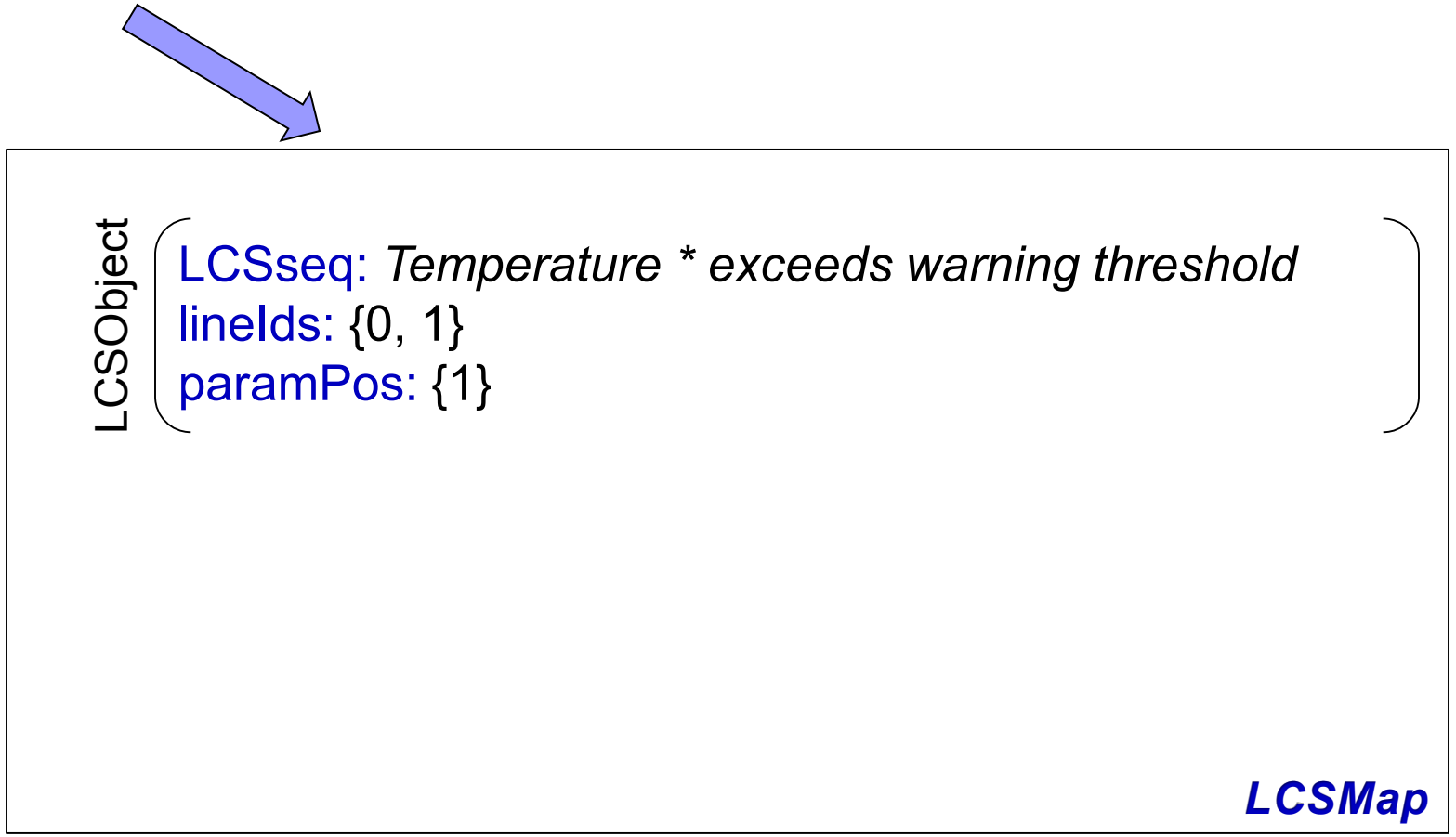
SPELL – Basic workflow

new log entry:



