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Unboxing Engineering Data.

Time Series Analysis with Spark in the Automotive R&D Process

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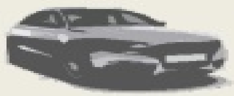
NorCom IT AG - Facts & Figures

NorCom

Numbers	• Established 1989 • IPO: 1999 • Turnover 16,5 Mio. € • about 130 Employees
Location	• München • Nürnberg • San Jose
Customer	• Automotive • Public (German) • Media • Finance

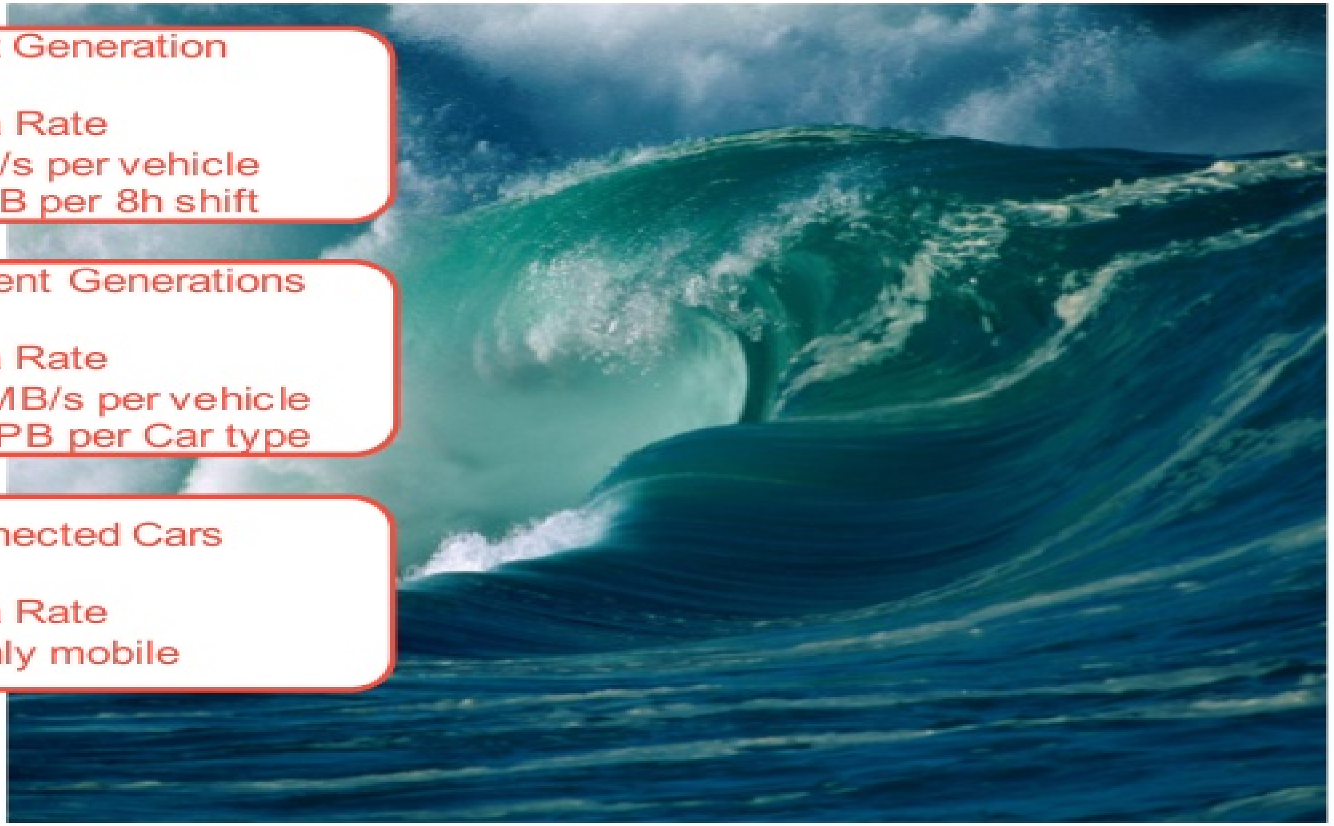
Consulting: Design | Build | Run — NorCom EXPERTS

NDOS
(NorCom Data Operating System)

INORMATION MANAGEMENT	BIG DATA	BIG INFRASTRUCTURE
		
News (Broadcast) Video Management Enterprise Communication	Hortonworks cloudera MAPR elasticsearch.	Hewlett Packard Enterprise ORACLE FUSION MIDDLEWARE Microsoft

Where is Big Data in Automotive?

