FUSING APACHE SPARK AND LUCENE FOR NEAR-REALTIME PREDICTIVE MODEL BUILDING

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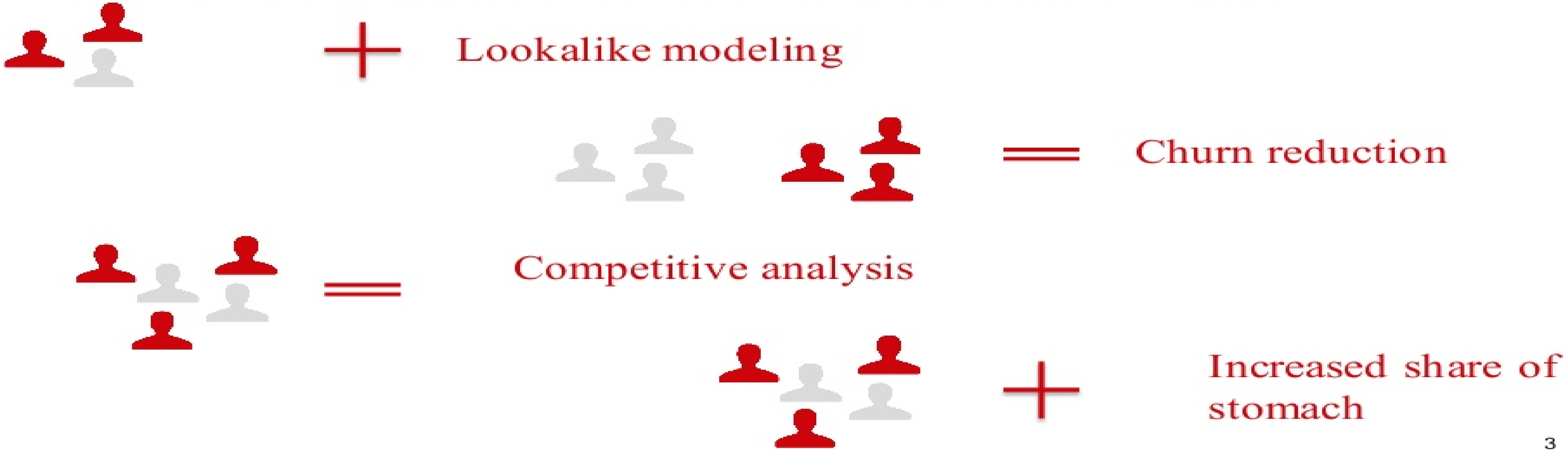
Data Overview

- Location data
  - Each srclp defined as unique row key
  - Provides approximate location of each key
  - Timeseries containing latitude, longitude, error bound, duration, timezone for each key
- Clickstream data
  - Contains clickstream data of each row key
  - Contains startTime, duration, httphost, httpuri, upload/download bytes, httpmethod
  - Compatible with IPFIX/Netflow formats

Marketing Analytics

- Anonymous aggregate analysis for customer insights



Lookalike modeling

Churn reduction

Competitive analysis

Increased share of stomach

Data Model

- Dense dimension, dense measure
  Schema: srcip, date, hour, tld, zip, tldvisits, zipvisits
  Data: 10.1.13.120, d1, H2, macys.com, 94555, 2, 4
- Sparse dimension, dense measure
  Schema: srcip, date, tld, zip, clickstreamvisits, zipvisits
  Data: 10.1.13.120, d1, {macys.com, kohls.com}, {94555, 94301}, 10, 15
- Sparse dimension, sparse measure
  Schema: srcip, date, tld, zip, tldvisits, zipvisits
  Data: 10.1.13.120, d1, {macys.com, kohls.com}, {94555, 94301}, {macys.com:4, kohls.com:6}, {94555:8, 94301:7}
  Schema: srcip, week, tld, zip, tldvisits, zipvisits
  Data: 10.1.13.120, week1, {macys.com, kohls.com}, {94555, 94301}, {macys.com:4, kohls.com:6}, {94555:8, 94301:7}
  - Sparse dimension, sparse measure, **last N days**
    Schema: srcip, tld, zip, tldvisits, zipvisits
    Data: 10.1.13.120, {macys.com, kohls.com}, {94555, 94301}, {macys.com:4, kohls.com:6}, {94555:8, 94301:7}
- Competing technologies: PowerDrill, Druid, LinkedIn Pinot, EssBase

Document Dataset Representation

- Example

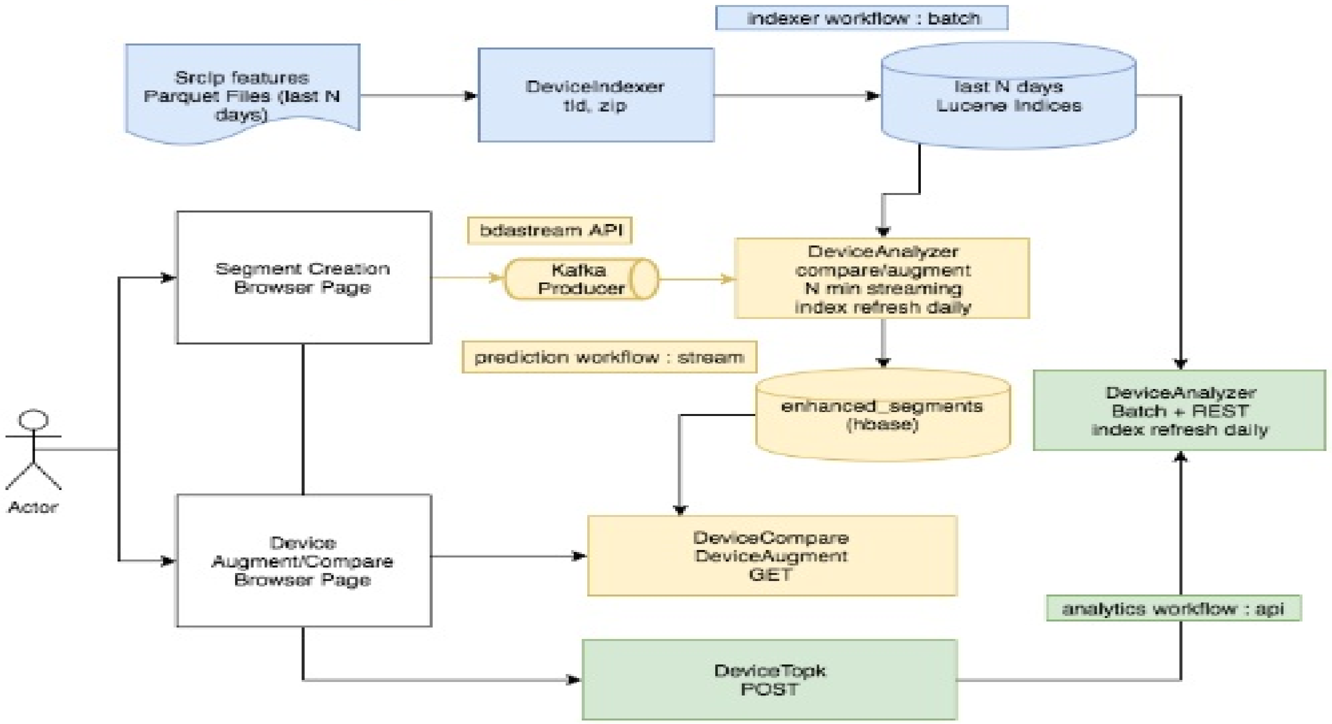
  Schema: srcip, tld, zip, tldvisits, zipvisits
  Data: 10.1.13.120, {macys.com, kohls.com}, {94555, 94301}, {macys.com:4, kohls.com:6}, {94555:8, 94301:7}
- DataFrame row to Lucene Document mapping

Store/schema	*Row*	*Document*
srcip	*primary key*	*docId*
tld *zip*	*String* *Array[String]*	*SingleValue/MultiValue* *Indexed Fields*
tldvisits *zipvisits*	*Double* *Map[String, Double]*	*SparseVector* *StoredField*

- Distributed collection of srcIp as RDD[Document]
  - ~100M srcip, 1M+ terms (sparse dimensions)

