基于Flink的文本流事件监测

小组成员及分工

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小组分工

- 陈炳生：复现算法Phase 1，集群部署
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- 赵一峰：数据接入，文档撰写

项目代码仓库：GitHub - SunflowerAries/Text-Event-Detection

系统目标及功能

项目选题为基于 Storm/Flink 的文本流事件监测，其实现主要参考论文 *Parameter Free Bursty Events Detection in Text Streams*。本系统基于Flink框架、Kaggle上新闻集完成论文中提出的算法，并对其进行改进，实现对文本流的事件监测系统。

本系统的功能主要为在文本流中实现事件监测，包括三个流程：

1. 首先通过输入文本流识别出突发特征；
2. 接着对特征进行聚类，将特征聚类成一个个事件；
3. 最后判断这些事件的热点时间。

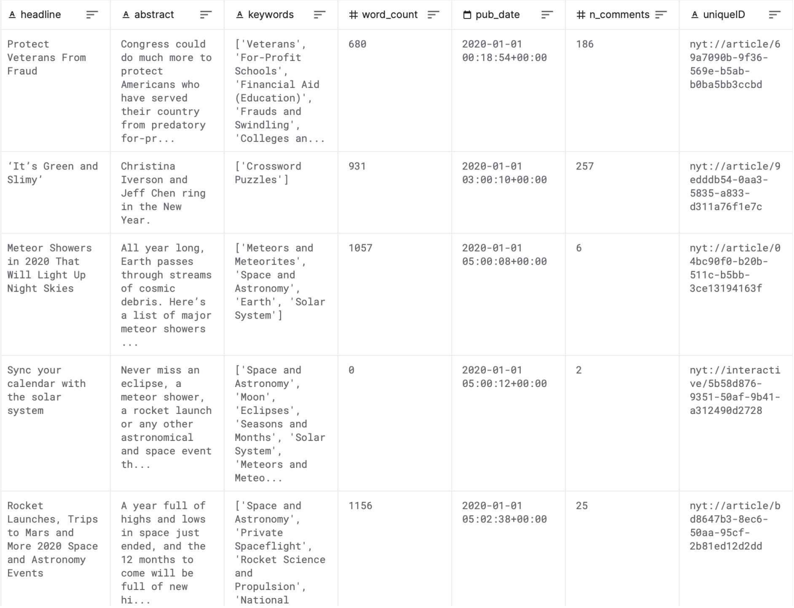
环境搭建与数据获取

环境搭建

在本项目中，选择使用 Flink 来进行文本流事件监测，Flink 是一款分布式的计算引擎，Flink 将计算过程建模为数据流上的有状态的计算（Stateful Computations Over Streams），认为有界数据集上的批处理是无界数据流的一种特例，实现了流批一体。基于 Flink 框架，我们首先进行了环境的搭建，在老师提供的五台服务器上构建 Flink 集群，主要包括：选择主节点并对其进行相关的配置，把配置好的 Flink 文件打包后分发给其他四台机器统一配置。

数据获取

本项目为文本流事件监测系统，需要数据来构造文本流，文本流是带有日期标签的一系列文本。在 kaggle 上找到了 New York Times Articles & Comments (2020) 新闻数据集，其中包含2020全年的纽约时报16K+的文章和相关评论，其主要包含内容标题、摘要、关键词、时间等。



headline	abstract	keywords	word_count	pub_date	n_comments	uniqueID
Protect Veterans From Fraud	Congress could do much more to protect Americans who have served their country from predatory for-pr...	['Veterans', 'For-Profit Schools', 'Financial Aid (Education)', 'Frauds and Swindling', 'Colleges an...	680	2020-01-01 00:18:54+00:00	186	nyt://article/69a7090b-9f36-569e-b5ab-b0ba5bb3ccbd
'It's Green and Slimy'	Christina Iverson and Jeff Chen ring in the New Year.	['Crossword Puzzles']	931	2020-01-01 03:00:10+00:00	257	nyt://article/9edddb54-0aa3-5835-a833-d311a76f1e7c
Meteor Showers in 2020 That Will Light Up Night Skies	All year long, Earth passes through streams of cosmic debris. Here's a list of major meteor showers ...	['Meteors and Meteorites', 'Space and Astronomy', 'Earth', 'Solar System']	1057	2020-01-01 05:00:08+00:00	6	nyt://article/04bc90f0-b20b-511c-b5bb-3ce13194163f
Sync your calendar with the solar system	Never miss an eclipse, a meteor shower, a rocket launch or any other astronomical and space event th...	['Space and Astronomy', 'Moon', 'Eclipses', 'Seasons and Months', 'Solar System', 'Meteors and Meteo...	0	2020-01-01 05:00:12+00:00	2	nyt://interactive/5b58d876-9351-50af-9b41-a312490d2728
Rocket Launches, Trips to Mars and More 2020 Space and Astronomy Events	A year full of highs and lows in space just ended, and the 12 months to come will be full of new hi...	['Space and Astronomy', 'Private Spaceflight', 'Rocket Science and Propulsion', 'National	1156	2020-01-01 05:02:38+00:00	25	nyt://article/bd8647b3-8ec6-50aa-95cf-2b81ed12d2dd

图1. 数据中包含主要内容

数据清洗及预处理

在数据集中，包含本项目中用不到的无关项，首先对数据进行进行清洗，仅保留数据中的时间及正文部分，删除其他如标题、作者、分类等项。同时，基于项目的需要，对新闻正文进行一些简单的预处理工作，包括：对新闻正文进行分词、大写字符替换为小写字符、复数转为单数、去掉停用词等。至此，本系统需要的输入数据已准备完成。

算法实现

算法实现是本项目的核心工作，基于 *Parameter Free Bursty Events Detection in Text Streams* 中所提出的算法，进行算法的改进与实现。

代码结构

```
Text-Event-Detection
|    BurstyAggregate.java
|    BurstyProcess.java
|    Document2Feature.java
|    Feature2Event.java
|
|----lib
|        Binomial.java
|        BurstyProb.java
|        UnionFind.java
|
|----module
|        Document.java
|        Event.java
|        Feature.java
|        FeatureOccurrence.java
|        FeatureWithTimeStamp.java
|        HotPeriod.java
|        PerDayInfo.java
```