- Development
  - Few development locations worldwide
  - Some test vehicles (<100)
  - Raw sensor data (camera, radar, lidar, ...)
  - Algorithm development (Autonomous driving)
- Testing Phase
  - Many locations worldwide
  - Lots of test vehicles
  - Compressed Data (Video)
  - Verification
- Field
  - All around the world (with many regulators)
  - Hundreds of thousands of connected cars
  - Triggered Data
  - Predictive maintainance



Next Generation

Data Rate
2GB/s per vehicle
60 TB per 8h shift

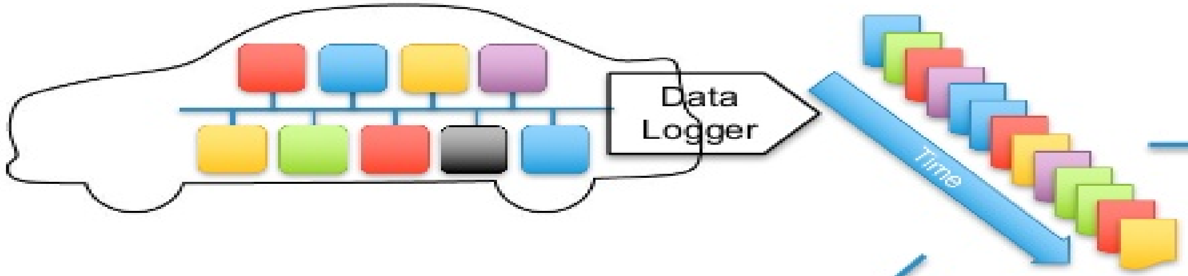
Current Generations

Data Rate
350MB/s per vehicle
~10 PB per Car type

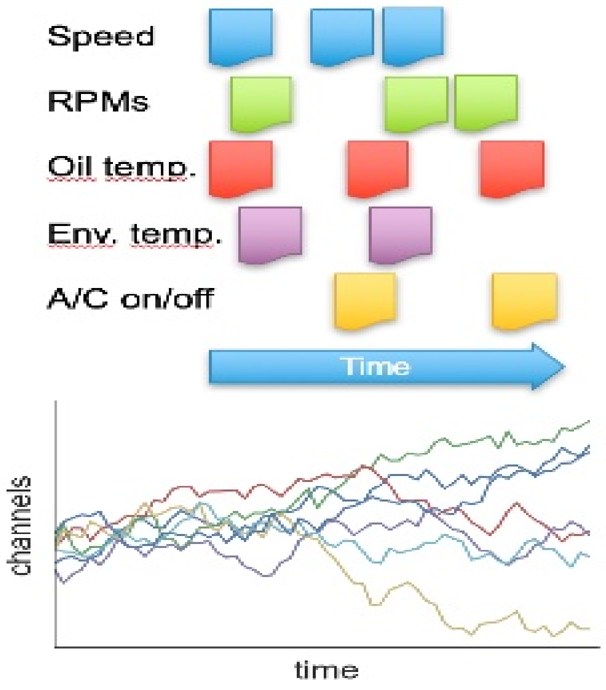
Connected Cars

Data Rate
mainly mobile

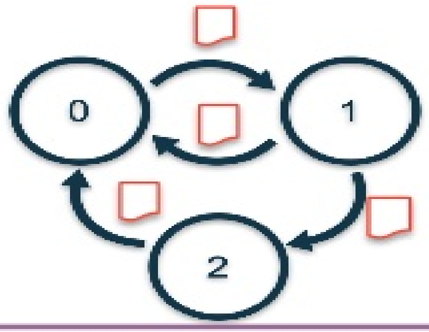
Automotive time series analysis requires parallel processing