DeviceAnalyzer

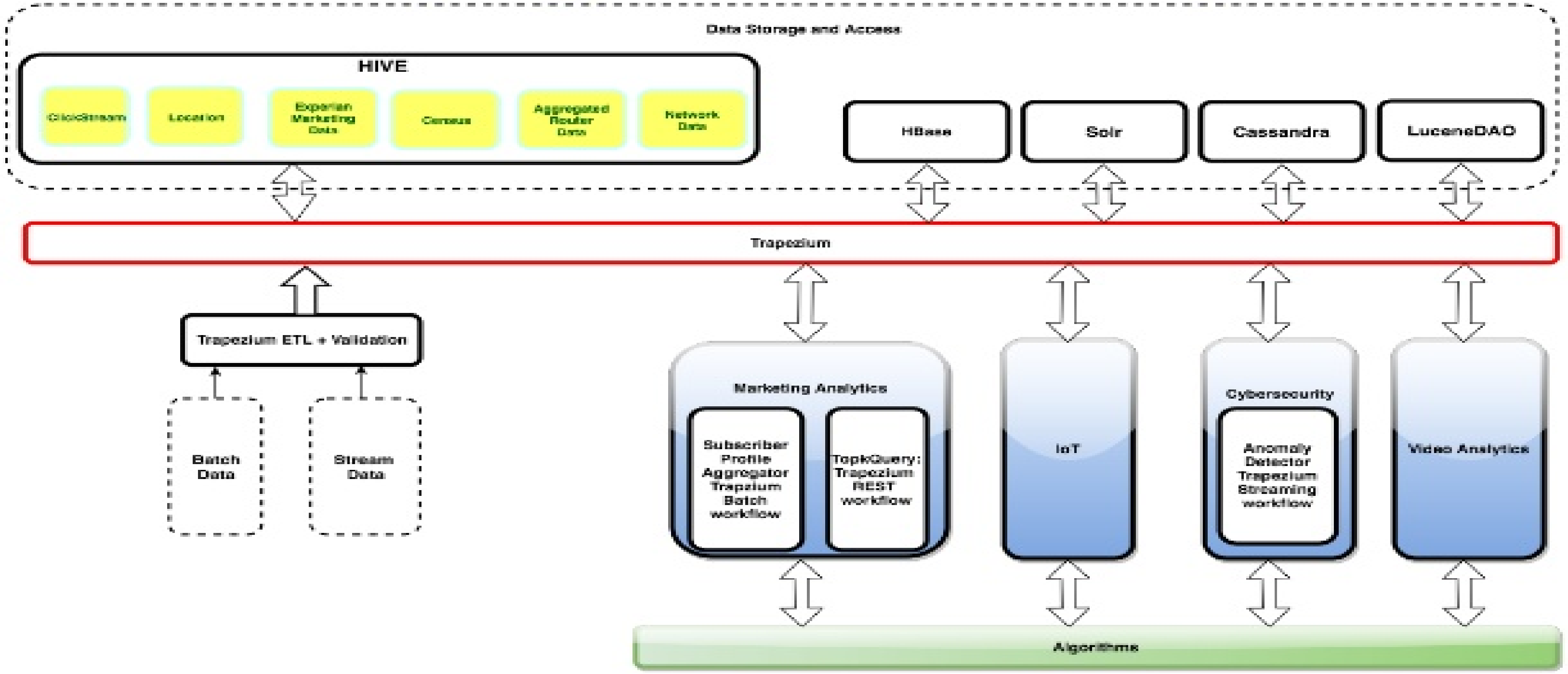
- DeviceAnalyzer goals
  - Search and retrieve devices that matched query
  - Generate statistical and predictive models on retrieved devices


indexer workflow : batch
Srcip features Parquet Files (last N days)
DeviceIndexer tld, zip
last N days Lucene Indices
bdastream API
Segment Creation Browser Page
Kafka Producer
DeviceAnalyzer compare/augment N min streaming index refresh daily
prediction workflow : stream
enhanced_segments (hbase)
DeviceAnalyzer Batch + REST index refresh daily
Actor
Device Augment/Compare Browser Page
DeviceCompare DeviceAugment GET
analytics workflow : api
DeviceTopk POST

What is Trapezium ?

DAIS Open Source framework to build batch, streaming and API services

https://github.com/Verizon/trapezium



Data Storage and Access

HIVE

ClickStream

Location

Experian Marketing Data

Census

Aggregated Router Data

Network Data

HBase

Solr

Cassandra

LuceneDAO

Trapezium

Trapezium ETL + Validation

Batch Data

Stream Data

Marketing Analytics

Subscriber Profile Aggregator Trapzium Batch workflow

TopkQuery: Trapezium REST workflow

IoT

Cybersecurity

Anomaly Detector Trapezium Streaming workflow

Video Analytics

Algorithms

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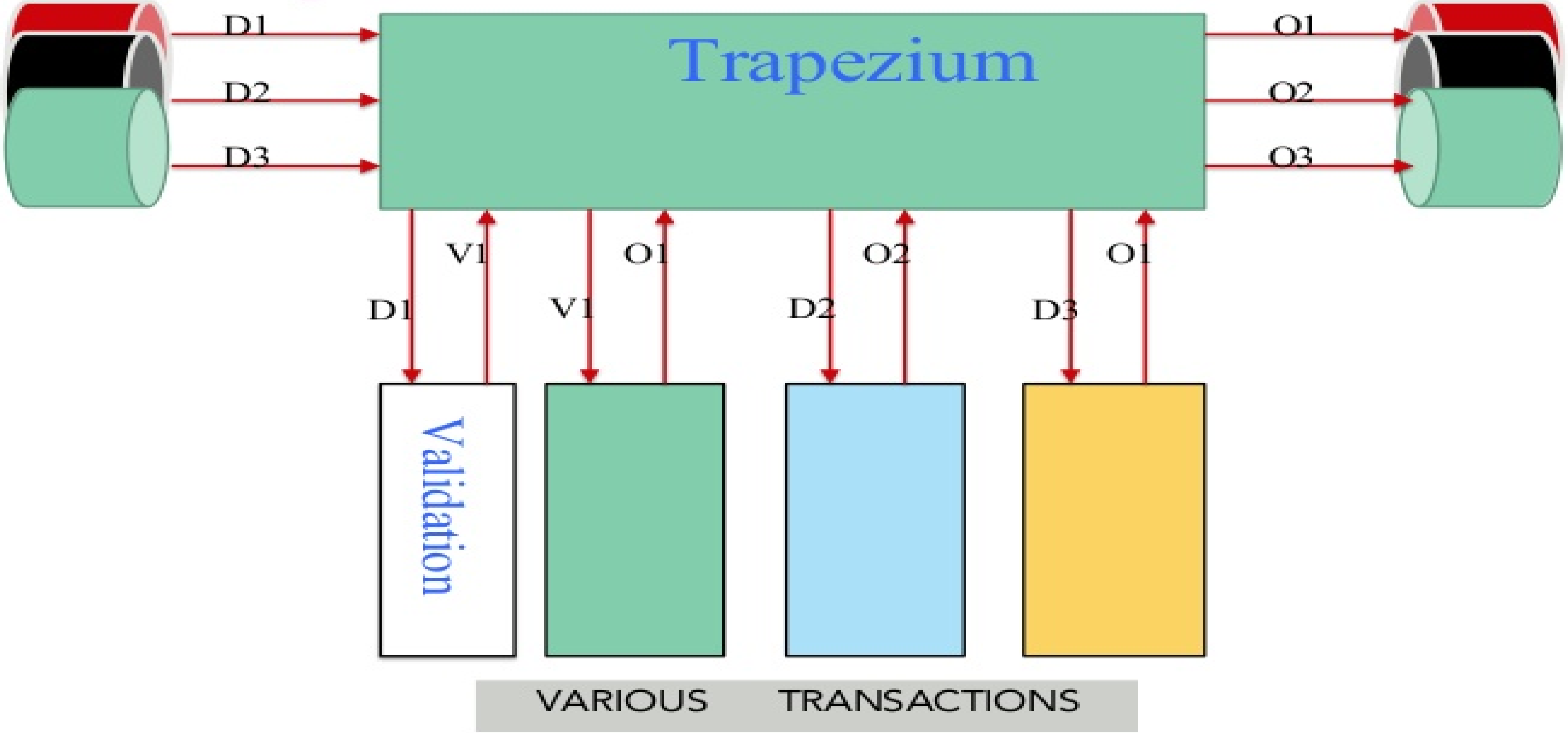
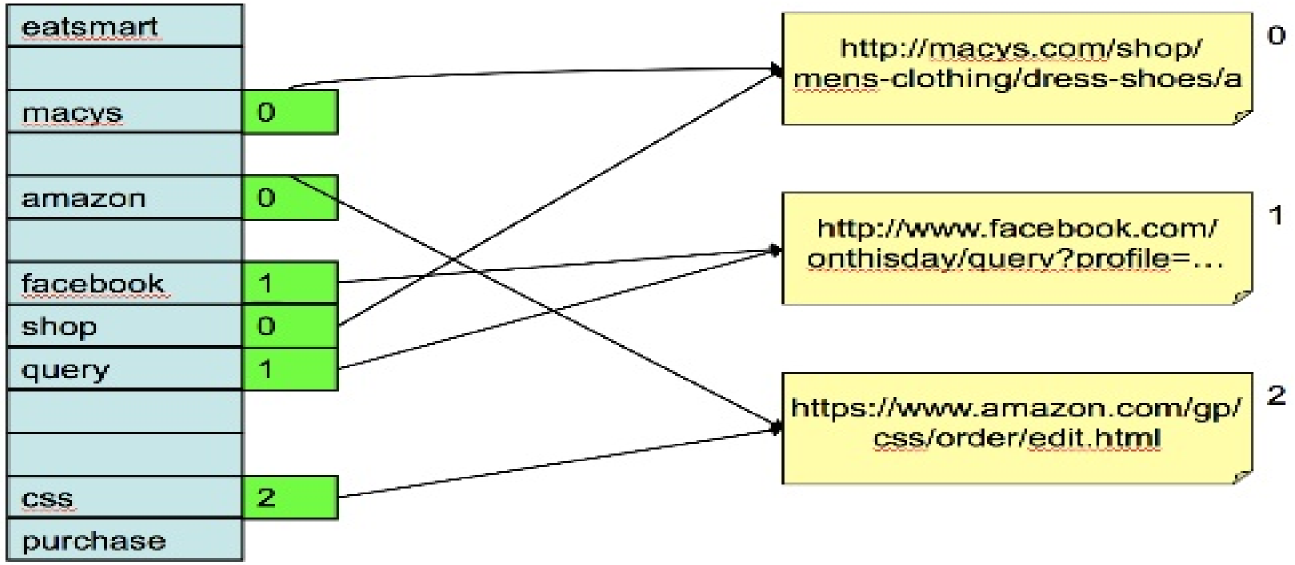
Trapezium Architecture



Lucene Overview

- Scalable, full-text search library
- Focus: Indexing + searching documents



eatsmart	
macys	0
amazon	0
facebook	1
shop	0
query	1
css	2
purchase	

0 http://macys.com/shop/mens-clothing/dress-shoes/a

1 http://www.facebook.com/onthisday/query?profile=...