UML类图

绘制UML类图，展示一个Java类的属性和功能。

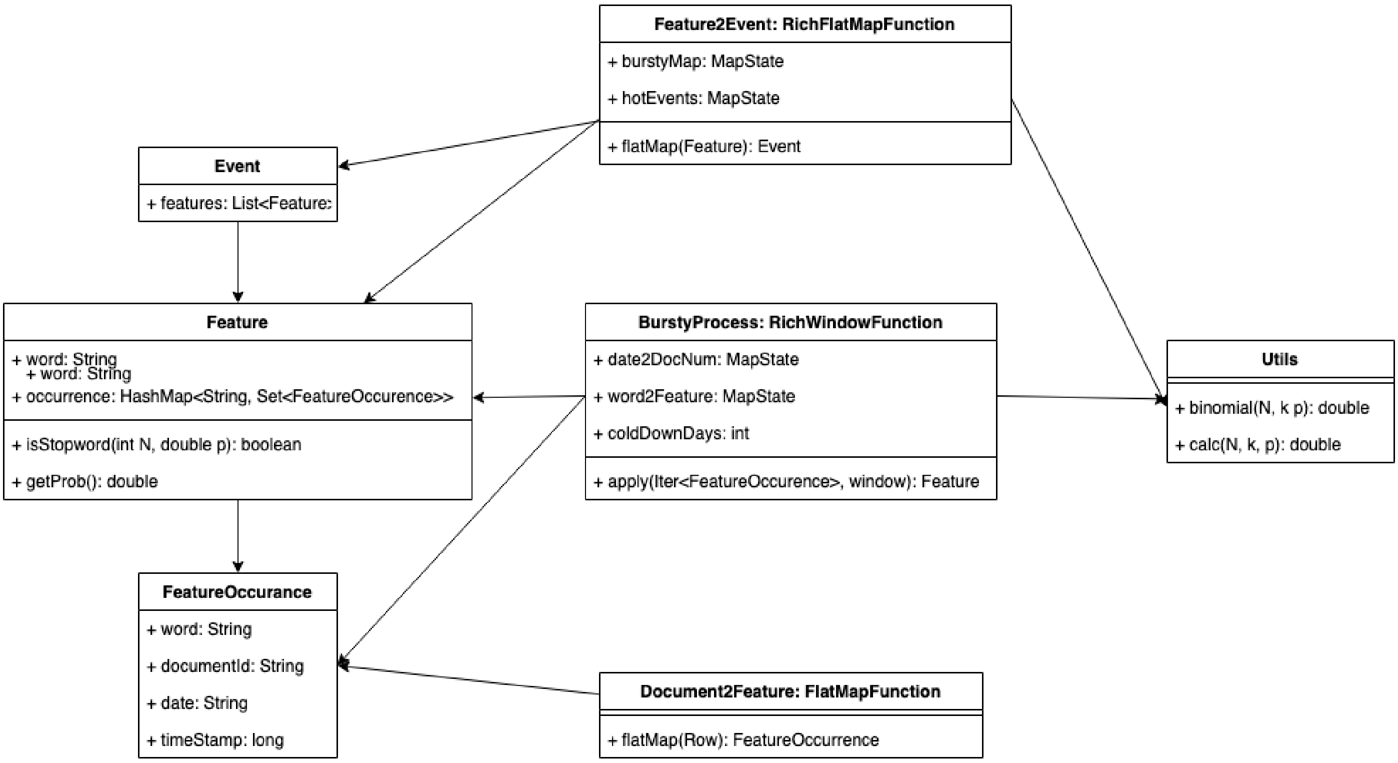

Feature2Event: RichFlatMapFunction
+ burstyMap: MapState
+ hotEvents: MapState
+ flatMap(Feature): Event
Event
+ features: List<Feature:
Feature
+ word: String
+ word: String
+ occurrence: HashMap<String, Set<FeatureOccurence>>
+ isStopword(int N, double p): boolean
+ getProb(): double
BurstyProcess: RichWindowFunction
+ date2DocNum: MapState
+ word2Feature: MapState
+ coldDownDays: int
+ apply(Iter<FeatureOccurence>, window): Feature
Utils
+ binomial(N, k p): double
+ calc(N, k, p): double
FeatureOccurance
+ word: String
+ documentId: String
+ date: String
+ timeStamp: long
Document2Feature: FlatMapFunction
+ flatMap(Row): FeatureOccurrence

图2. 算法UML类图

算法中存在问题及改进

1. 批处理转化为流处理

原文中的算法均基于批处理，每个步骤都需要收集全体的数据才能进行下一步，这样不具有检出突发事件任务的实时性；

在我们的实现过程中，基于Flink流处理框架对算法进行部分改进，将批处理转化为流处理。

2. 冷启动

   在流处理环境下，原文中算法在实现过程中存在冷启动问题：在数据较少时，将所有feature判定为bursty，与真实情况存在较大偏差，造成算法失效；

   在我们的实现过程中，设置cooldowndays阈值，在第一步中收集一部分初始数据后再流入下一步。

3. 算法复杂度

   在算法第2步“From Bursty Features To Bursty Events”过程中，在计算时需要搜索所有 E_k 算法复杂度极高；

   在我们的实现过程中，改用贪心算法来实现相关过程：

   a. 初始化 $E = \emptyset$。

   b. 取当前未被聚类的feature中出现次数最多的记为 f_{max} ，对E中所有事件 E_k ，求 $E_k + \{f_{max}\}$ 中最小的 $cost_1$ ，再当前未被聚类的feature中与 f_{max} 不同的所有 f ，取所有 $\{f_{max}, f\}$ 中的最小 $cost_2$ ，比较 $cost_1$、$cost_2$ ，若 $cost_1$ 更小，且其比原 E_k 的cost更小，则将 f_{max} 加入 E_k ，否则将其丢弃，若 $cost_2$ 更小，则将 $\{f, f_{max}\}$ 加入E。