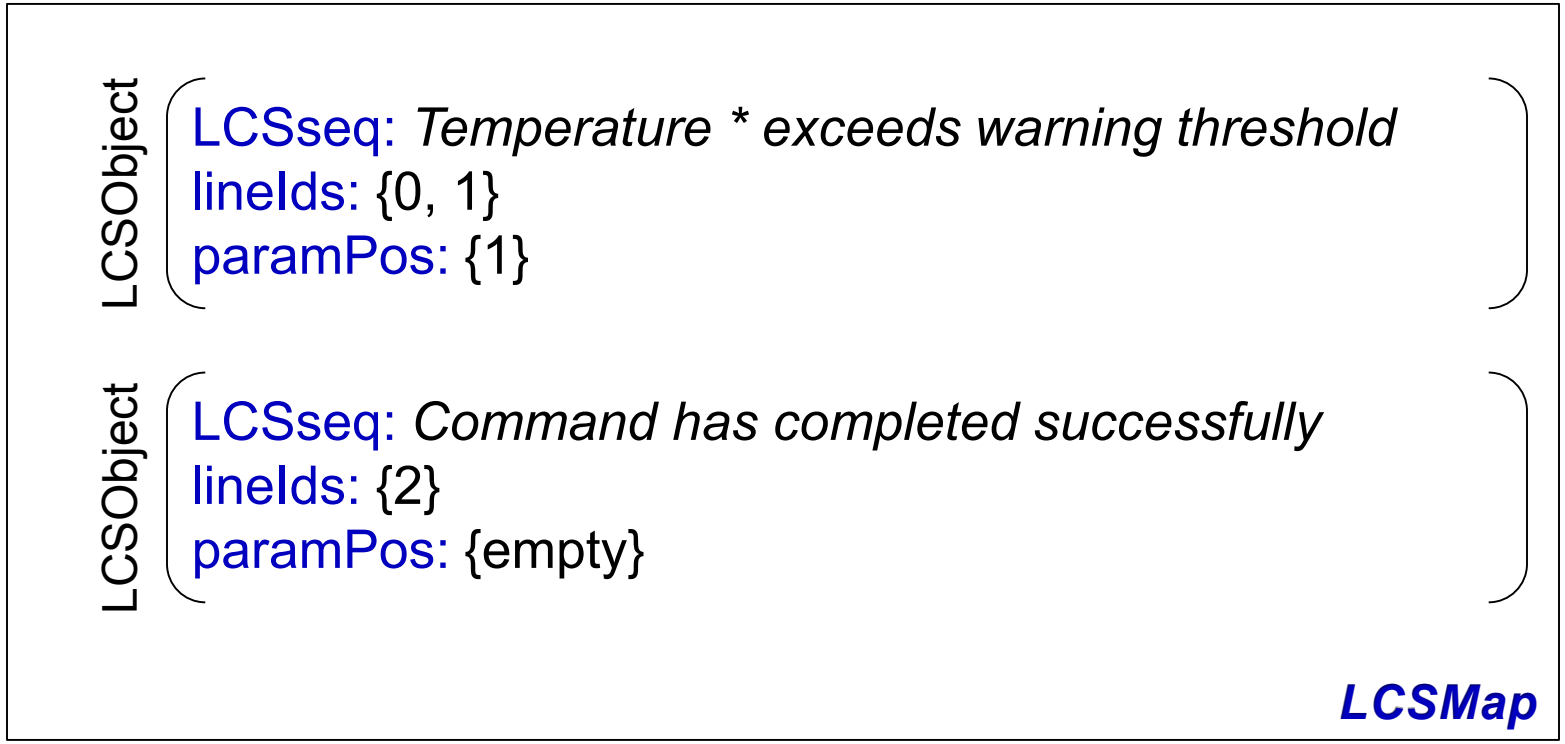
SPELL – Basic workflow

new log entry: *Command has completed successfully*



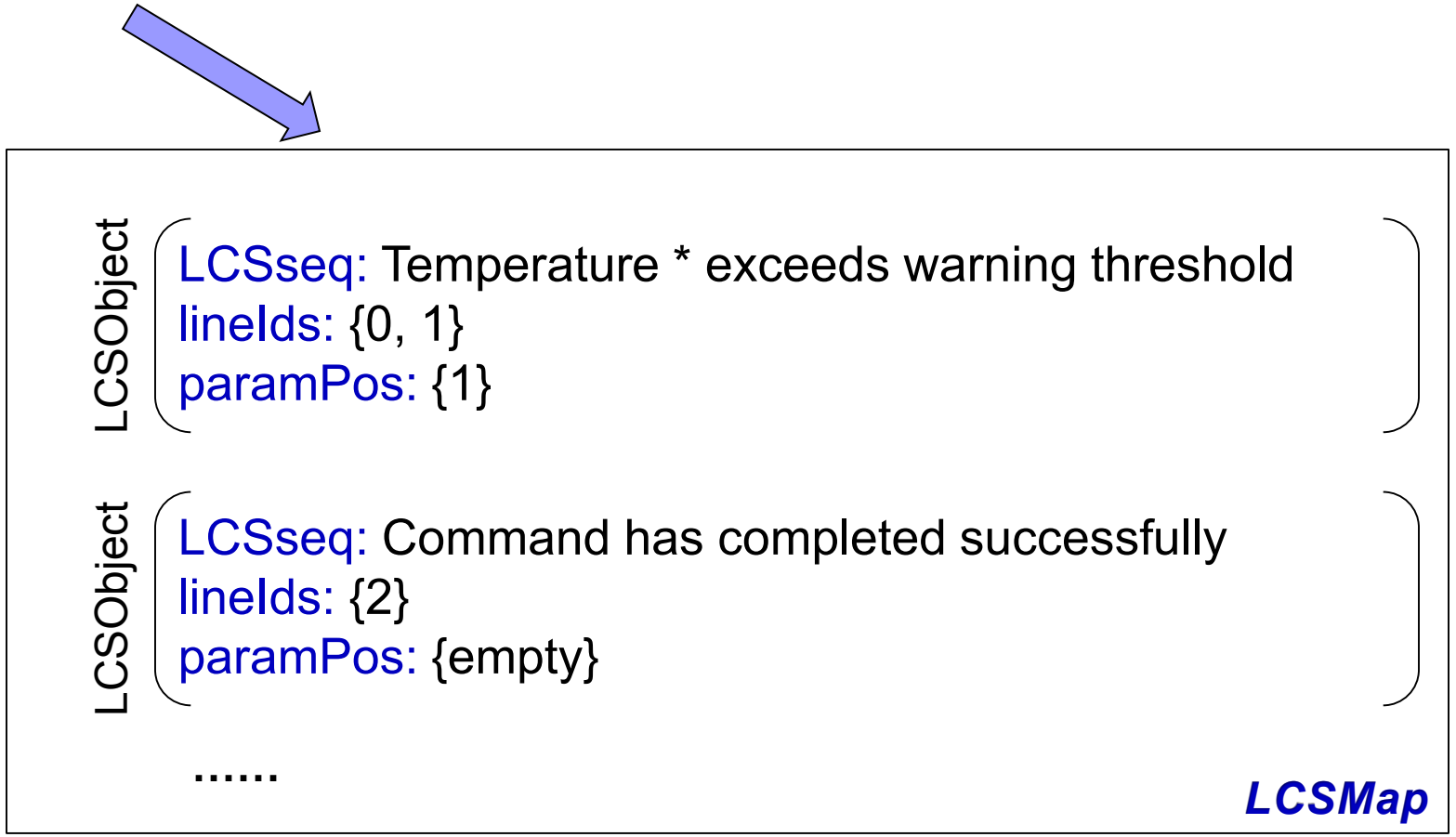
SPELL – Basic workflow

new log entry:



SPELL – Basic workflow

new log entry: ……



SPELL – Improvement on efficiency

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Time complexity:

To compare a log entry with an existing message type: $O(n^2)$

To compare a new log entry with $O(m)$ existing message types: $O(mn^2)$

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Can we do better?

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Observation.

For a complex system,

number of log entries: millions

number of message types: hundreds

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For example:

Blue Gene/L log:

4,457,719 log entries, 394 message types

Hadoop log used in Xu'SOSP09:

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For a majority of new log entries, their message types already exist in LCSMap!

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Improvement 1: Prefix Tree

Existing message types:

A B C
A C D
A D
E F

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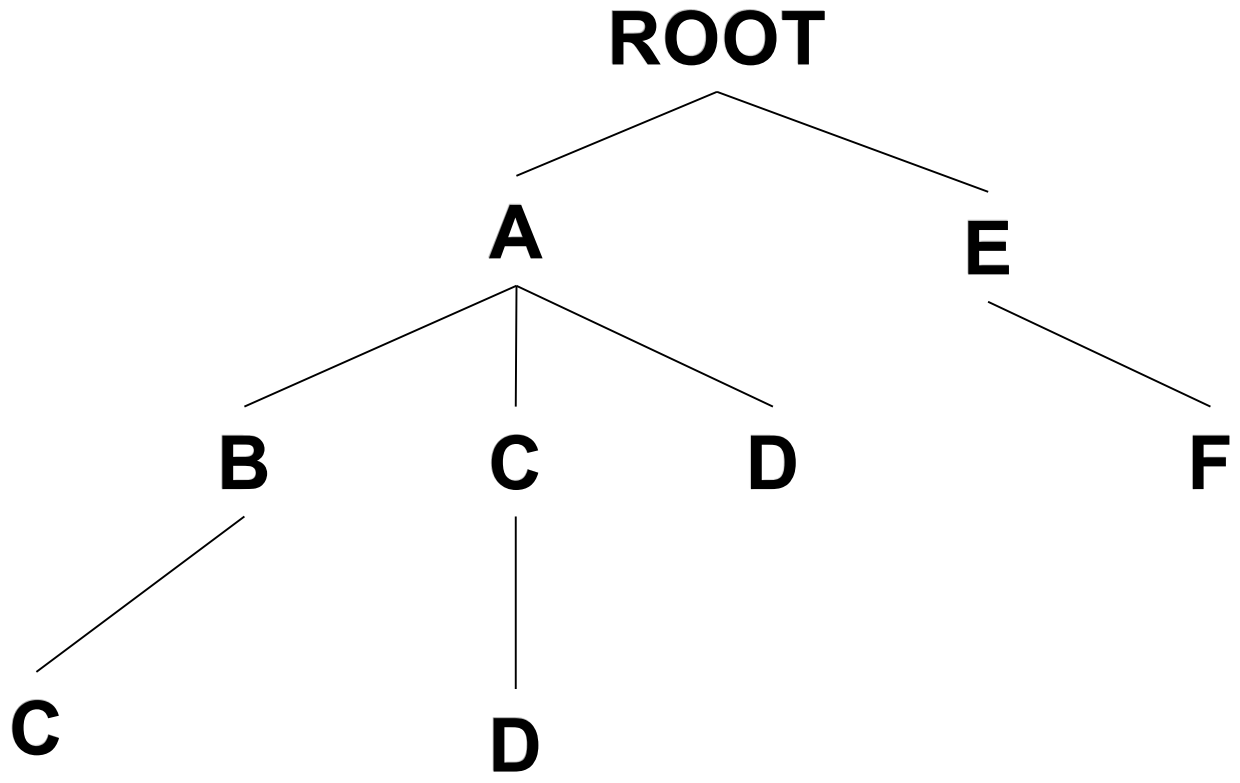
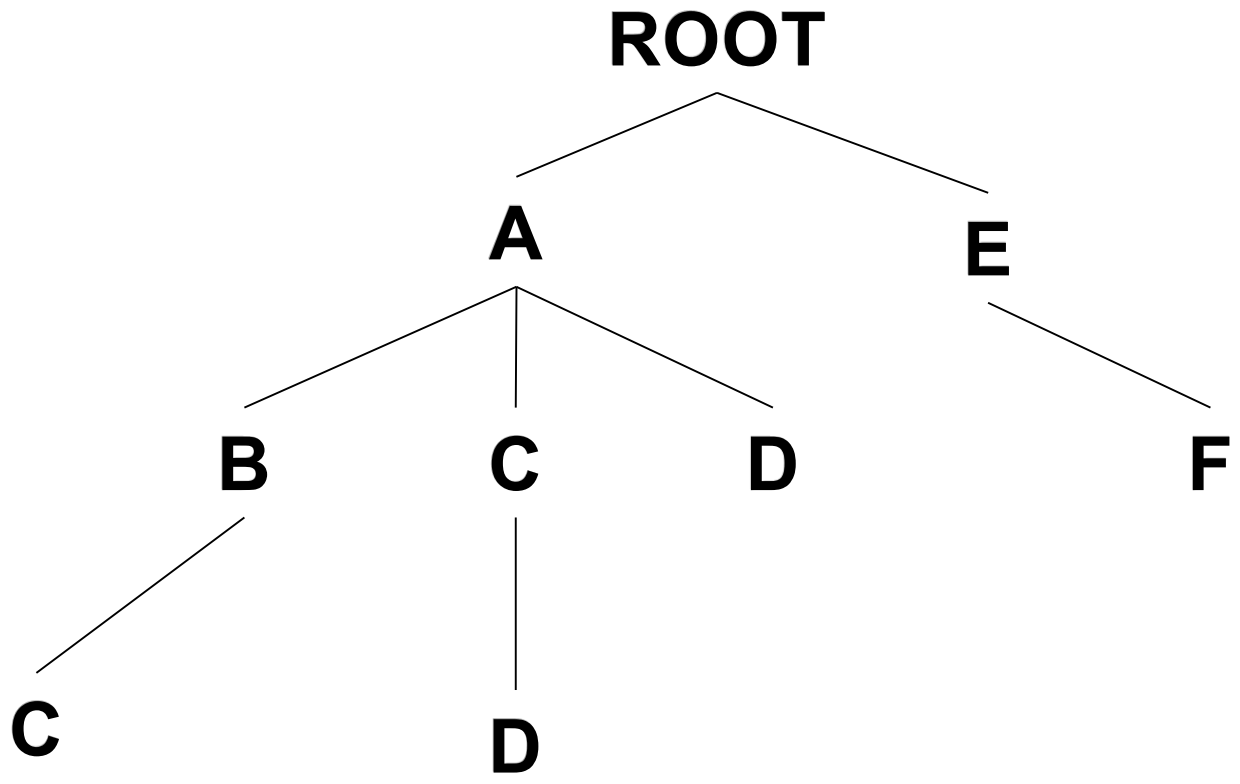