Part 1:
A Spark-API for Multi-Sensor Time Series



Part 2:
State machine analysis with Spark



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DaSense: A Spark-API for Multi-Sensor Time Series

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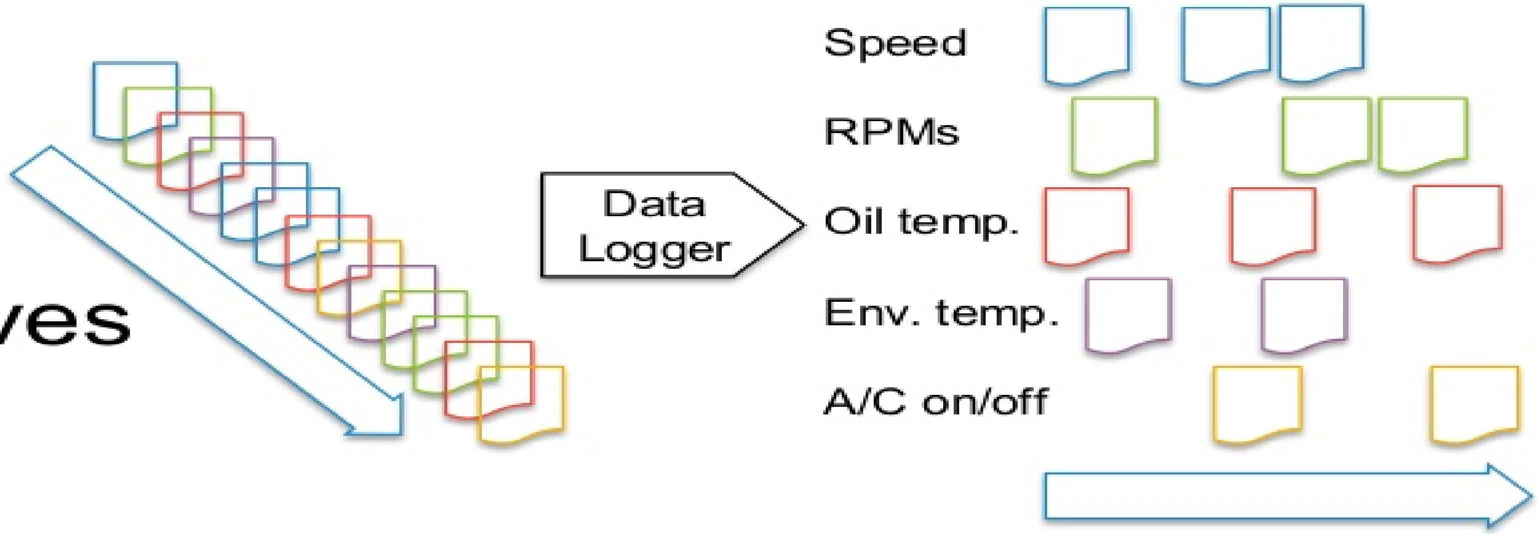
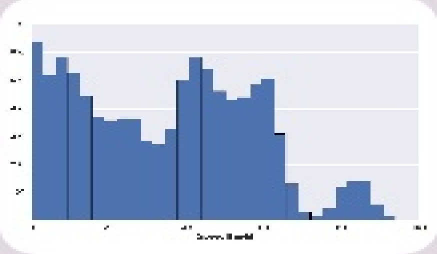
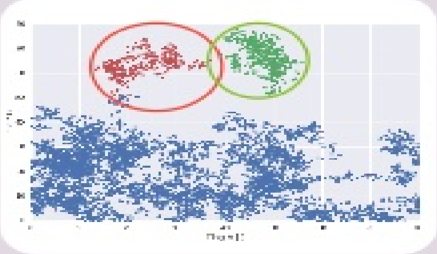
Multi-sensor time series