   c. 重复步骤b，直到所有feature均被聚类。

系统部署及结果展示

部署环境

操作系统：

CentOS

软件环境：

Java8、Flink-1.14.4

系统部署及运行

系统整体Pipeline如下图所示，两种记号分别代表数据流和处理过程。

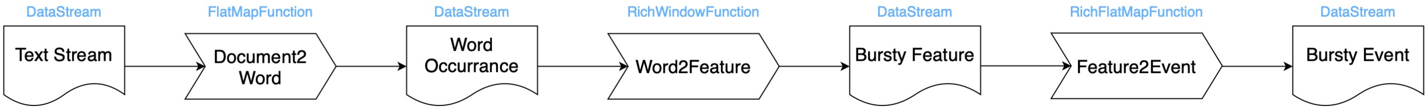
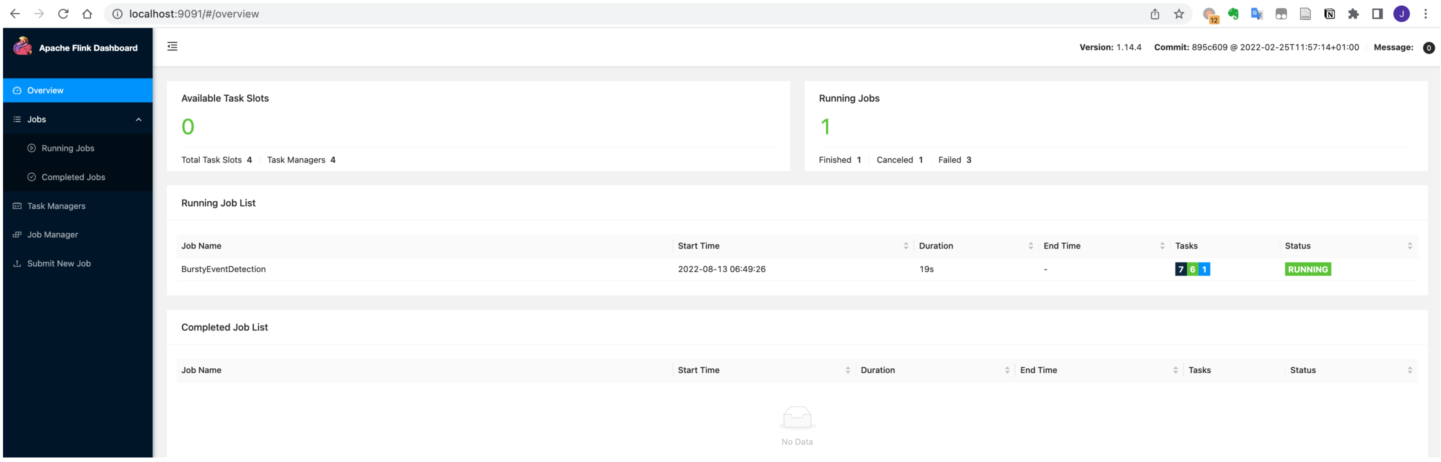


图3. 算法部署Pipeline

系统部署在 Flink 集群中，基于 Flink 的可视化管理界面，可以对系统运行状态、运行结果的进行可视化的展示，部分系统运行时可视化结果如下图。



Version: 1.14.4 **Commit:** 895c609 @ 2022-02-25T11:57:14+01:00 **Message:** 0

Available Task Slots

0

Total Task Slots 4 Task Managers 4

Running Jobs

1

Finished 1 Canceled 1 Failed 3

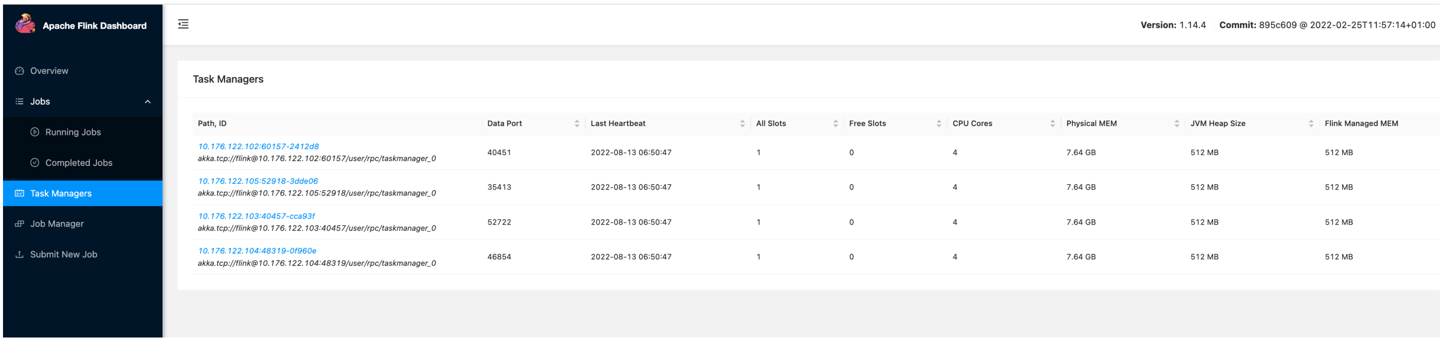
Running Job List

Job Name	Start Time	Duration	End Time	Tasks	Status
BurstyEventDetection	2022-08-13 06:49:26	19s	-	7 6 1	RUNNING