SPELL – Improvement on efficiency

Improvement 1: Prefix Tree

New log entry: *A B P C*



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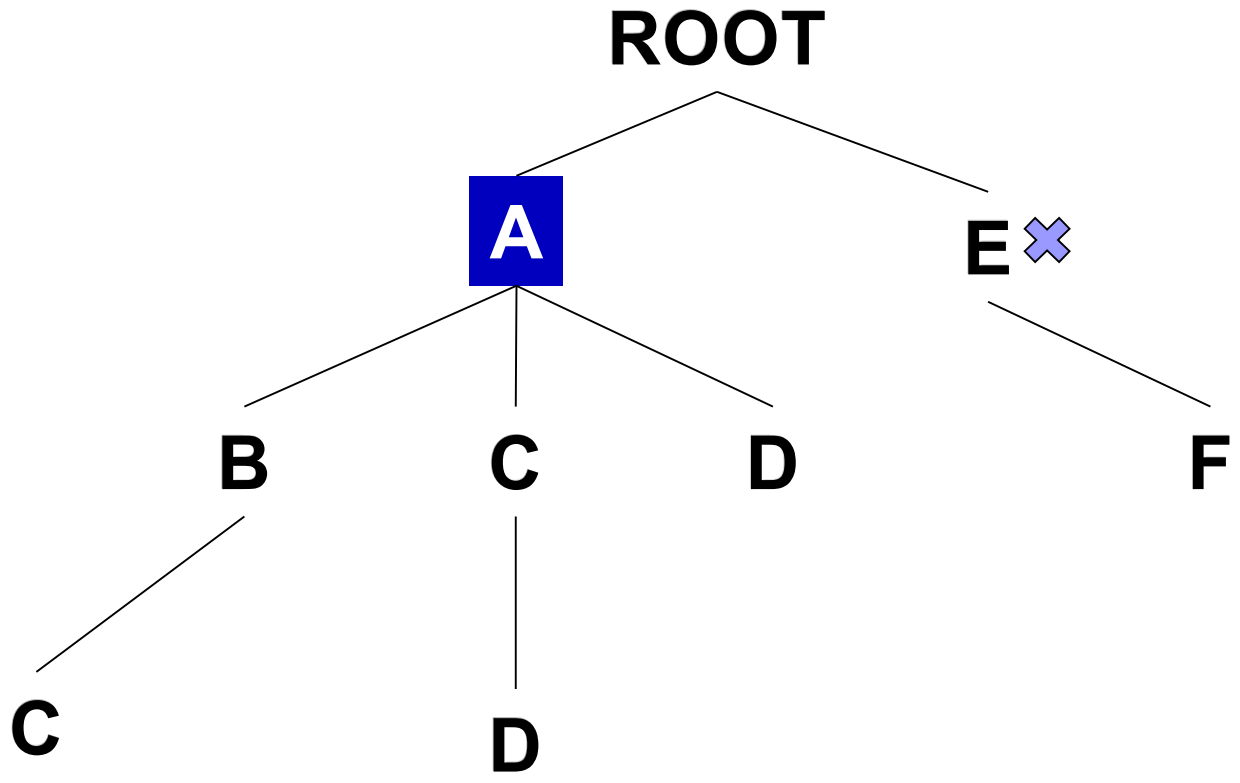
Improvement 1: Prefix Tree