2 https://www.amazon.com/gp/css/order/edit.html

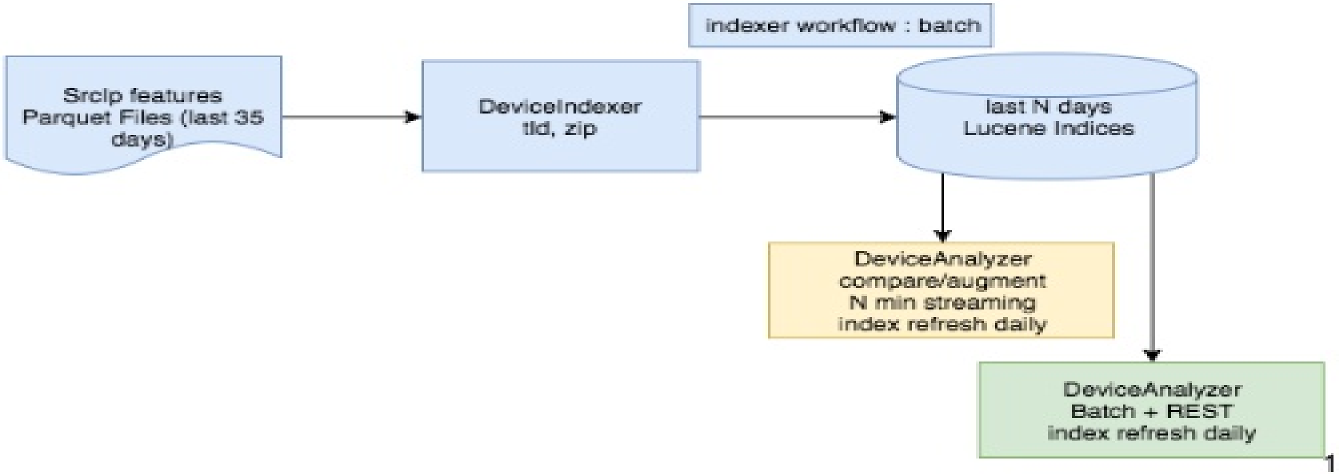
Trapezium LuceneDAO

- SparkSQL and MLlib optimized for full scan, **column indexing not supported**
- Why Spark + Lucene integration
  - Lucene is battle tested Apache Licensed Open Source Project
  - Adds column search capabilities to Spark
  - Adds spark operators (treeAggregate, treeReduce, map) to Lucene
- LuceneDAO features
  - Build distributed lucene shards from Dataframe
  - Save shards to HDFS for QueryProcessor (CloudSolr)
  - Access saved shards through LuceneDAO for ML pipelines

Trapezium Batch

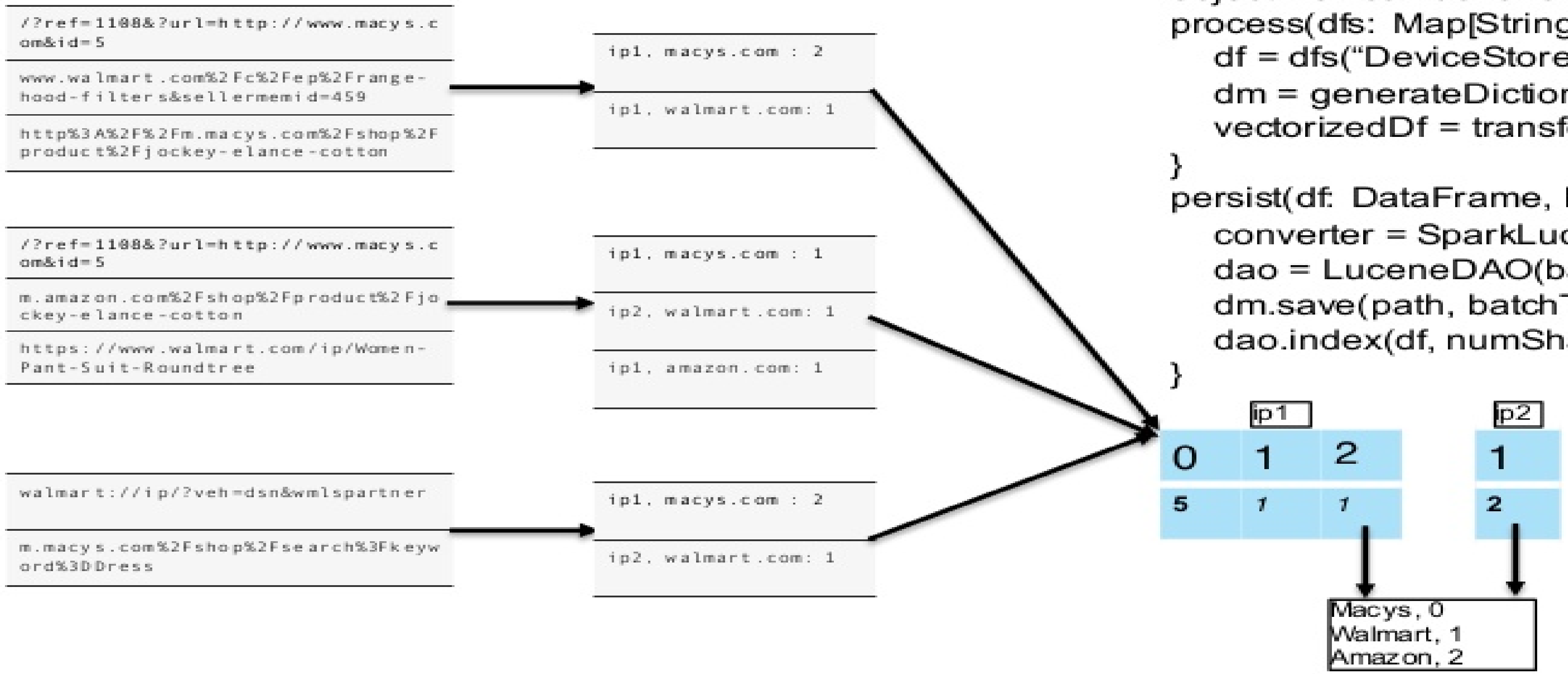
```
runMode = "BATCH"
dataSource = “HDFS”
dependentWorkflows= {
    workflows=[aggregate]
    frequencyToCheck=100
}
hdfsFileBatch = {
  batchTime = 86400
  timerStartDelay = 1
  batchInfo = [{
      name = "DeviceStore"
      dataDirectory = {saiph-devqa=/aggregates}
      fileFormat = "parquet"
    }]
}
```

```
transactions = [{
  transactionName  = “DeviceIndexer”
  inputData  = [{name  = "DeviceStore"}]
  persistDataName  = “indexed"
}]
```


indexer workflow : batch
SrcIp features Parquet Files (last 35 days)
DeviceIndexer tld, zip
last N days Lucene Indices
DeviceAnalyzer compare/augment N min streaming index refresh daily
DeviceAnalyzer Batch + REST index refresh daily

DeviceAnalyzer: Indexing

```
object DeviceIndexer extend BatchTransaction {
process(dfs: Map[String, DataFrame], batchTime: Time): {
   df = dfs(“DeviceStore”)
   dm = generateDictionary(df)
   vectorizedDf = transform(df, dm)
}
persist(df: DataFrame, batchTime: Time): {
   converter = SparkLuceneConverter(dm.size)
   dao = LuceneDAO(batchTime,...).setConverter(converter)
   dm.save(path, batchTime)
   dao.index(df, numShards)
}
```