Completed Job List

Job Name	Start Time	Duration	End Time	Tasks	Status

图4. Flink 可视化管理主界面

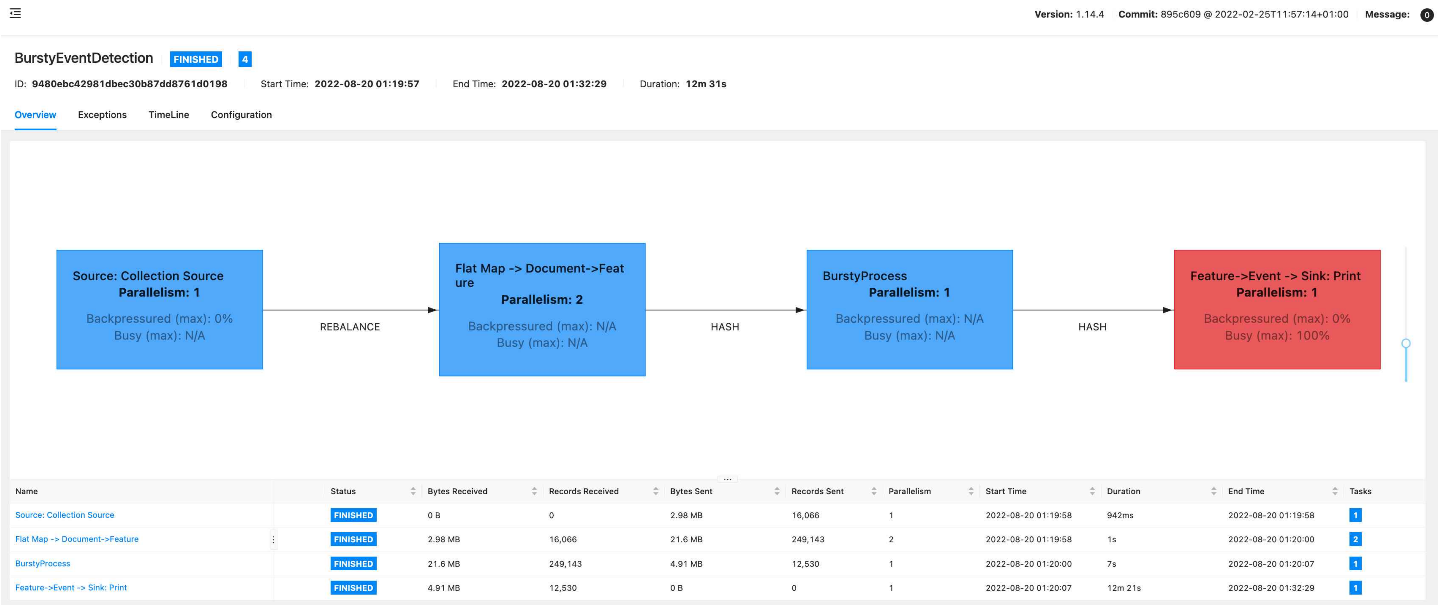


Version: 1.14.4 **Commit:** 895c609 @ 2022-02-25T11:57:14+01:00

Task Managers

Path, ID	Data Port	Last Heartbeat	All Slots	Free Slots	CPU Cores	Physical MEM	JVM Heap Size	Flink Managed MEM
10.176.122.102:60157-2412d8 akka.tcp://flink@10.176.122.102:60157/user/rpc/taskmanager_0	40451	2022-08-13 06:50:47	1	0	4	7.64 GB	512 MB	512 MB
10.176.122.105:52918-3dde06 akka.tcp://flink@10.176.122.105:52918/user/rpc/taskmanager_0	35413	2022-08-13 06:50:47	1	0	4	7.64 GB	512 MB	512 MB
10.176.122.103:40457-cca93f akka.tcp://flink@10.176.122.103:40457/user/rpc/taskmanager_0	52722	2022-08-13 06:50:47	1	0	4	7.64 GB	512 MB	512 MB
10.176.122.104:48319-0f960e akka.tcp://flink@10.176.122.104:48319/user/rpc/taskmanager_0	46854	2022-08-13 06:50:47	1	0	4	7.64 GB	512 MB	512 MB

图5. 对子节点进行任务管理



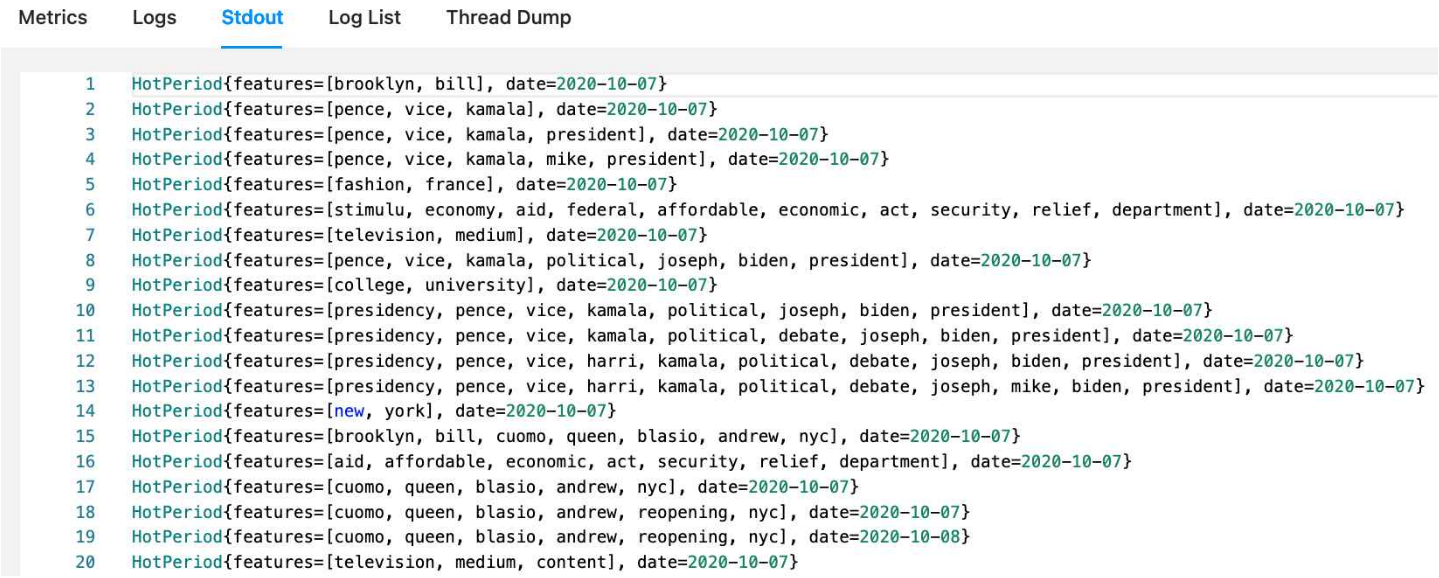
Version: 1.14.4 **Commit:** 895c609 @ 2022-02-25T11:57:14+01:00 **Message:** 0

BurstyEventDetection FINISHED 4

ID: **9480ebc42981dbec30b87dd8761d0198** Start Time: **2022-08-20 01:19:57** End Time: **2022-08-20 01:32:29** Duration: **12m 31s**

Name	Status	Bytes Received	Records Received	Bytes Sent	Records Sent	Parallelism	Start Time	Duration	End Time	Tasks
Source: Collection Source	FINISHED	0 B	0	2.98 MB	16,066	1	2022-08-20 01:19:58	942ms	2022-08-20 01:19:58	1
Flat Map -> Document->Feature	FINISHED	2.98 MB	16,066	21.6 MB	249,143	2	2022-08-20 01:19:58	1s	2022-08-20 01:20:00	2
BurstyProcess	FINISHED	21.6 MB	249,143	4.91 MB	12,530	1	2022-08-20 01:20:00	7s	2022-08-20 01:20:07	1
Feature->Event -> Sink: Print	FINISHED	4.91 MB	12,530	0 B	0	1	2022-08-20 01:20:07	12m 21s	2022-08-20 01:32:29	1