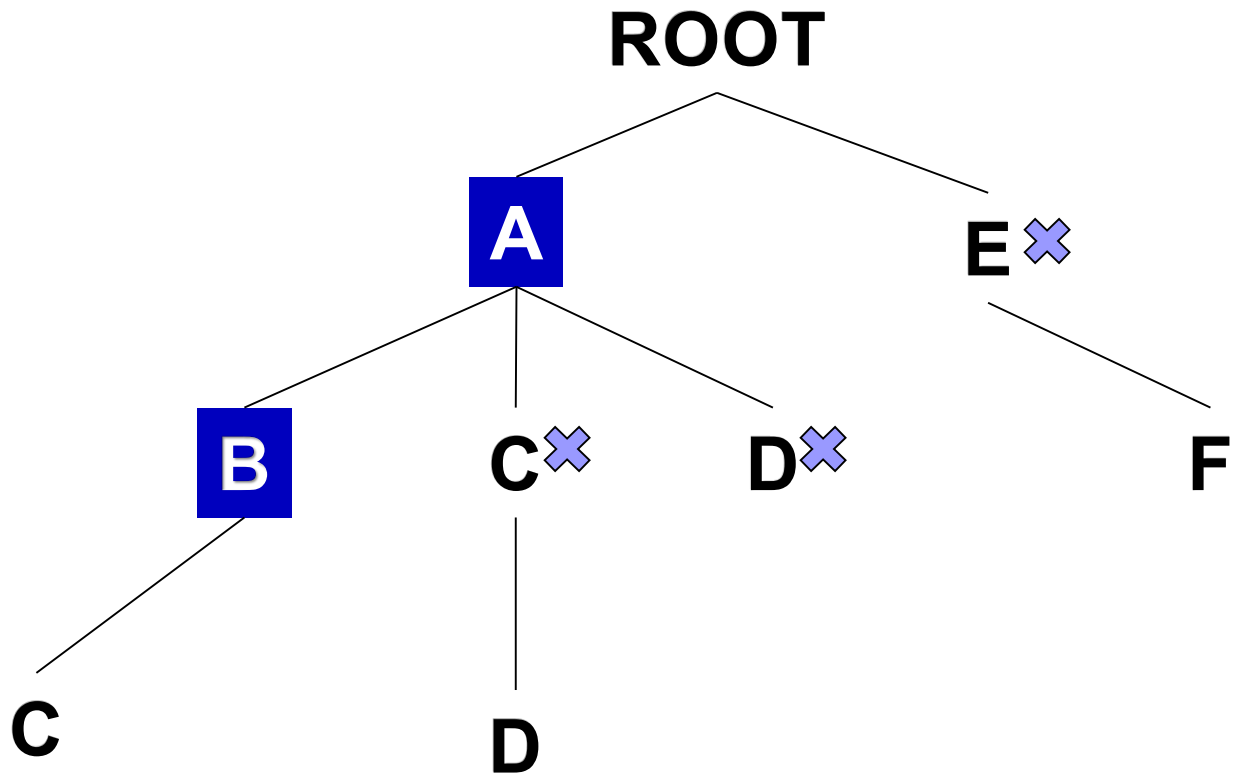
New log entry: **A** *B* *P* *C*



SPELL – Improvement on efficiency

Improvement 1: Prefix Tree

New log entry: **A** **B** *P* *C*

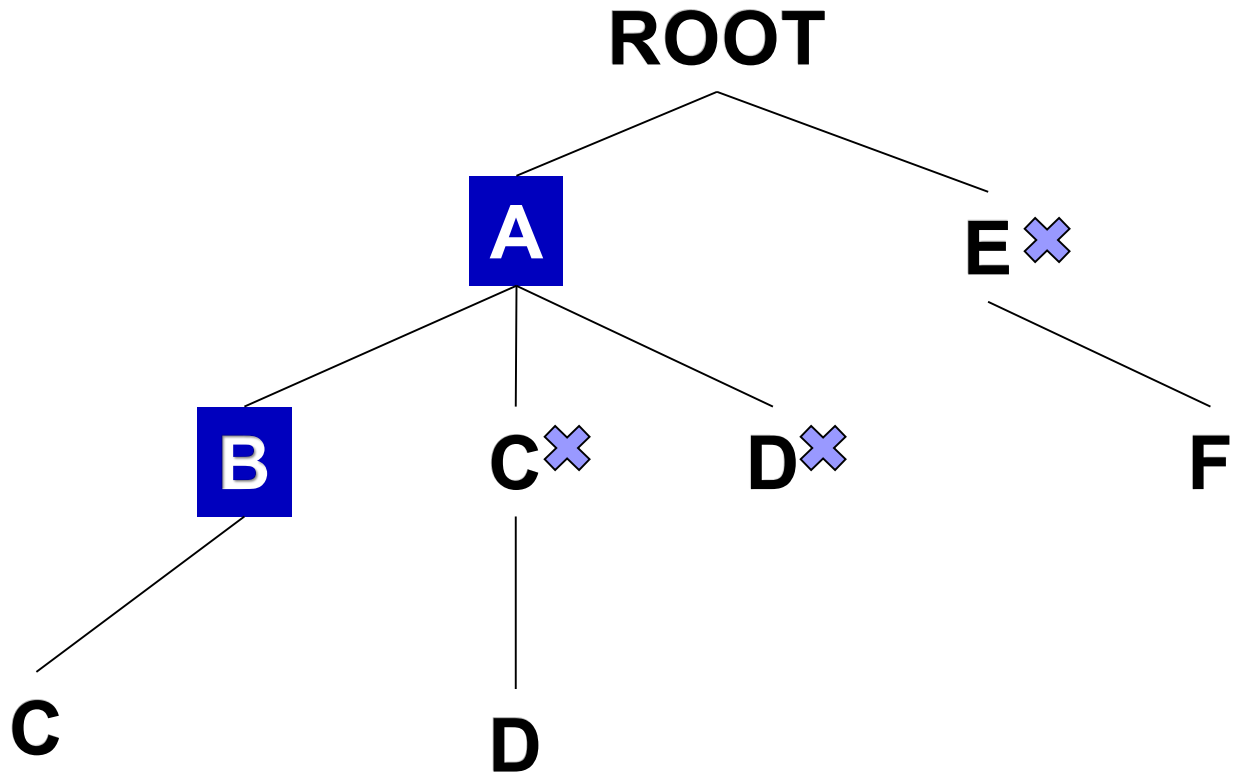


SPELL – Improvement on efficiency

Improvement 1: Prefix Tree

New log entry: **A** **B** *P* *C*

Parameter:

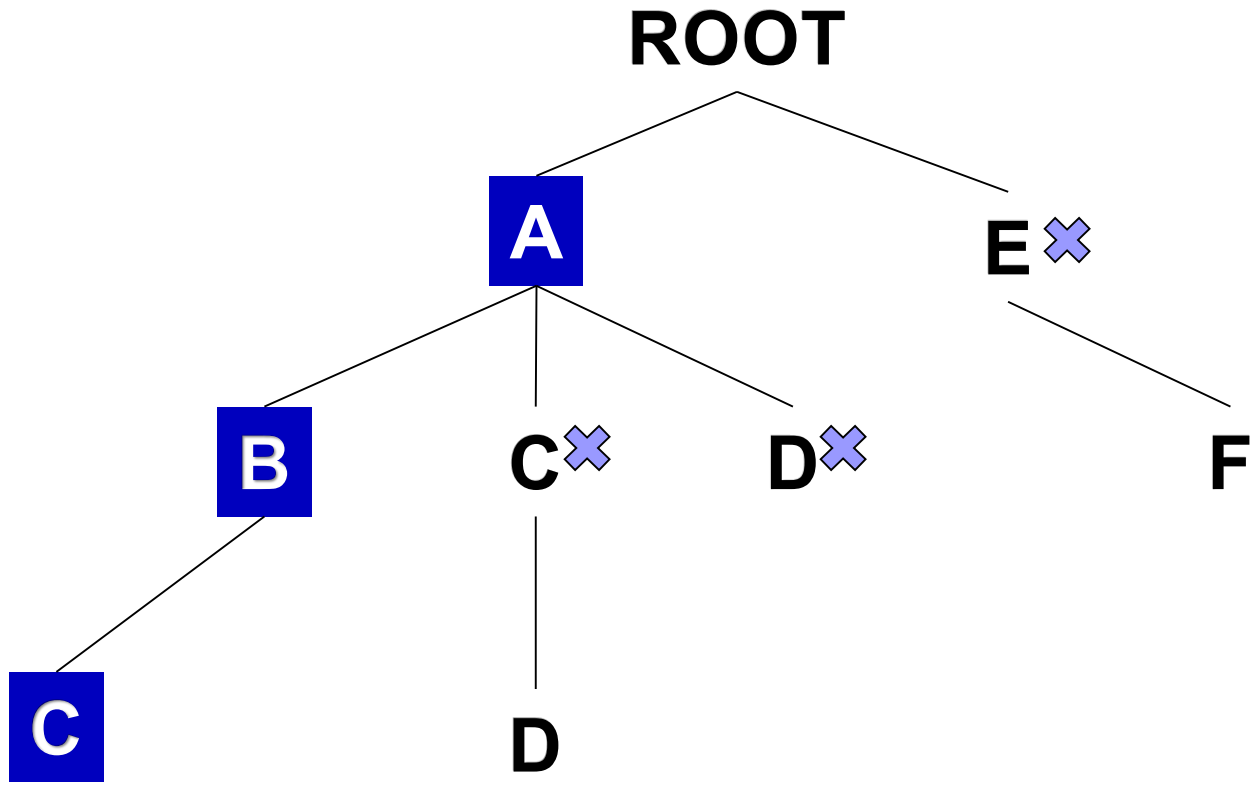


SPELL – Improvement on efficiency

Improvement 1: Prefix Tree

New log entry: **A** **B** *P* **C**

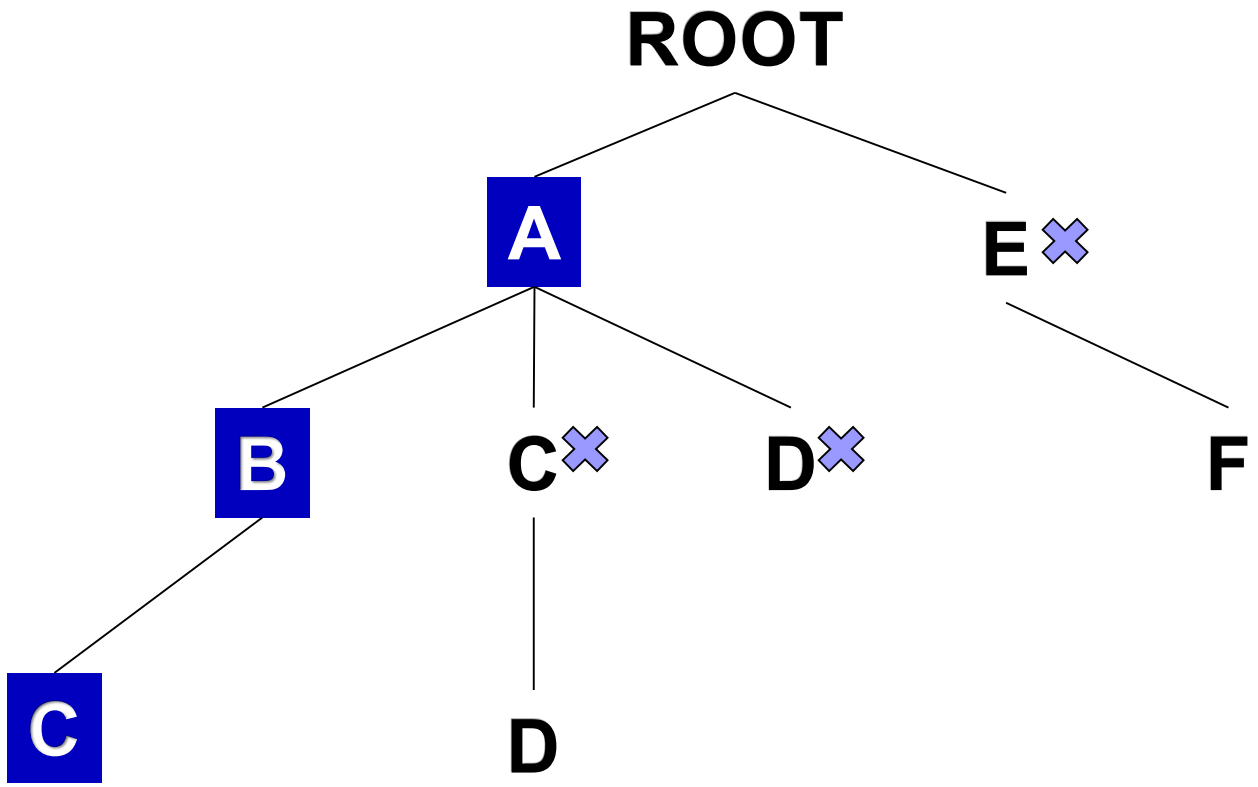
Parameter:



SPELL – Improvement on efficiency

Improvement 1: Prefix Tree

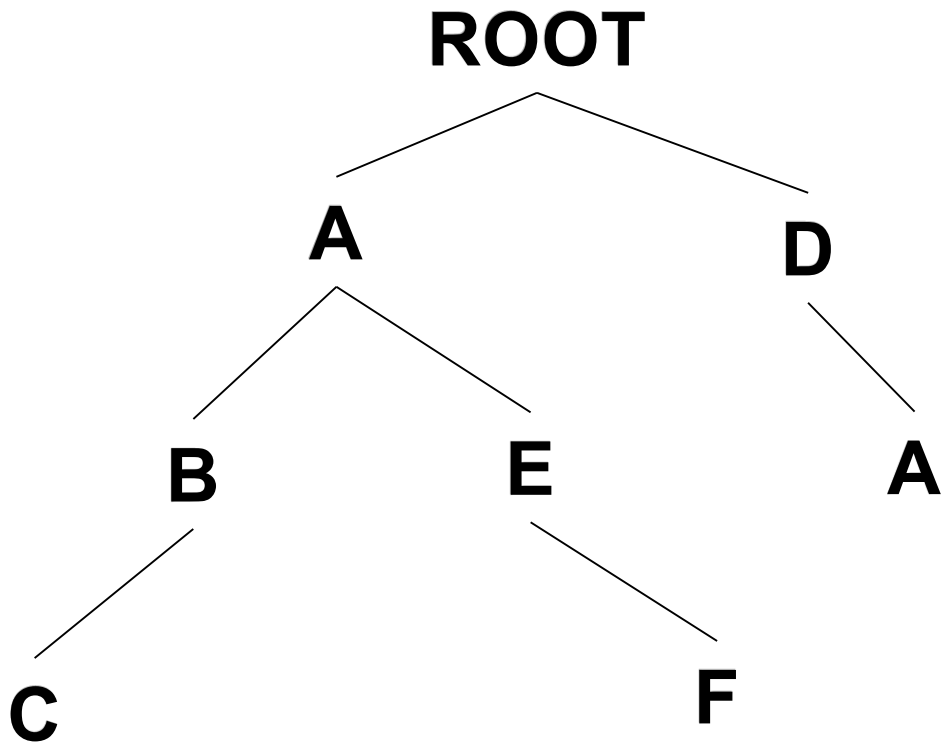
Time Complexity:
$O(n)$ for each log entry



SPELL – Improvement on efficiency

Improvement 1: Prefix Tree

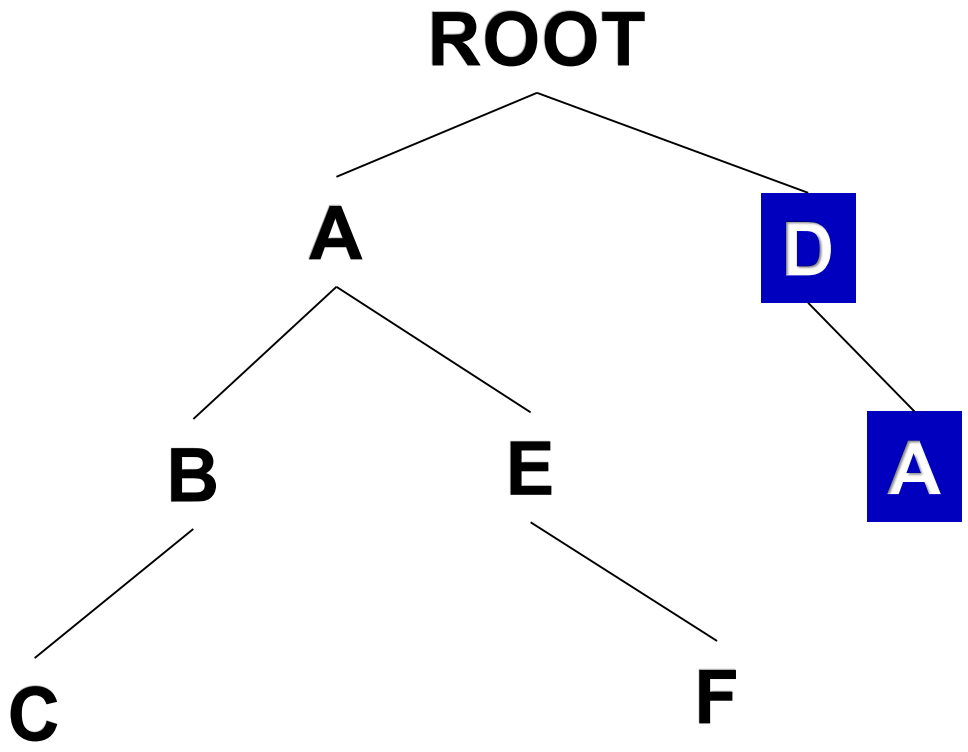
Problem:
New log entry: *D A P B C*



SPELL – Improvement on efficiency

Improvement 1: Prefix Tree

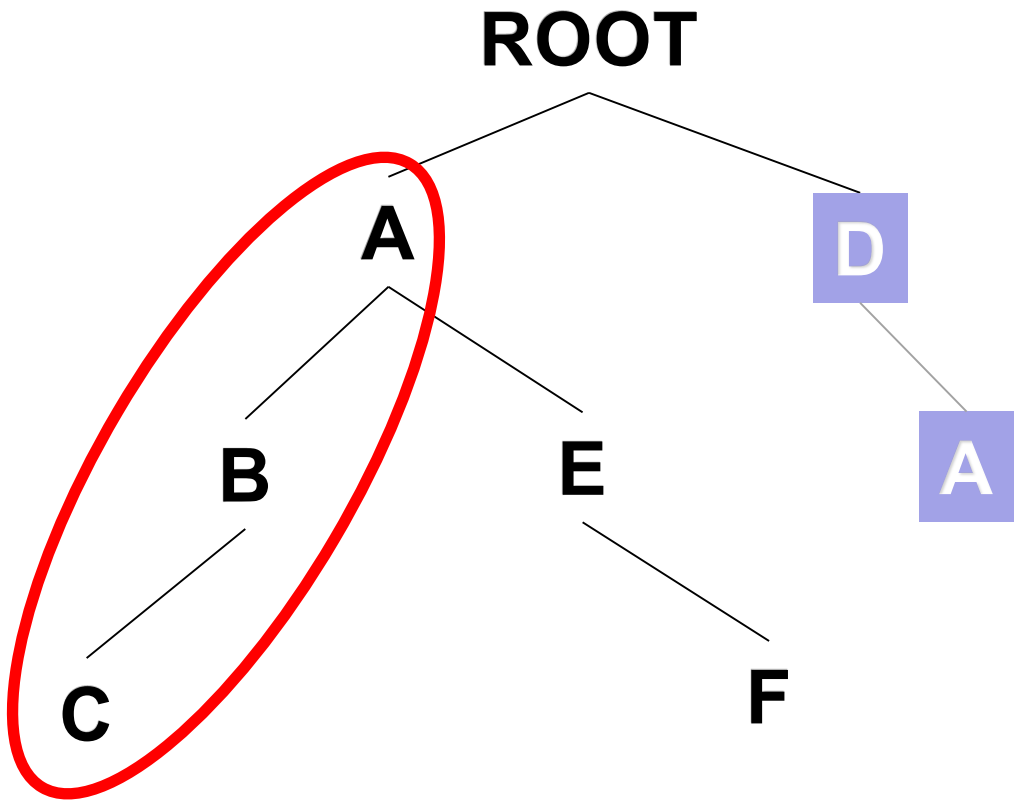
Problem:
New log entry: D A *P B C*
Matches D A



SPELL – Improvement on efficiency

Improvement 1: Prefix Tree

Problem:
New log entry: D *A* P *B C*
Matches D A
Should be: A B C



SPELL – Improvement on efficiency

Improvement 2: Simple Loop

Compare each message type with new log entry

Message types:

[A B C]

[A E F]

[D A]

New log entry: [D A P B C]

SPELL – Improvement on efficiency

Improvement 2: Simple Loop

Compare each message type with new log entry

$Pointer\ P_m$

Message types:

[A B C]

[A E F]

[D A]