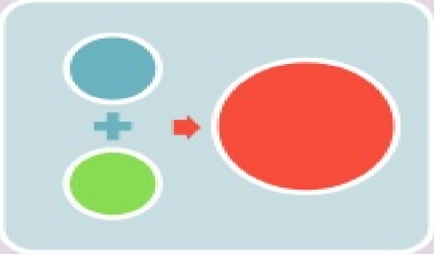
- Bus communication is filtered and sorted
- Thousands of signal types
- Time series with millions of entries
- Hundreds of measurement drives



Typical tasks







Criteria tests
&
Pattern search

Aggregation
&
Reporting

Classification
&
Machine Learning

Correlations
&
Root-Cause Analysis

Time series API

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- Python-based

- Reduces complexity by focusing on time series

- Preserves lazy evaluation

Important concepts:

- Expressions
- Data Extractors

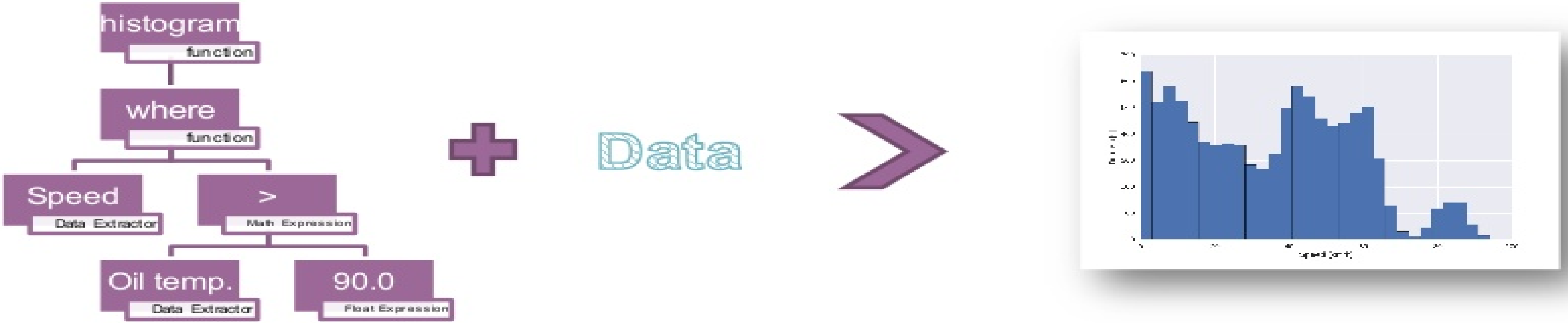
Concepts - expressions

```
context = Context()
all_data = ChannelData("/mapr/norcom_cluster/test_data/test_drive.parquet", context)

OilTemp = ChannelExtractor('t_oil', unit='deg C')
Speed   = ChannelExtractor('Speed', unit='km/h')

hist_expression = Speed.where(OilTemp > 90.0).histogram(bins=100)

result = all_data.evaluate({'Speed_histogram' : hist_expression})
```