/?ref=1108&?url=http://www.macys.com&id=5

www.walmart.com%2Fc%2Fep%2Frange-hood-filters&sellermemid=459

http%3A%2F%2Fm.macys.com%2Fshop%2Fproduct%2Fjockey-elance-cotton

ip1, macys.com : 2

ip1, walmart.com: 1

/?ref=1108&?url=http://www.macys.com&id=5

m.amazon.com%2Fshop%2Fproduct%2Fjockey-elance-cotton

https://www.walmart.com/ip/Women-Pant-Suit-Roundtree

ip1, macys.com : 1

ip2, walmart.com: 1

ip1, amazon.com: 1

walmart://ip/?veh=dsn&wmlspartner

m.macys.com%2Fshop%2Fsearch%3Fkeyword%3DDress

ip1, macys.com : 2

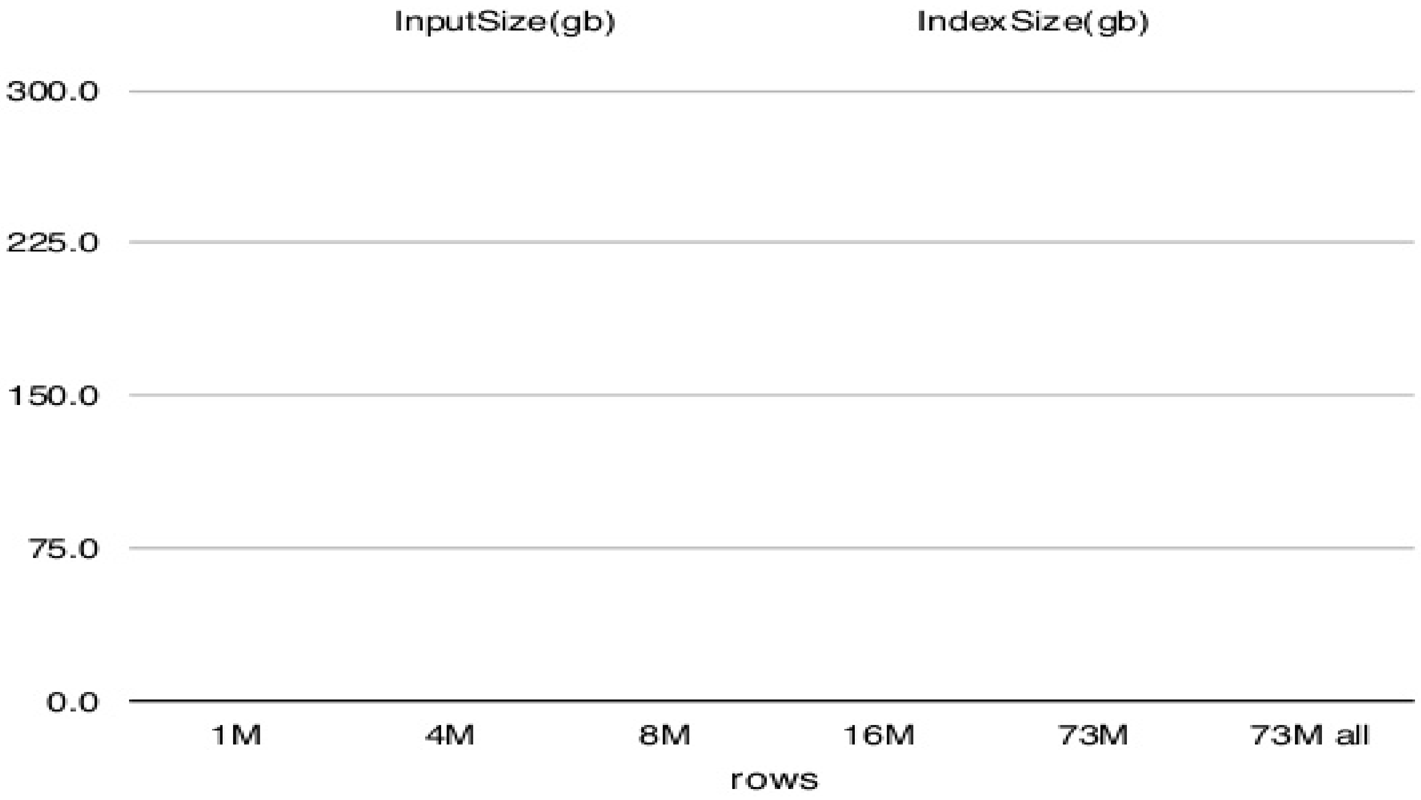
ip2, walmart.com: 1

ip1			ip2
0	1	2	1
5	1	1	2

Macys, 0
Walmart, 1
Amazon, 2

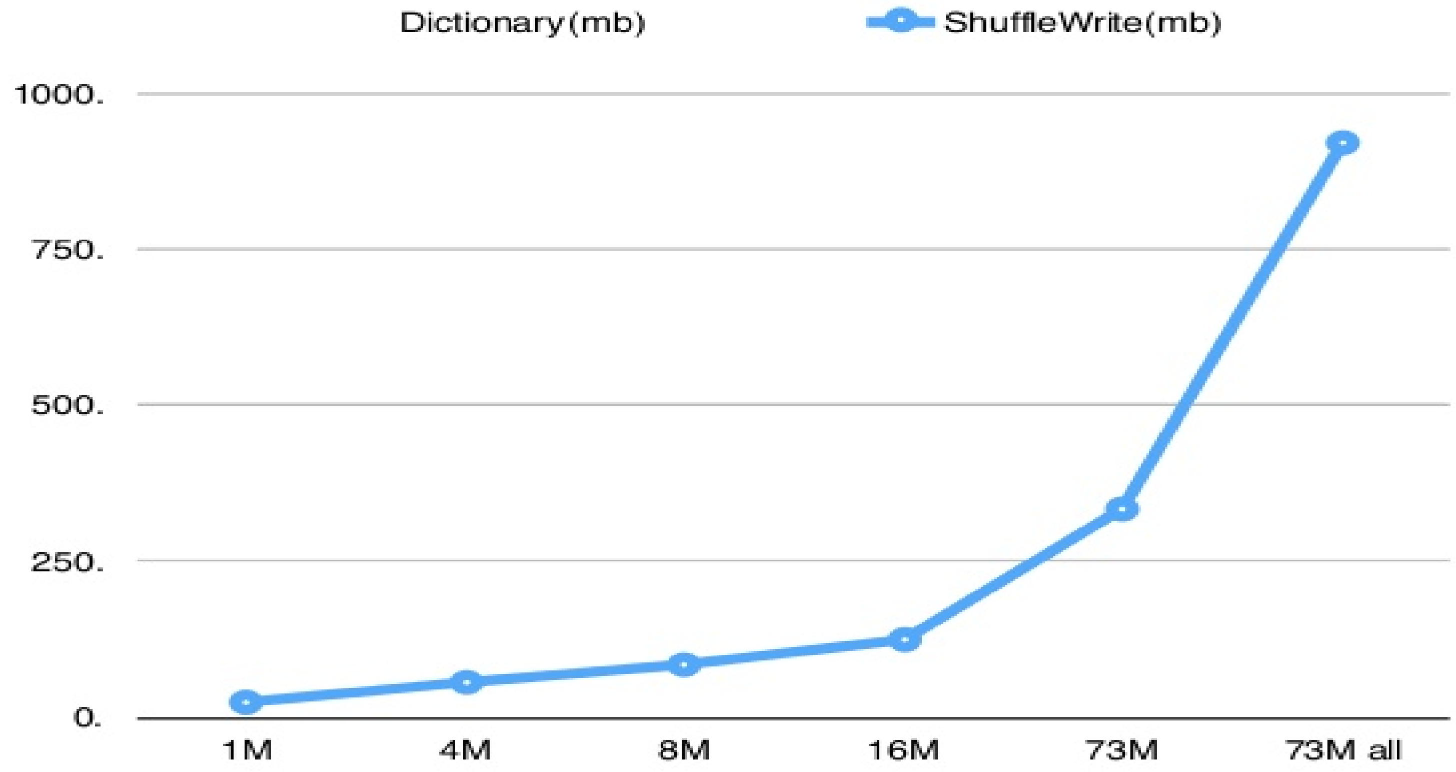
LuceneDAO Index Size

rows	InputSize(gb)	IndexSize(gb)
1M	4.0	5.1
4M	14.4	19.0
8M	27.9	35.7
16M	58.8	63.2
73M	276.5	228.0
73M all	276.5	267.1



LuceneDAO Shuffle Size

rows	ShuffleWrite(mb)	Dictionary(mb)
1M	25	22.0
4M	56	30.0
8M	85	31.6
16M	126	32.2
73M	334	32.4
73M all	921	146.5