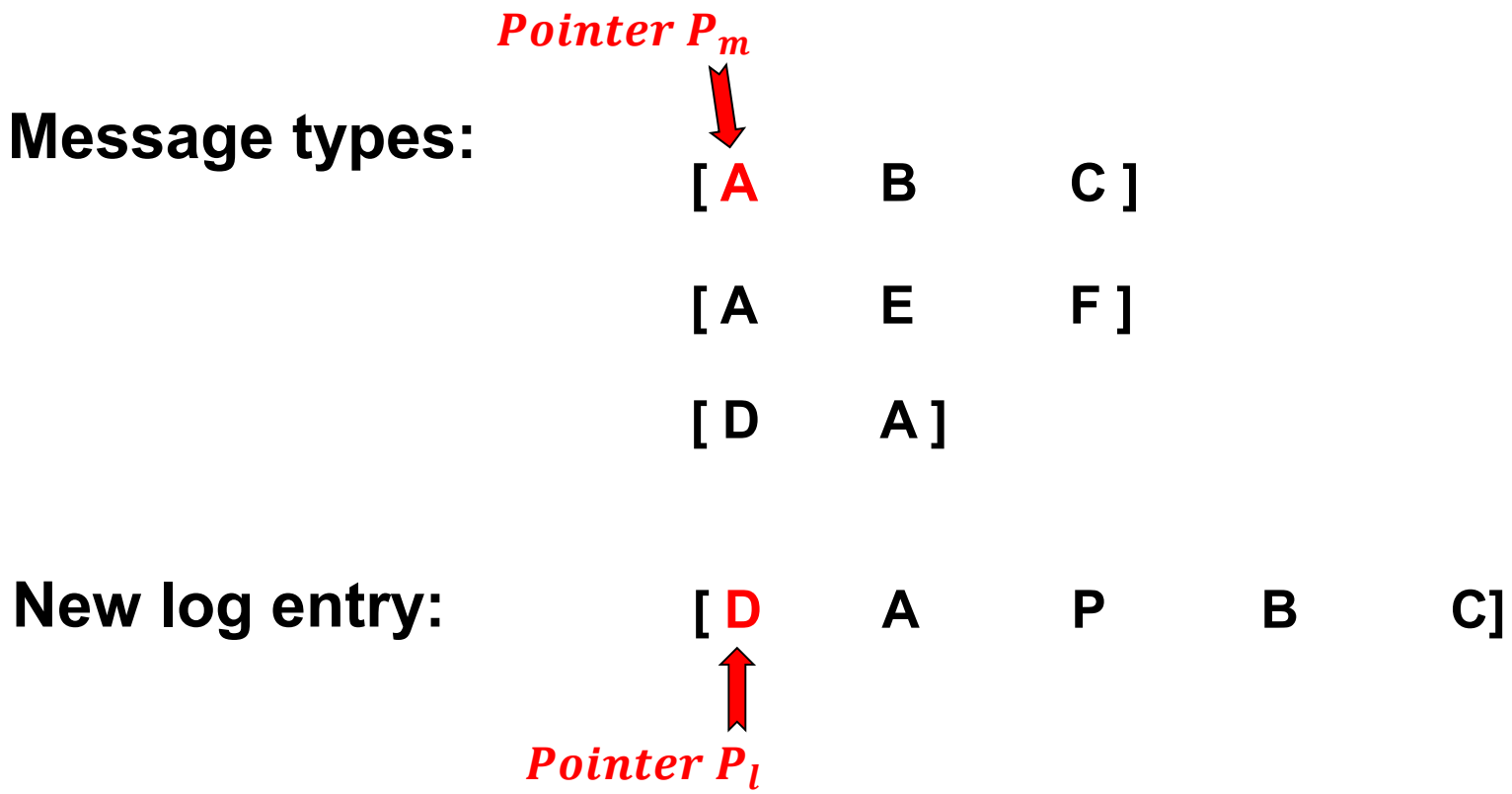
New log entry: [D A P B C]

$Pointer\ P_l$

SPELL – Improvement on efficiency

Improvement 2: Simple Loop

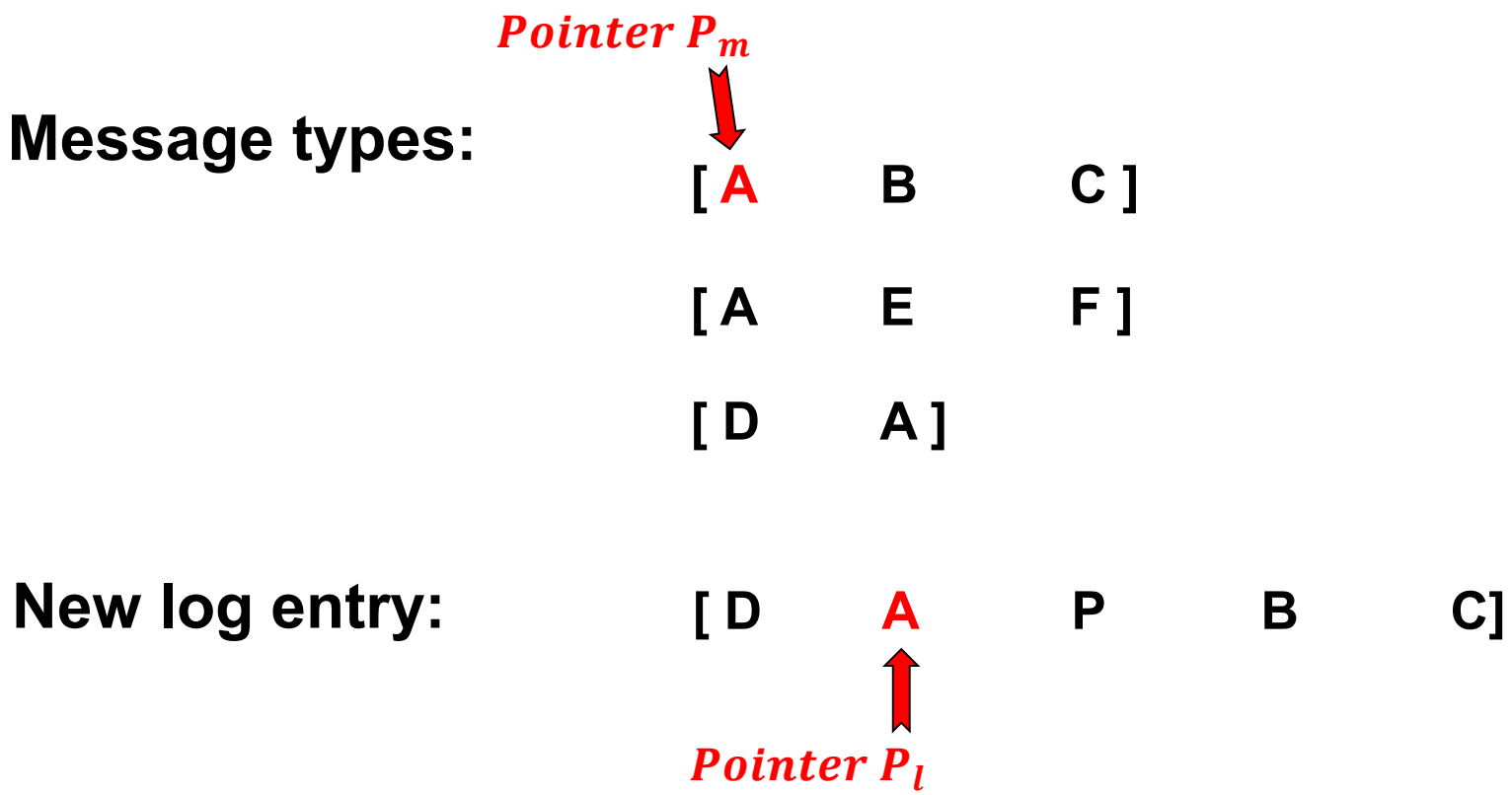
Compare each message type with new log entry



SPELL – Improvement on efficiency

Improvement 2: Simple Loop

Compare each message type with new log entry

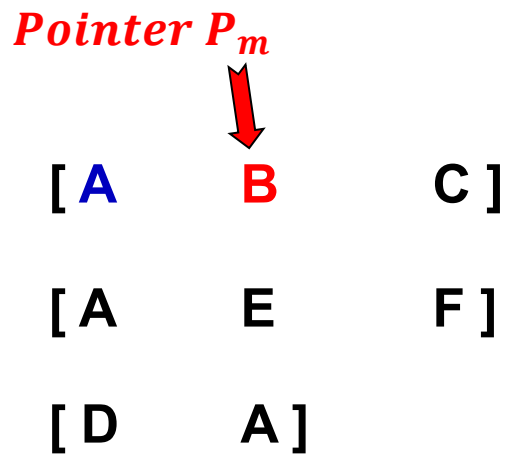


SPELL – Improvement on efficiency

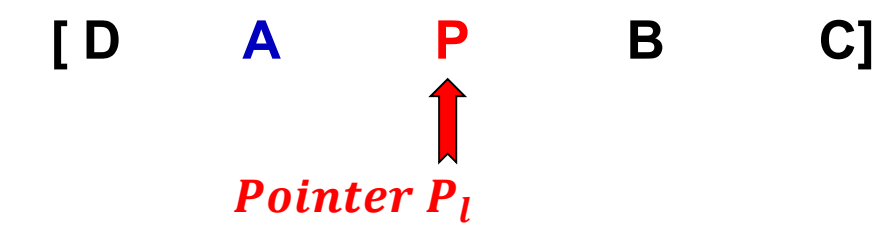
Improvement 2: Simple Loop

Compare each message type with new log entry

Message types:



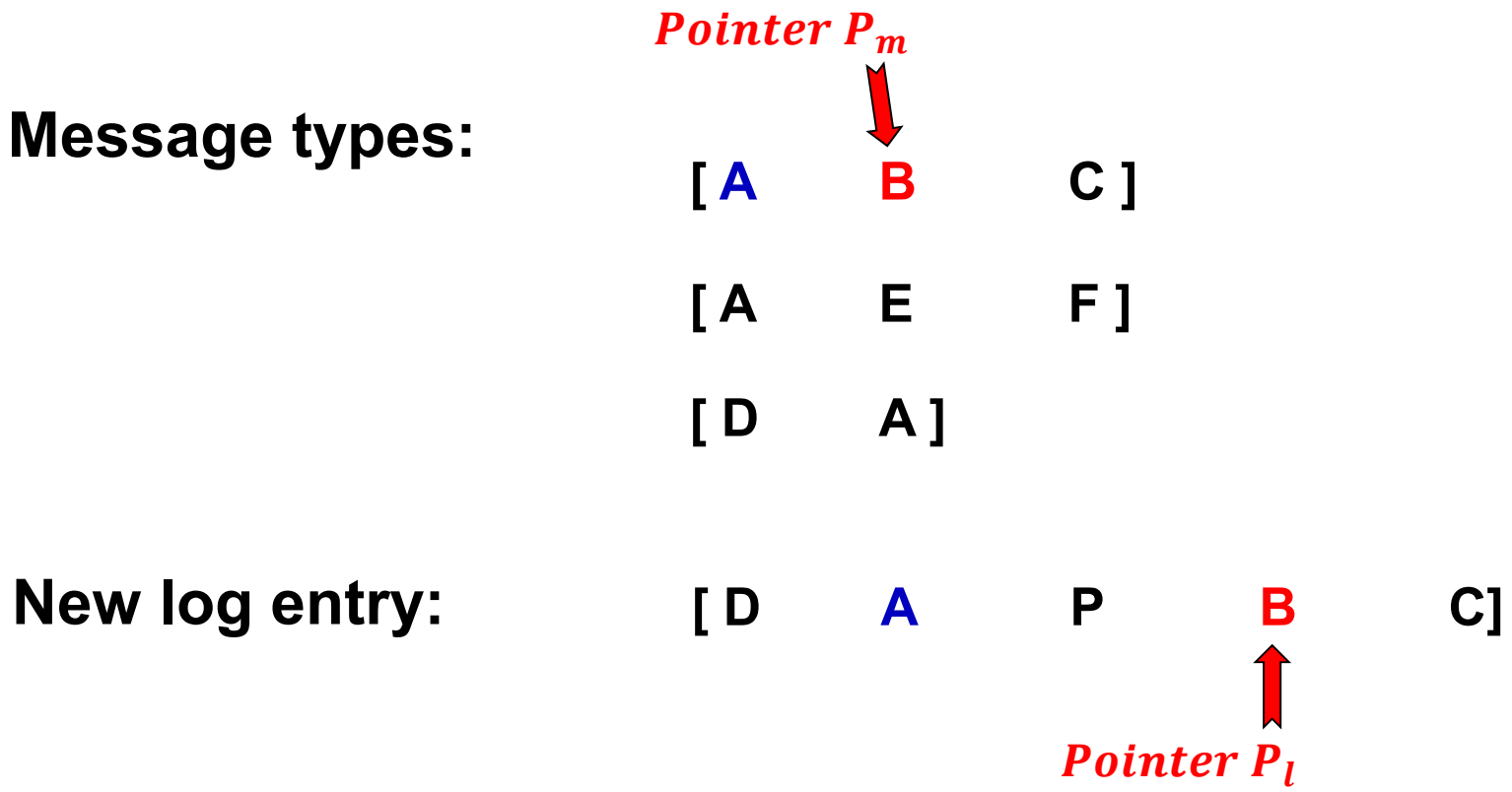
New log entry:



SPELL – Improvement on efficiency

Improvement 2: Simple Loop

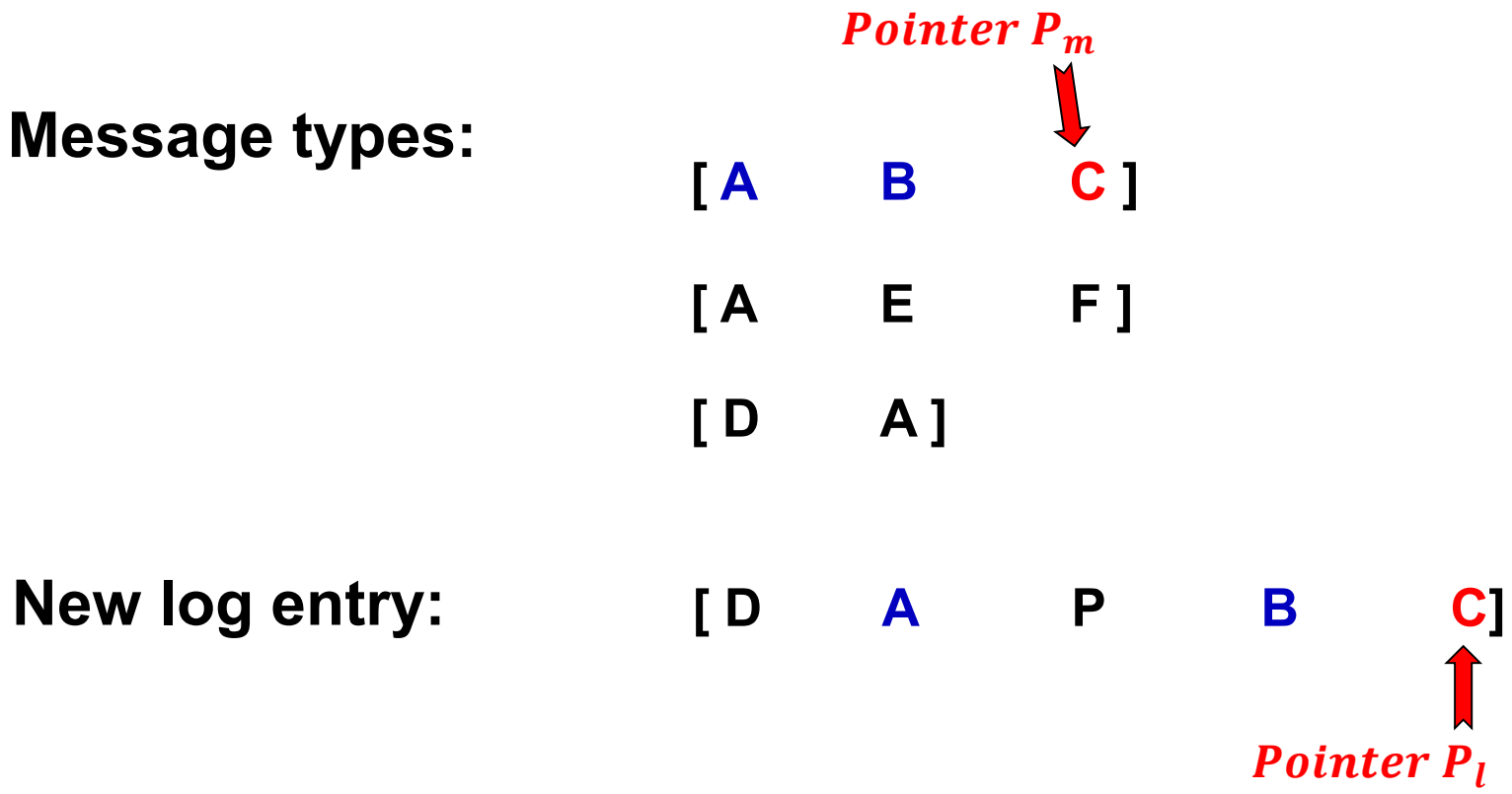
Compare each message type with new log entry



SPELL – Improvement on efficiency

Improvement 2: Simple Loop

Compare each message type with new log entry

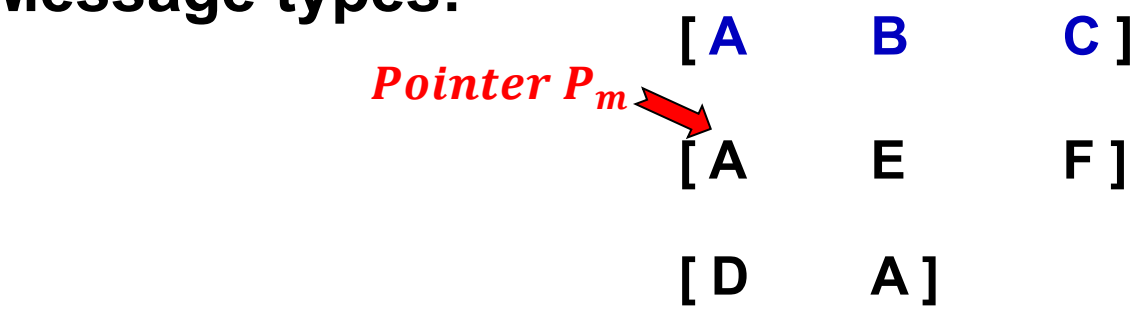


SPELL – Improvement on efficiency

Improvement 2: Simple Loop

Compare each message type with new log entry

Message types:



New log entry: [D A P B C]