Concepts – data extractors

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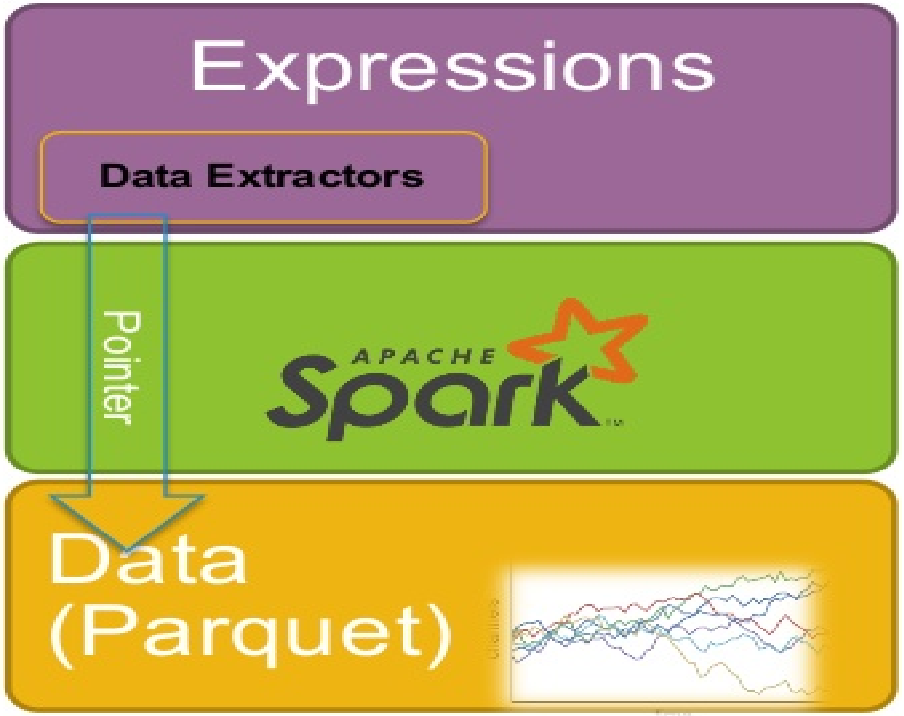
- Basic time series expression
- Interface to actual data
- Handles
  - channel name aliases (Speed or VehV_v?)
  - units and conversions (mph to km/h)
  - interpolation requirements (linear, zero-order,...)



Workflow example

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Ingest
- Data quality gate
- Convert raw data to parquet

Filter
- Select relevant measurements
- Extract gear shift events

Processing
- Fourier transform
- Frequency filter
- Feature extraction

Classification

DaSense Time series API

e.g. SparkML

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Parallelization of a State Machine

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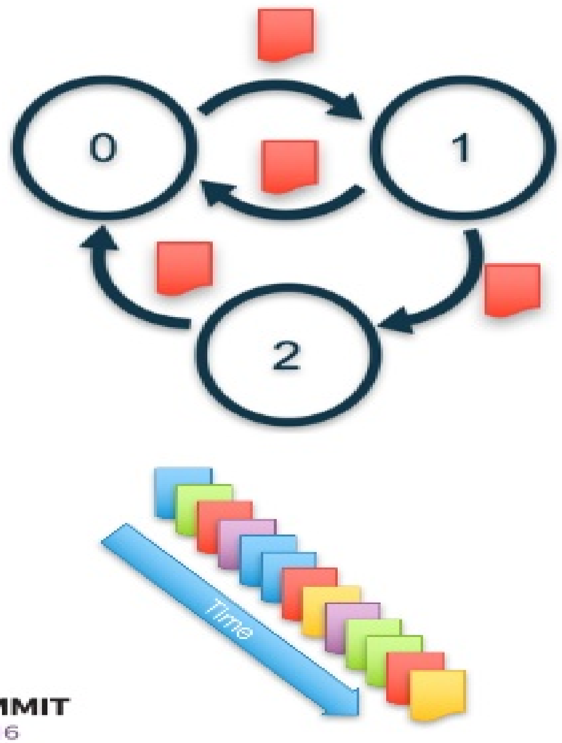
State machines in automotive industry

States and transitions



Examples of states:

- Engine on / off / ready to start
- Current Gear
- States on the communication bus

Example of analytical use-case:
Analyze / Validate the communication protocol from the logs.

Need for parallel Big Data solutions

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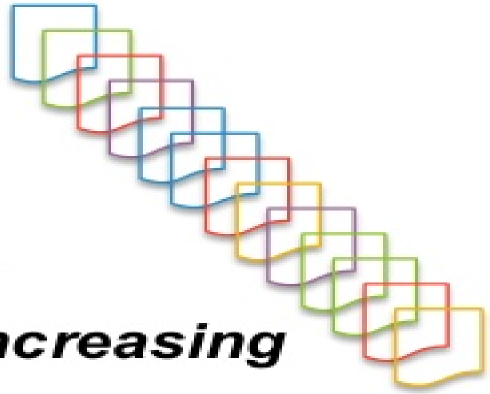
Current approach – sequential:
- Sequential replay of messages used for analysis
- No way of scaling within the single log

Desired approach – parallel:
- Split the log in partitions and analyze in parallel
- Enables scaling within the single log