图6. 系统实时运行状态



```
HotPeriod{features=[brooklyn, bill], date=2020-10-07}
HotPeriod{features=[pence, vice, kamala], date=2020-10-07}
HotPeriod{features=[pence, vice, kamala, president], date=2020-10-07}
HotPeriod{features=[pence, vice, kamala, mike, president], date=2020-10-07}
HotPeriod{features=[fashion, france], date=2020-10-07}
HotPeriod{features=[stimulu, economy, aid, federal, affordable, economic, act, security, relief, department], date=2020-10-07}
HotPeriod{features=[television, medium], date=2020-10-07}
HotPeriod{features=[pence, vice, kamala, political, joseph, biden, president], date=2020-10-07}
HotPeriod{features=[college, university], date=2020-10-07}
HotPeriod{features=[presidency, pence, vice, kamala, political, joseph, biden, president], date=2020-10-07}
HotPeriod{features=[presidency, pence, vice, kamala, political, debate, joseph, biden, president], date=2020-10-07}
HotPeriod{features=[presidency, pence, vice, harri, kamala, political, debate, joseph, biden, president], date=2020-10-07}
HotPeriod{features=[presidency, pence, vice, harri, kamala, political, debate, joseph, mike, biden, president], date=2020-10-07}
HotPeriod{features=[new, york], date=2020-10-07}
HotPeriod{features=[brooklyn, bill, cuomo, queen, blasio, andrew, nyc], date=2020-10-07}
HotPeriod{features=[aid, affordable, economic, act, security, relief, department], date=2020-10-07}
HotPeriod{features=[cuomo, queen, blasio, andrew, nyc], date=2020-10-07}
HotPeriod{features=[cuomo, queen, blasio, andrew, reopening, nyc], date=2020-10-07}
HotPeriod{features=[cuomo, queen, blasio, andrew, reopening, nyc], date=2020-10-08}
HotPeriod{features=[television, medium, content], date=2020-10-07}
```

图7. 系统输出结果

系统结果展示

Bursty Features

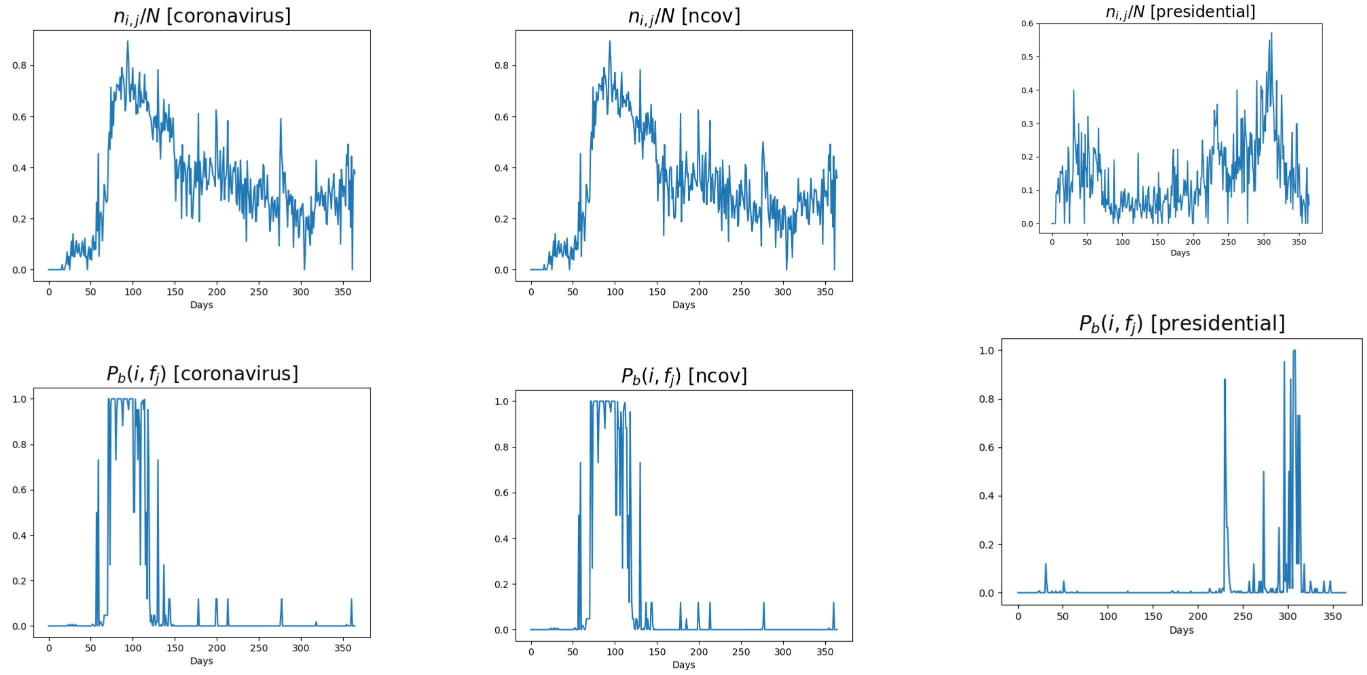
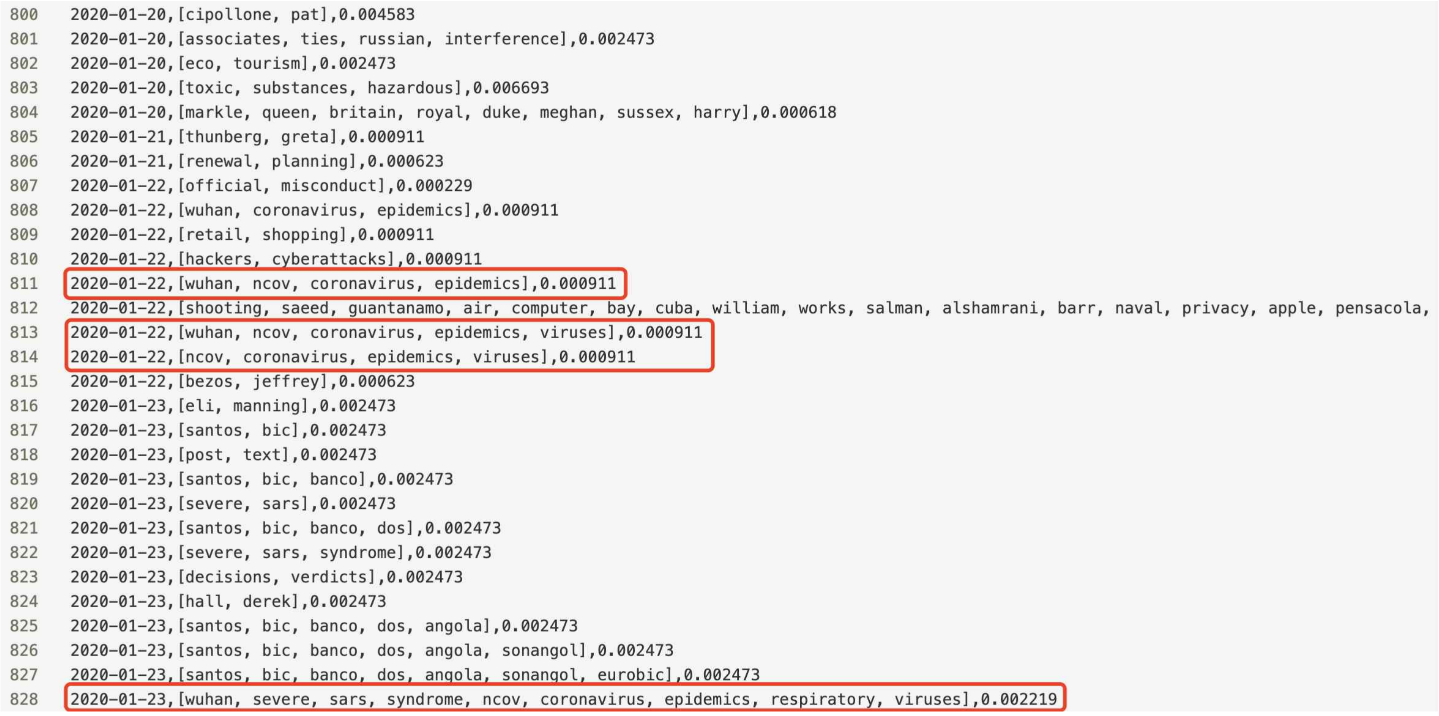