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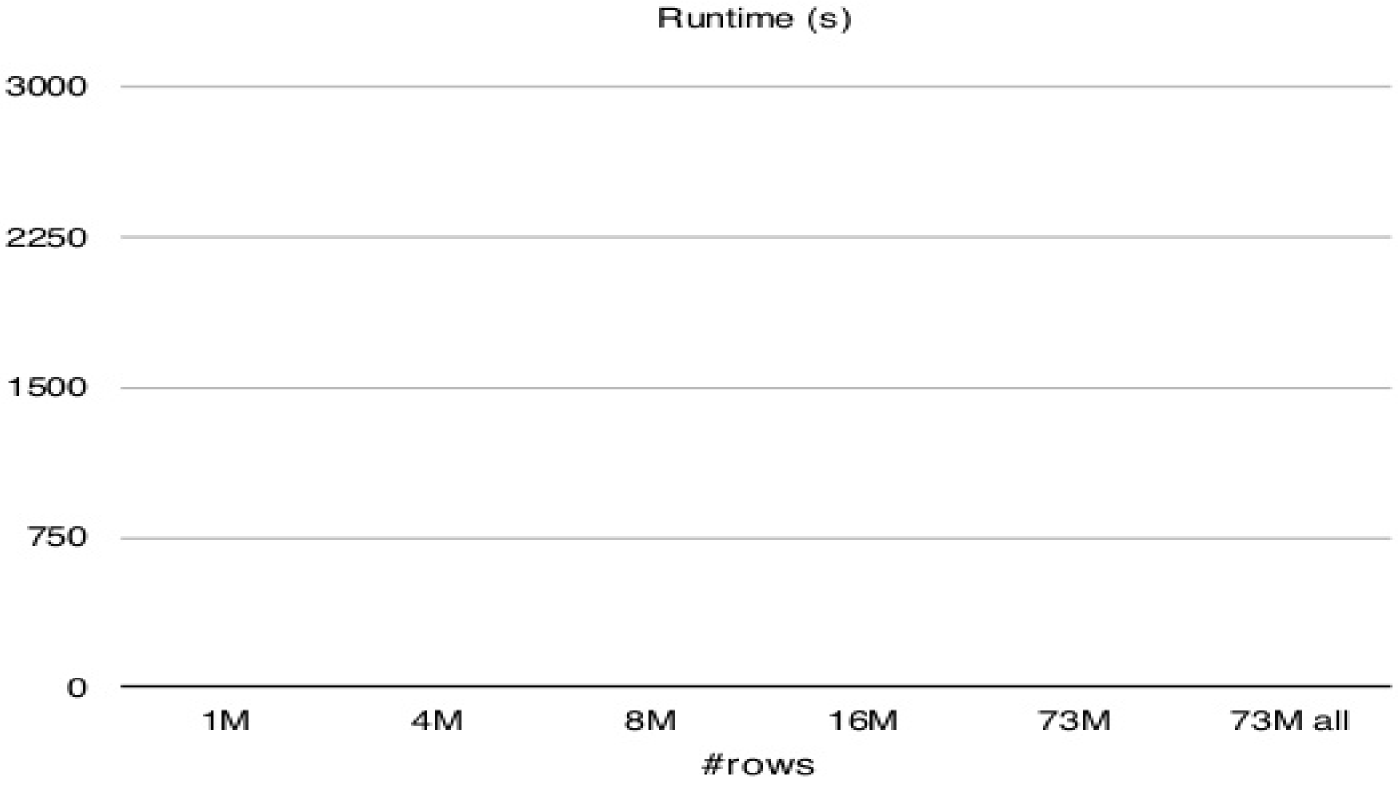
LuceneDAO Index Runtime

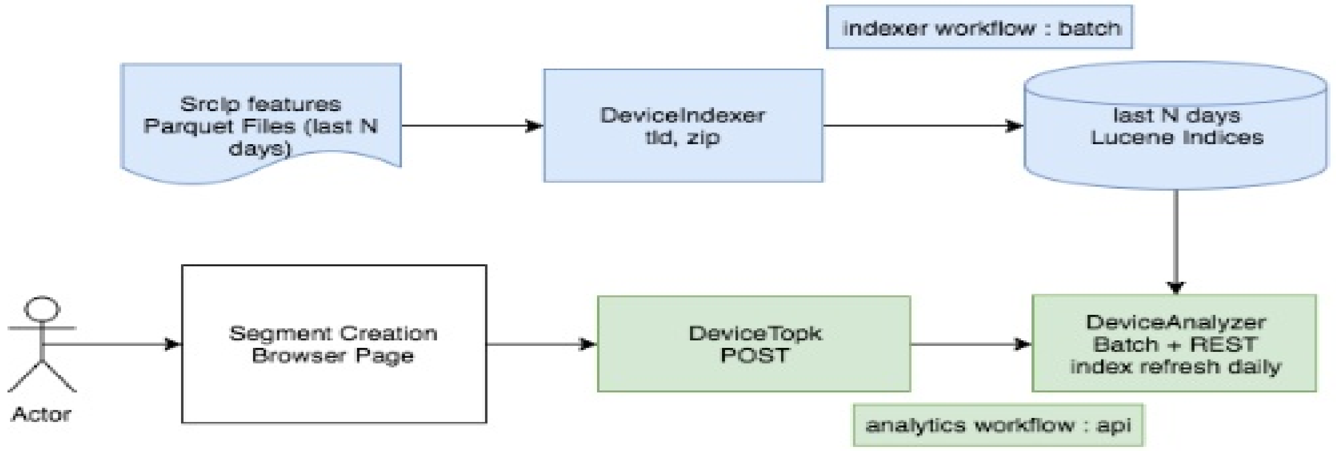
20 executors 16 cores
Executor RAM 16 GB
Driver RAM 8g

rows	Runtime (s)
1M	135
4M	228
8M	434
16M	571
73M	1726
73M all	2456



Trapezium Api

```
runMode = "BATCH"
dataSource = "HDFS"
httpServer = {
 provider = "akka"
 hostname = "localhost"
 port = 19999
 contextPath = "/"
 endPoints = [{
    path = “analyzer-api"
    className = "TopKEndPoint"
   }]
}
```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DeviceIndexer tld, zip
last N days Lucene Indices
Actor
Segment Creation Browser Page
DeviceTopk POST
DeviceAnalyzer Batch + REST index refresh daily
analytics workflow : api

DeviceAnalyzer: Topk

- Given a query select * from devices where tld='macys.com' OR 'nordstorm.com' AND (city='SanFrancisco' OR 'Brussels') AND (device='Android') ...
  - ML: Find topk dimensions highly correlated with selected device
  - BI: group by tld order by sum(visits) as tldVisits limit topk

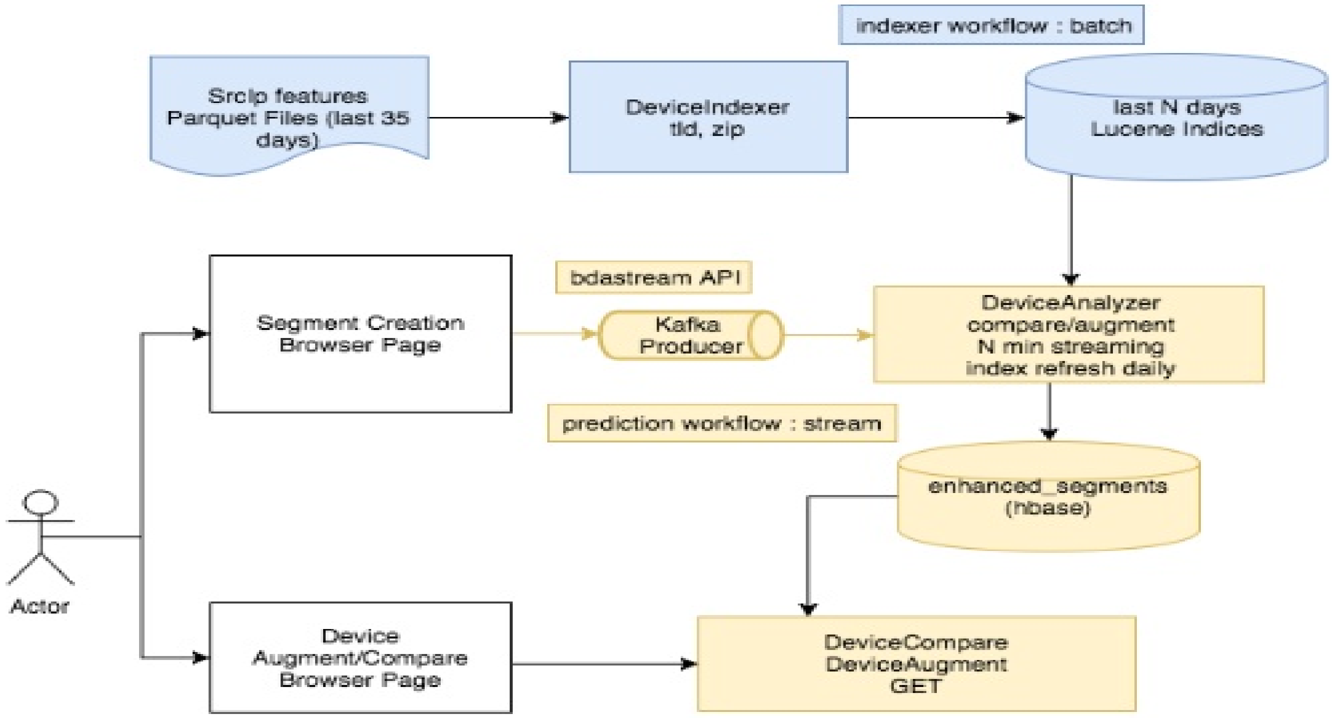
```
class TopkController(sc: SparkContext) extends
SparkServiceEndPoint(sc) {
override def route : topkRoute
converter = SparkLuceneConverter(dm.size)
batchTime = Trapezium.getSyncTime("indexer")
dao = LuceneDAO(batchTime...)
    .setConverter(converter).load(sc, indexPath)
dict = loadDictionary(sc, indexPath, batchTime)
def topkRoute : {
 post { request => {
  devices = dao.search(request)
  response = getCorrelates(devices, dict, topk)
 }
}
```

df[deviceId, vector]

sum, support
mean, median, stddev

Trapezium Stream

```
runMode = "STREAM"
dataSource = “KAFKA"
kafkaTopicInfo = {
  consumerGroup = "KafkaStreamGroup"
  maxRatePerPartition = 970
  batchTime = "5"
  streamsInfo = [{
    name = "queries"
    topicName = “deviceanalyzer”
}]
}
transactions = [{
  transactionName = DeviceAnalyzer"
  inputStreams = [{name: "queries"}]
  persistStreamName = "deviceanalyzer"
  isPersist = "true"
}]
```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DeviceCompare DeviceAugment GET

DeviceAnalyzer: Compare

- Given two queries

```
select * from Devices where
tld='macys.com' OR 'nordstorm.com' AND
(city='SanFrancisco') AND (device='Android')
select * from Devices where
tld='macys.com' OR 'nordstorm.com' AND
(city='Brussels') AND (device='Android')
```

- Find the dimensions that discriminate the devices associated with two groups

```
def processStream(streams: Map[String,
DStream[Row]], workflowTime: Time): {
 streams("queries").collect().map{ requests =>
   group1 = dao.search(requests(0))
   group2 = dao.search(requests(1))
   response = runLDA(aud1, aud2, dict)
}
```

- Sparse weighted least squares using Breeze QuadraticMinimizer
- L1 Regularized logistic regression

```
def persistStream(responses: RDD[Row],
batchTime: Time) {
    HBaseDAO.write(responses)
}
```

DeviceAnalyzer: Augment

- Given a query

select * from Devices where
tld='macys.com' OR 'nordstorm.com'
AND (city='SanFrancisco' OR 'Brussels')
AND (device='Android')...