The density of messages is increasing

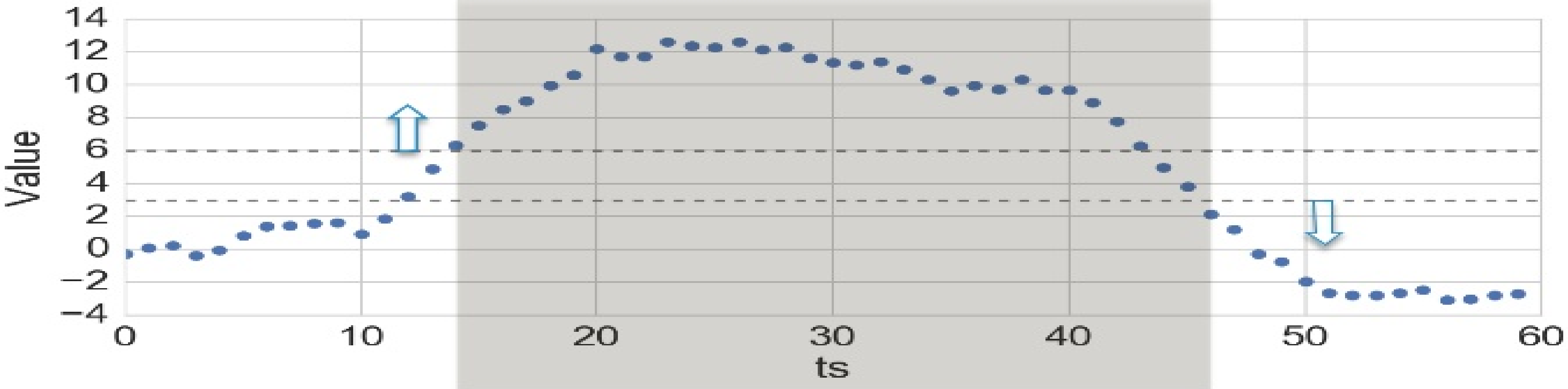
What is the status at the beginning of the partition?

Various encodings of state machine transitions

Explicitly in a message

ts	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
state	0	0	1	1	1	0	0	1	1

Implicitly via message value



Implicitly via message timing

ts	0.01	0.02	0.03	0.07	0.08	0.09	0.15	0.16	0.17

Basic parallel solution

Original log

ts	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
state	0	0	1	1	1	0	0	1	1

Basic parallel solution

Original log

ts	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
state	0	0	1	1	1	0	0	1	1

Parallelized processing (mapPartitions)

ts	0.01	0.02	0.03
state	0	0	1

0.04	0.05	0.06	0.07
1	1	0	0

0.08	0.09
1	1

Basic parallel solution

Original log

ts	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
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1	1

Collect status changes and border messages

ts	0.01	0.03	0.04	0.06	0.07	0.08	0.09
state	0	1	1	0	0	1	1

Basic parallel solution

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Original log

ts	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
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1	1

Collect status changes and border messages

ts	0.01	0.03	0.04	0.06	0.07	0.08	0.09
state	0	1	1	0	0	1	1

Final clean-up (locally, serial)

ts	0.03	0.06	0.08
state	1	0	1

Alternatives

- Use windowing functions
  - Window size unknown, could span the full time series
- "Broadcast" the borders from neighboring partitions (mapPartition → groupByKey)
  - groupByKey expensive, does not generalize well
- mapPartitionWithIndex → reduceByKey
  - Needs complex data structure to handle associativity and commutativity requirement

In our experience

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keep it simple.

Sample code available at:
http://github.com/dasense/state_machine_analysis_with_spark

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Summary

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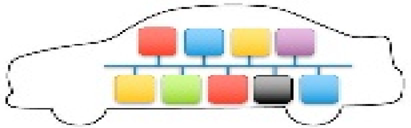
Summary

Automotive Industry is a major data producer



Data & problems are somewhat specific, but fun!

DaSense

We are bringing Spark into production in Automotive R&D

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THANK YOU.

We are hiring!

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