图8. Bursty Features阶段输出结果展示

上图展示了系统中Bursty Feautres阶段的算法结果，包括[coronavirus, ncov, presidential]的结果。

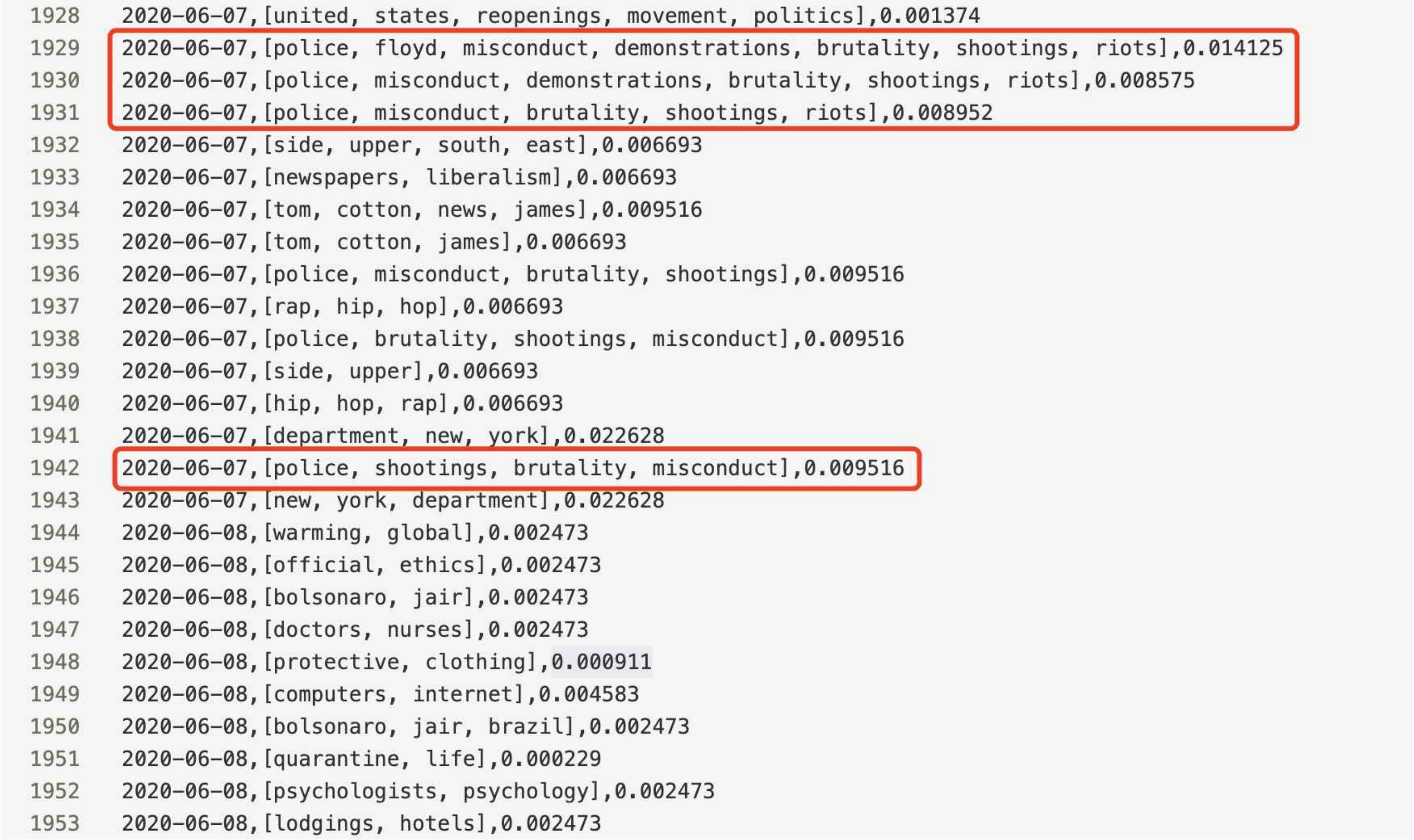
Bursty Events



```
2020-01-20,[cipollone, pat],0.004583
2020-01-20,[associates, ties, russian, interference],0.002473
2020-01-20,[eco, tourism],0.002473
2020-01-20,[toxic, substances, hazardous],0.006693
2020-01-20,[markle, queen, britain, royal, duke, meghan, sussex, harry],0.000618
2020-01-21,[thunberg, greta],0.000911
2020-01-21,[renewal, planning],0.000623
2020-01-22,[official, misconduct],0.000229
2020-01-22,[wuhan, coronavirus, epidemics],0.000911
2020-01-22,[retail, shopping],0.000911
2020-01-22,[hackers, cyberattacks],0.000911
2020-01-22,[wuhan, ncov, coronavirus, epidemics],0.000911
2020-01-22,[shooting, saeed, guantanamo, air, computer, bay, cuba, william, works, salman, alshamrani, barr, naval, privacy, apple, pensacola,
2020-01-22,[wuhan, ncov, coronavirus, epidemics, viruses],0.000911
2020-01-22,[ncov, coronavirus, epidemics, viruses],0.000911
2020-01-22,[bezos, jeffrey],0.000623
2020-01-23,[eli, manning],0.002473
2020-01-23,[santos, bic],0.002473
2020-01-23,[post, text],0.002473
2020-01-23,[santos, bic, banco],0.002473
2020-01-23,[severe, sars],0.002473
2020-01-23,[santos, bic, banco, dos],0.002473
2020-01-23,[severe, sars, syndrome],0.002473
2020-01-23,[decisions, verdicts],0.002473
2020-01-23,[hall, derek],0.002473
2020-01-23,[santos, bic, banco, dos, angola],0.002473
2020-01-23,[santos, bic, banco, dos, angola, sonangol],0.002473
2020-01-23,[santos, bic, banco, dos, angola, sonangol, eurobic],0.002473
2020-01-23,[wuhan, severe, sars, syndrome, ncov, coronavirus, epidemics, respiratory, viruses],0.002219
```