  - Find devices similar to seed as lookalikes
  - Find dimensions that represent lookalikes

```
object DeviceAnalyzer extends StreamingTransaction {
converter = SparkLuceneConverter(dm.size)
batchTime = Trapezium.getSyncTime("indexer")
dao = LuceneDAO(batchTime...)
    .setConverter(converter).load(sc, indexPath)
dict = loadDictionary(sc, indexPath, batchTime)
all = dao.search("*:*")
def processStream(streams: Map[String, DStream[Row]]) :
{
 streams("queries").collect().map{ request =>
  audience = dao.search(request)
  response = getLookalikeDimensions(all, audience, dict)
}
```

- Sparse weighted least squares using Breeze QuadraticMinimizer
- L2 regularized linear regression

FastSummarizer

- Statistical and predictive operators
  - sum: sum over numeric measures
  - support: sum over distinct docID
  - sumSquared: L2 norm
  - gram: Uses BLAS sspr
  - solve: Uses BreezeQuadraticMinimizer to support L1
- Implemented using Array[Float] for shuffle opt
- Scala/Java for Level1 operations
- OpenBLAS for Level3 operations

Sync API Benchmark

73M rows 1M+ search terms

1 measure on 250K sparse dimensions

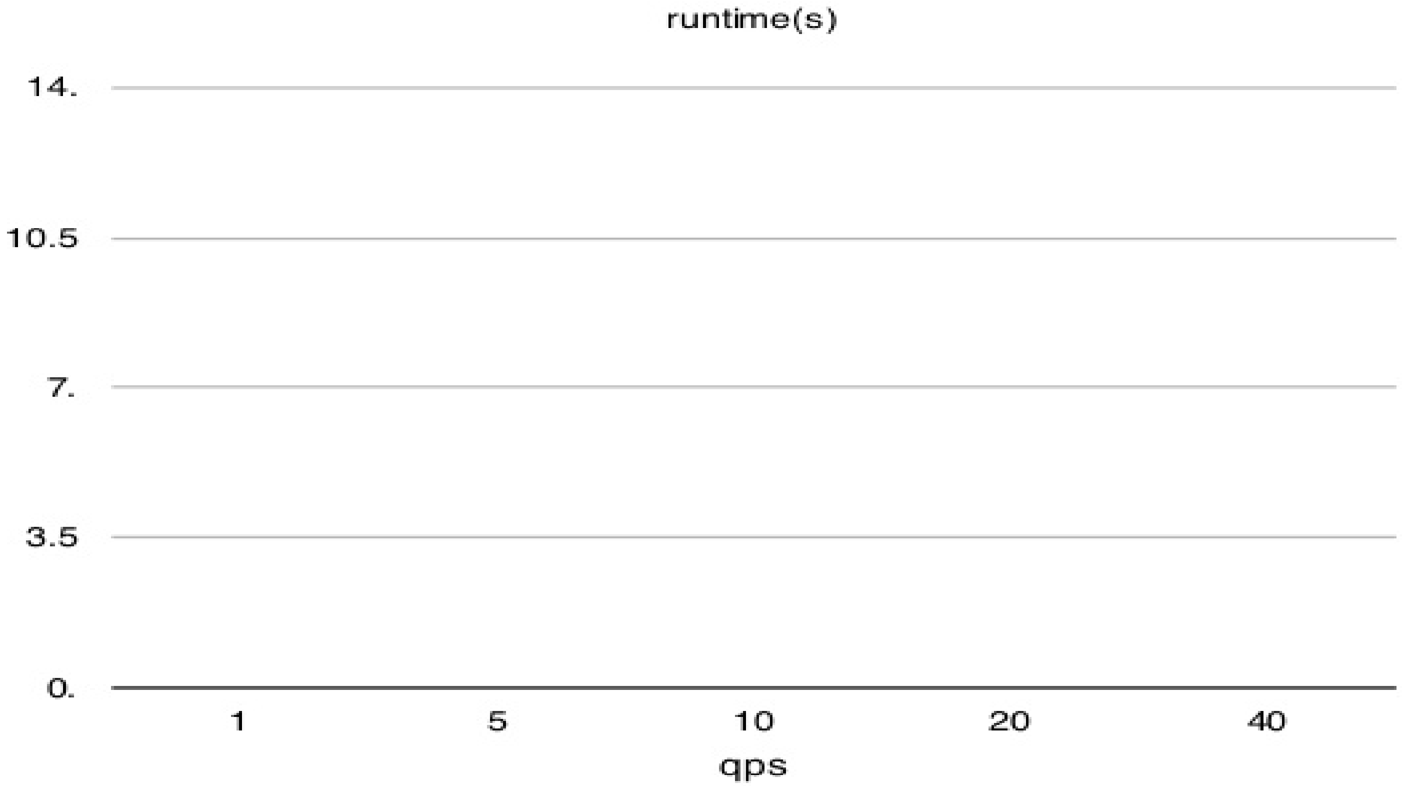
20 executors 8 cores

32 GB driver RAM 16 GB executor RAM

akka-http cores: 24 default

topk

qps	runtime(s)
1	1.389
5	1.663
10	3.214
20	5.992
40	12.174



Async API Benchmark

73M rows, 1M+ search terms

1 measure on 250K sparse dimensions