SPELL – Improvement on efficiency

Improvement 2: Simple Loop

Compare each message type with new log entry

Message types:		Matched length:
	[A B C]	3
	[A E F]	N/A
	[D A]	2

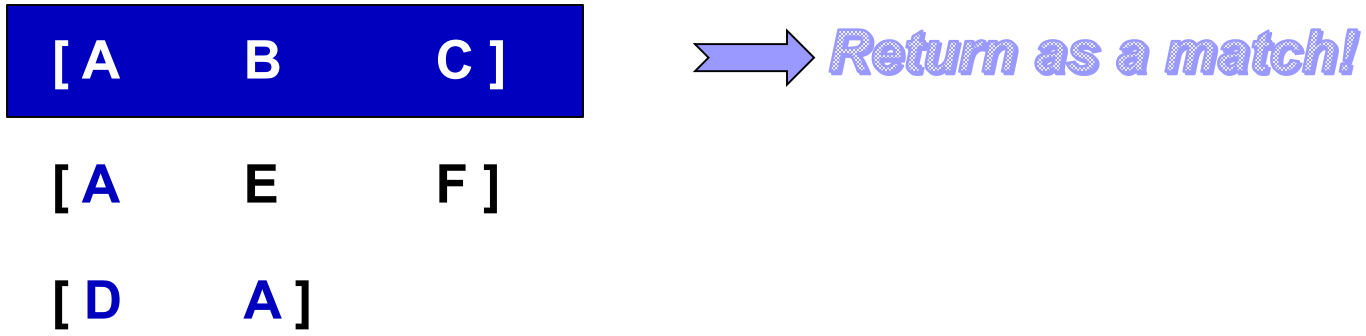
New log entry: [D A P B C]

SPELL – Improvement on efficiency

Improvement 2: Simple Loop

Compare each message type with new log entry

Message types:



New log entry: [D A P B C]

SPELL – Improvement on efficiency

Improvement 2: Simple Loop

Compare each message type with new log entry

Message types:

[A	B	C]
[A	E	F]
[D	A]	

New log entry: [D A P B C]

Time complexity

$$O(m\,n)$$

Number of message types

Log entry length

SPELL – Improvement on efficiency

Improvement 2: Simple Loop

Compare each message type with new log entry

Message types:

[A	B	C]
[A	E	F]
[D	A]	

New log entry: [D A P B C]

For remaining log entries, compare it with each message type using simple DP.

Time complexity

$$O(m\,n)$$

Number of message types

Log entry length

Evaluation

Methods to compare:

IPLoM (Makanju'KDD09):

Partition log file using 3-step heuristics (log entry length, etc.)

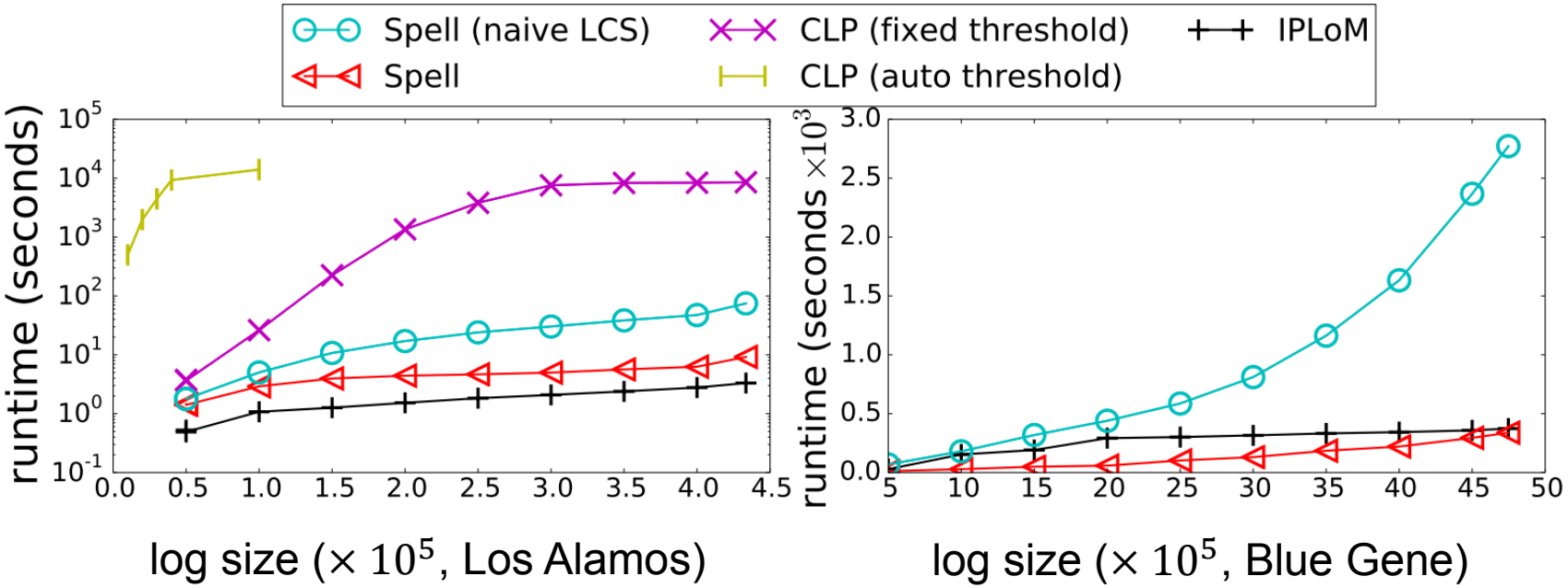
CLP (Fu'ICDM09)

Cluster similar logs together based on weighted edit distance

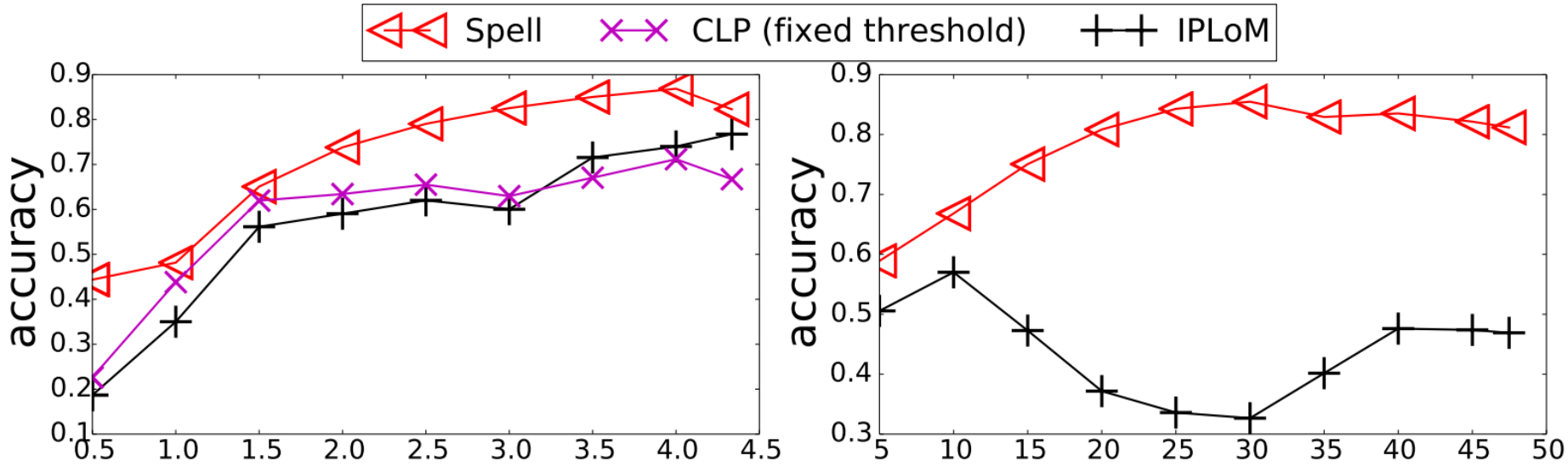
Log dataset:

Log type	Count	Message type ground truth
Los Alamos HPC log	433,490	Available online
BlueGene/L log	4,747,963	Available online

Evaluation - Efficiency



Evaluation - Effectiveness



Conclusion

Spell:

- ❑ A streaming system event log parser
- ❑ Using LCS
- ❑ Prefix tree and simple loop to improve efficiency
- ❑ Outperform offline methods on large system log dataset

Thank you

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Evaluation - Efficiency

NUMBER (PERCENTAGE) OF LOG ENTRIES RETURNED BY EACH STEP

	Los Alamos HPC log	BlueGene/L log
prefix tree	397,412 (91.68%)	4,457,719 (93.89%)
simple loop	35,691 (8.23%)	288,254 (6.07%)
naive LCS	387 (0.09%)	1,990 (0.042%)

AMORTIZED COST OF EACH MESSAGE TYPE LOOKUP STEP IN Spell

	Los Alamos HPC log	BlueGene/L log
prefix tree (ms)	0.006	0.011
simple loop (ms)	0.020	0.087
naive LCS (ms)	0.175	0.580

Evaluation - Effectiveness

COMPARISON OF Spell WITH AND WITHOUT PRE-FILTER

Spell$_I$	Los Alamos HPC log		BlueGene/L log	
With pre-filtering	True message types found	Accuracy	True message types found	Accuracy
False	55	0.822786	165	0.811798
True	55	0.822786	164	0.811791