图9. ncov-19事件输出结果展示

上图为Bursty Events阶段，2020年1月对ncov-19事件的检测结果。



```
2020-06-07,[united, states, reopenings, movement, politics],0.001374
2020-06-07,[police, floyd, misconduct, demonstrations, brutality, shootings, riots],0.014125
2020-06-07,[police, misconduct, demonstrations, brutality, shootings, riots],0.008575
2020-06-07,[police, misconduct, brutality, shootings, riots],0.008952
2020-06-07,[side, upper, south, east],0.006693
2020-06-07,[newspapers, liberalism],0.006693
2020-06-07,[tom, cotton, news, james],0.009516
2020-06-07,[tom, cotton, james],0.006693
2020-06-07,[police, misconduct, brutality, shootings],0.009516
2020-06-07,[rap, hip, hop],0.006693
2020-06-07,[police, brutality, shootings, misconduct],0.009516
2020-06-07,[side, upper],0.006693
2020-06-07,[hip, hop, rap],0.006693
2020-06-07,[department, new, york],0.022628
2020-06-07,[police, shootings, brutality, misconduct],0.009516
2020-06-07,[new, york, department],0.022628
2020-06-08,[warming, global],0.002473
2020-06-08,[official, ethics],0.002473
2020-06-08,[bolsonaro, jair],0.002473
2020-06-08,[doctors, nurses],0.002473
2020-06-08,[protective, clothing],0.000911
2020-06-08,[computers, internet],0.004583
2020-06-08,[bolsonaro, jair, brazil],0.002473
2020-06-08,[quarantine, life],0.000229
2020-06-08,[psychologists, psychology],0.002473
2020-06-08,[lodgings, hotels],0.002473
```

图10. George Floyd事件输出结果展示

上图为Bursty Events阶段，2020年6月对George Floyd事件的检测结果。

表1. 部分事件结果展示

Bursty Events	Bursty Features
E1（ncov-2019）	wuhan, ncov, coronavirus, epidemics, viruses, ...
E2（impeachment）	ukraine, impeachment, inquiry, complaint, ...
E3（new energy）	electronics, motors, hybird, vehicles, ...
E4（shooting）	riots, shootings, floyd, blacks, ...
E5（election）	election, presidential, trump, ...