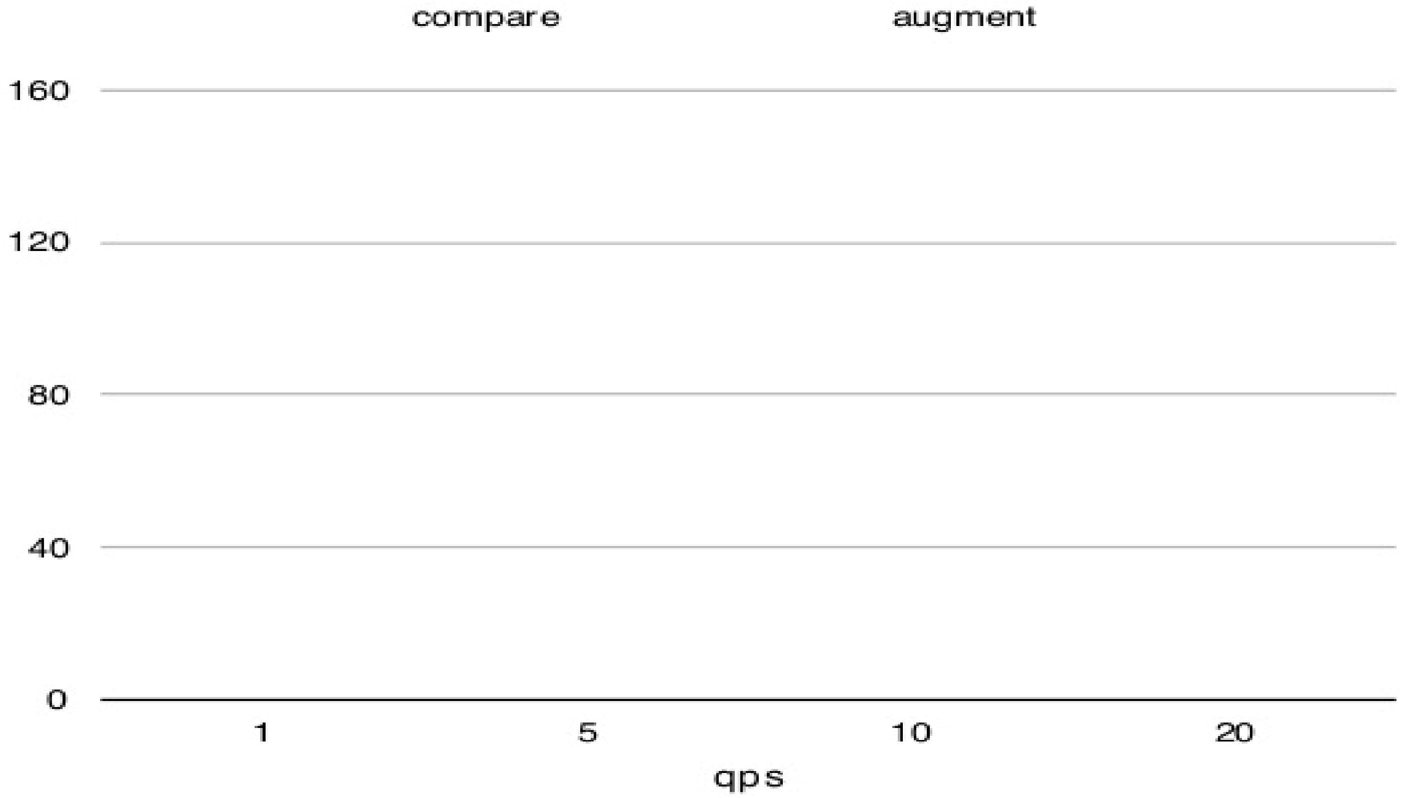
20 executors 8 cores

32 GB driver RAM 16 GB executor RAM

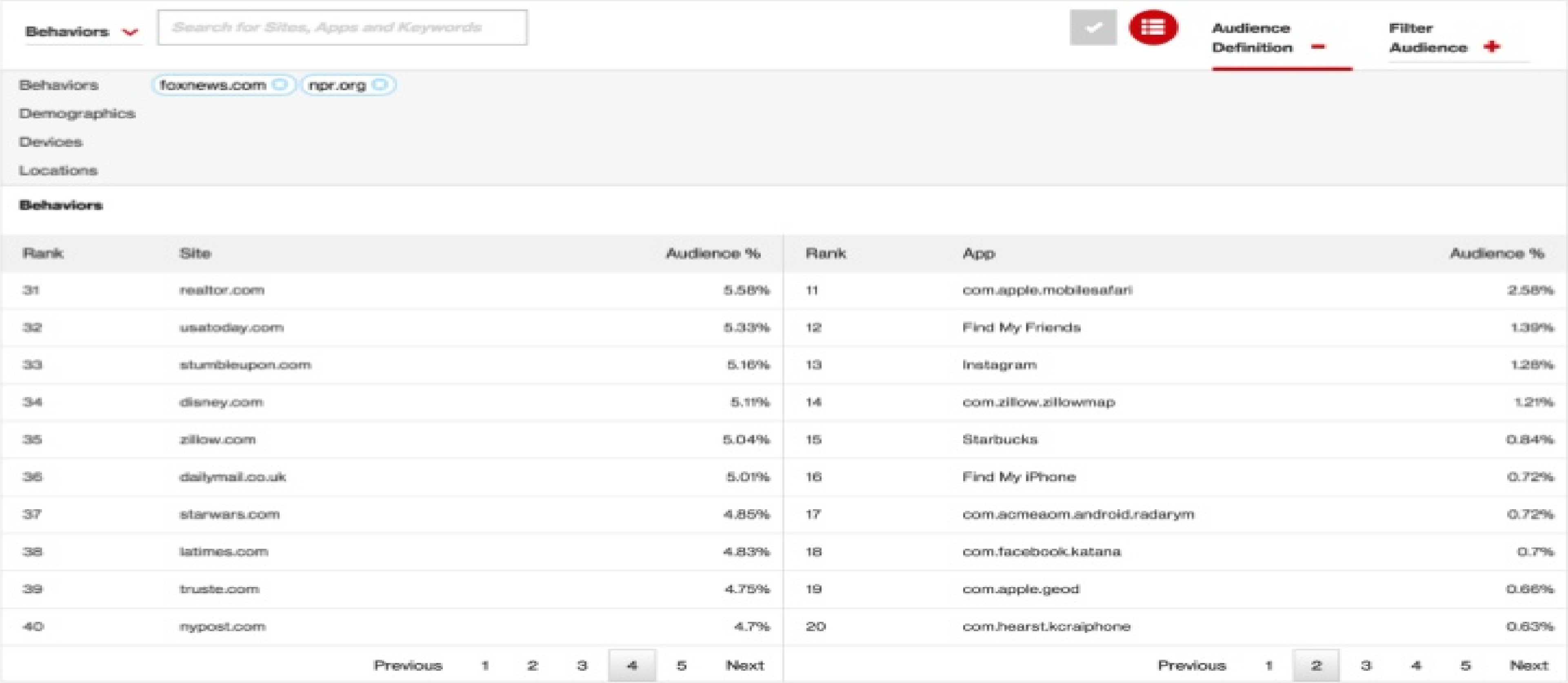
forkjoinpool = 40

Kafka Fetch + compare/augment + HBase Persist

	predictions	
qps	**compare(s)**	**augment(s)**
1	9	16
5	13	36
10	23	70
20	42	142



topk tld + apps



Behaviors: foxnews.com, npr.org

Demographics

Devices

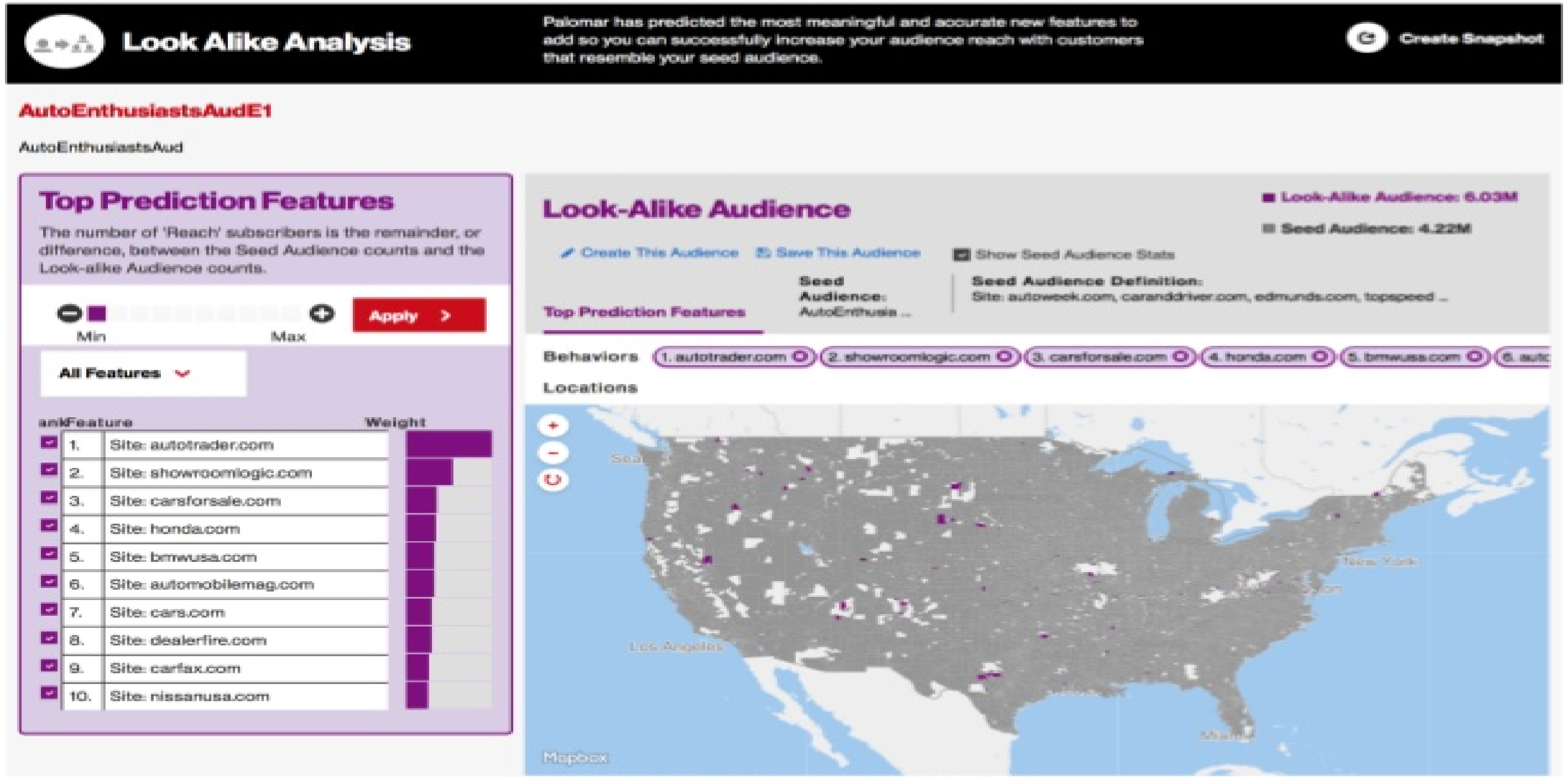
Locations

Behaviors

Rank	Site	Audience %
31	realtor.com	5.58%
32	usatoday.com	5.33%
33	stumbleupon.com	5.16%
34	disney.com	5.11%
35	zillow.com	5.04%
36	dailymail.co.uk	5.01%
37	starwars.com	4.85%
38	latimes.com	4.83%
39	truste.com	4.75%
40	nypost.com	4.7%

Rank	App	Audience %
11	com.apple.mobilesafari	2.58%
12	Find My Friends	1.39%
13	Instagram	1.28%
14	com.zillow.zillowmap	1.21%
15	Starbucks	0.84%
16	Find My iPhone	0.72%
17	com.acmeaom.android.radarym	0.72%
18	com.facebook.katana	0.7%
19	com.apple.geod	0.66%
20	com.hearst.kcraiphone	0.63%

Augment: Auto Enthusiastic



Look Alike Analysis

Palomar has predicted the most meaningful and accurate new features to add so you can successfully increase your audience reach with customers that resemble your seed audience.

Create Snapshot

AutoEnthusiastsAudE1

AutoEnthusiastsAud

Top Prediction Features

The number of 'Reach' subscribers is the remainder, or difference, between the Seed Audience counts and the Look-alike Audience counts.