上表展示了部分突发事件的预测结果，可以看到算法对突发事件有较好的预测能力。

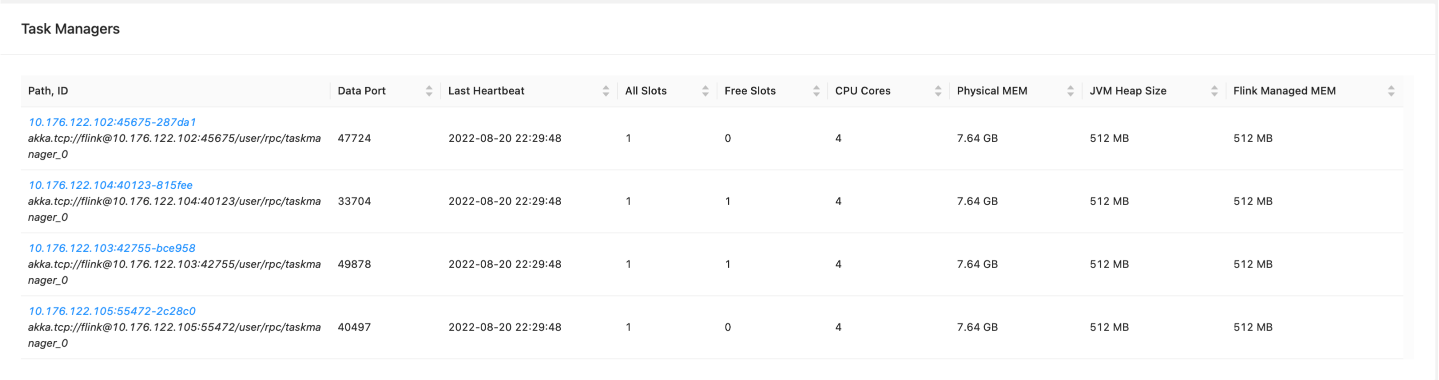
单机运行配置及运行时间

处理器 11th Gen Intel(R) Core(TM) i5-1135G7 @ 2.40GHz

内存 16.0 GB

对所获取的16K+条数据进行文本流的事件监测，单机运行时间为**17m29s。**

分布式集群配置及运行时间

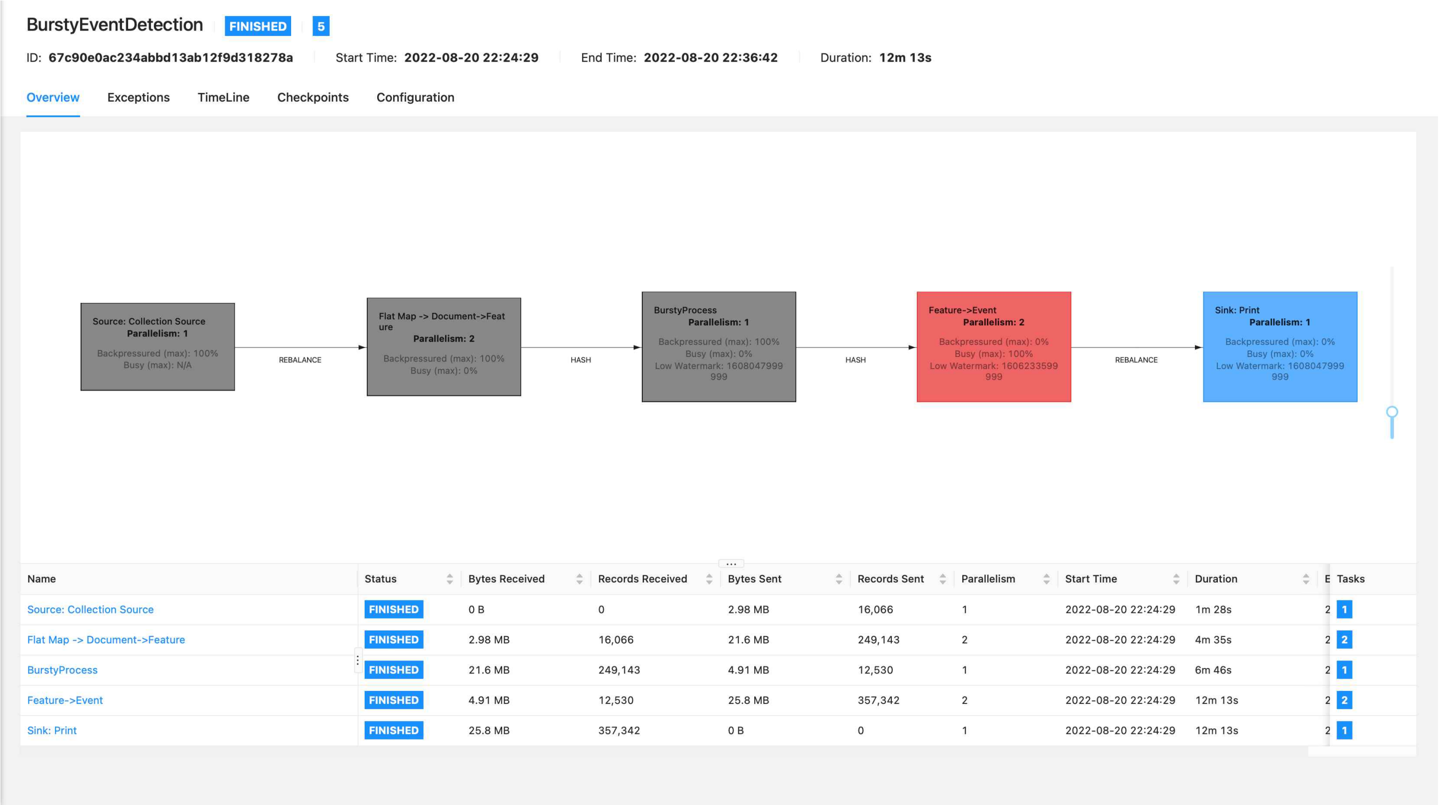


Task Managers

Path, ID	Data Port	Last Heartbeat	All Slots	Free Slots	CPU Cores	Physical MEM	JVM Heap Size	Flink Managed MEM
10.176.122.102:45675-287da1 *akka.tcp://flink@10.176.122.102:45675/user/rpc/taskmanager_0*	47724	2022-08-20 22:29:48	1	0	4	7.64 GB	512 MB	512 MB
10.176.122.104:40123-815fee *akka.tcp://flink@10.176.122.104:40123/user/rpc/taskmanager_0*	33704	2022-08-20 22:29:48	1	1	4	7.64 GB	512 MB	512 MB
10.176.122.103:42755-bce958 *akka.tcp://flink@10.176.122.103:42755/user/rpc/taskmanager_0*	49878	2022-08-20 22:29:48	1	1	4	7.64 GB	512 MB	512 MB
10.176.122.105:55472-2c28c0 *akka.tcp://flink@10.176.122.105:55472/user/rpc/taskmanager_0*	40497	2022-08-20 22:29:48	1	0	4	7.64 GB	512 MB	512 MB

图11. 分布式集群配置

分布式集群的配置信息如上图所示，每台独立机器有4核CPU及8GB的运行内存，共5台机器构成分布式集群，以10.176.122.101为主节点构建分布式集群。



BurstyEventDetection FINISHED 5

ID: 67c90e0ac234abbd13ab12f9d318278a Start Time: 2022-08-20 22:24:29 End Time: 2022-08-20 22:36:42 Duration: 12m 13s

Name	Status	Bytes Received	Records Received	Bytes Sent	Records Sent	Parallelism	Start Time	Duration	E	Tasks
Source: Collection Source	FINISHED	0 B	0	2.98 MB	16,066	1	2022-08-20 22:24:29	1m 28s	2	1
Flat Map -> Document->Feature	FINISHED	2.98 MB	16,066	21.6 MB	249,143	2	2022-08-20 22:24:29	4m 35s	2	2
BurstyProcess	FINISHED	21.6 MB	249,143	4.91 MB	12,530	1	2022-08-20 22:24:29	6m 46s	2	1
Feature->Event	FINISHED	4.91 MB	12,530	25.8 MB	357,342	2	2022-08-20 22:24:29	12m 13s	2	2
Sink: Print	FINISHED	25.8 MB	357,342	0 B	0	1	2022-08-20 22:24:29	12m 13s	2	1

图12. 分布式集群运行时间及状态

对所获取的16K+条数据进行文本流的事件监测，其运行时间为**12m13s**，其算法效率较批处理算法（1～2h）提升明显，符合算法预期。

项目排期及参考文献

项目排期

时间节点	完成工作
5.23～6.6	学习原论文工作，学习流处理框架
6.6～6.20	技术选型，讨论复现细节，寻找数据集
6.20～7.4	复现论文，接入数据集
7.4～7.18	优化实现逻辑
7.18～8.1	集群部署，优化实现逻辑
8.1～8.15	可视化结果，整理报告

参考文献

Fung, Gabriel Pui Cheong, et al. "Parameter free bursty events detection in text streams." *Proceedings of the 31st international conference on Very large data base*. 2005.