Min Max Apply >

All Features

	ankFeature		Weight
☑	1.	Site: autotrader.com	
☑	2.	Site: showroomlogic.com	
☑	3.	Site: carsforsale.com	
☑	4.	Site: honda.com	
☑	5.	Site: bmwusa.com	
☑	6.	Site: automobilemag.com	
☑	7.	Site: cars.com	
☑	8.	Site: dealerfire.com	
☑	9.	Site: carfax.com	
☑	10.	Site: nissanusa.com	

Look-Alike Audience

▪ Look-Alike Audience: 6.03M

▪ Seed Audience: 4.22M

Create This Audience · Save This Audience · ☑ Show Seed Audience Stats

Top Prediction Features

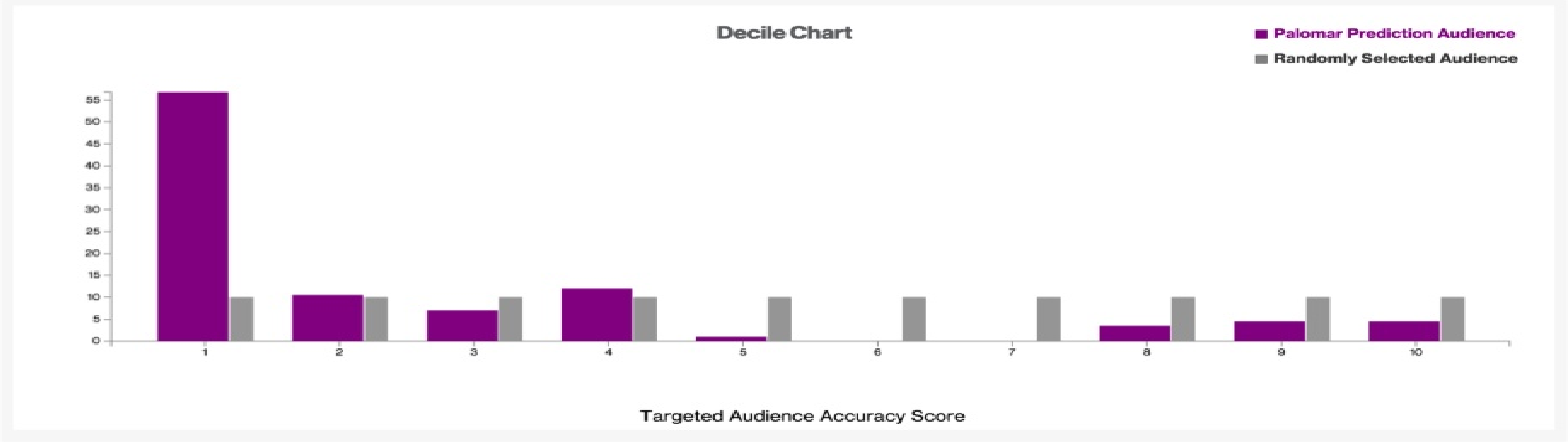
Seed Audience: AutoEnthusia ...

Seed Audience Definition: Site: autoweek.com, caranddriver.com, edmunds.com, topspeed ...

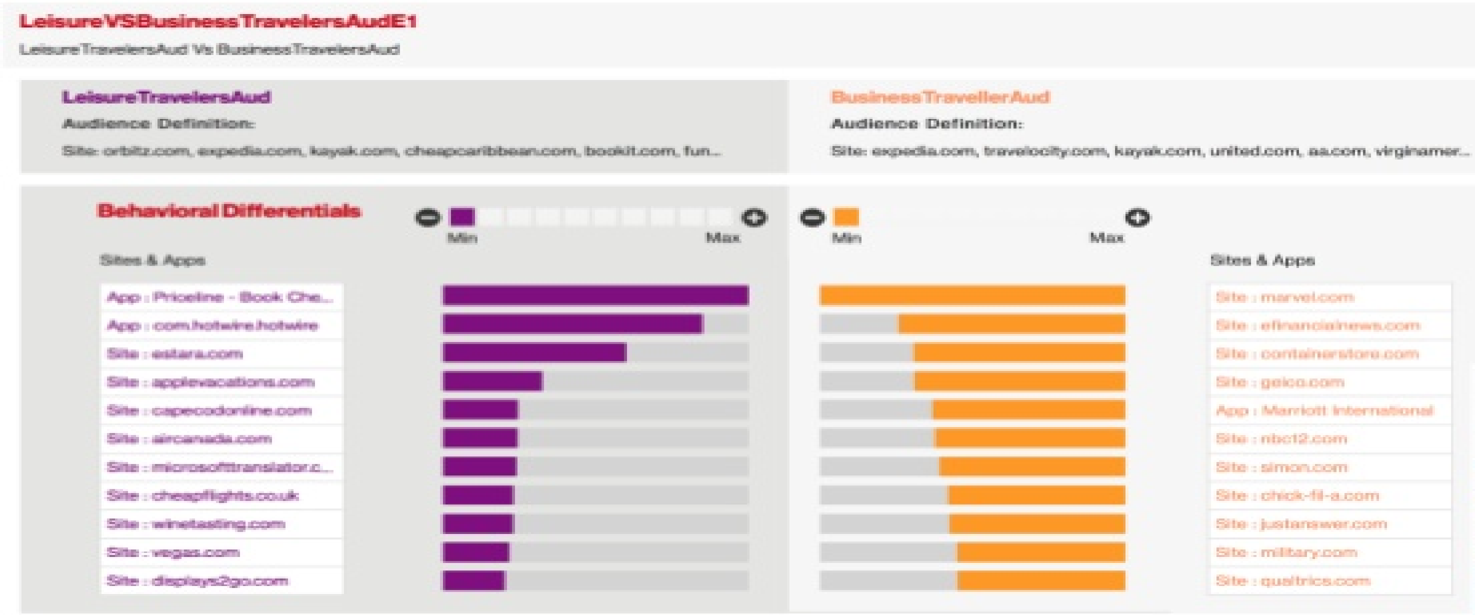
Behaviors (1. autotrader.com) (2. showroomlogic.com) (3. carsforsale.com) (4. honda.com) (5. bmwusa.com) (6. auto

Locations

Augment Model Performance



Compare: Leisure vs Business Travellers



LeisureVSBusinessTravelersAudE1

LeisureTravelersAud Vs BusinessTravelersAud

LeisureTravelersAud

Audience Definition:

Site: orbitz.com, expedia.com, kayak.com, cheapcaribbean.com, bookit.com, fun...

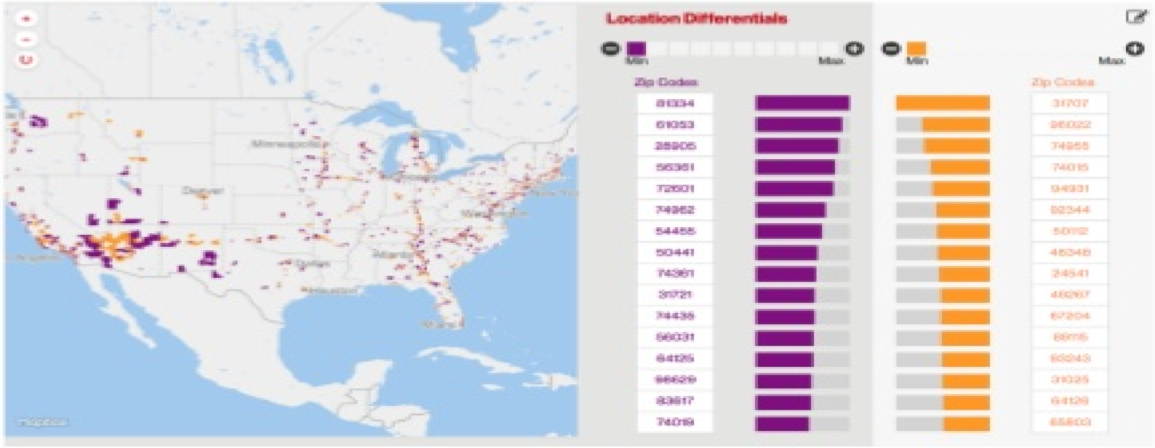
BusinessTravellerAud

Audience Definition:

Site: expedia.com, travelocity.com, kayak.com, united.com, aa.com, virginamer...

Behavioral Differentials

Sites & Apps	Sites & Apps
App : Priceline - Book Che...	Site : marvel.com
App : com.hotwire.hotwire	Site : efinancialnews.com
Site : estara.com	Site : containerstore.com
Site : applevacations.com	Site : geico.com
Site : capecodonline.com	App : Marriott International
Site : aircanada.com	Site : nbc12.com
Site : microsofttranslator.c...	Site : simon.com
Site : cheapflights.co.uk	Site : chick-fil-a.com
Site : winetasting.com	Site : justanswer.com
Site : vegas.com	Site : military.com
Site : displays2go.com	Site : qualtrics.com



Location Differentials

Zip Codes	Zip Codes
81334	31707
61053	96022
28905	74955
56361	74015
72601	94931
74962	92344
54455	50112
50441	46346
74361	24541
31721	46267
74436	67204
56031	68115
64125	80243
66629	31025
83617	64126
74019	65803

THANK YOU.
Q&A

Join us and make machines intelligent
Data & Artificial Intelligence Systems
499 Hamilton Ave, Palo Alto
California

verizon