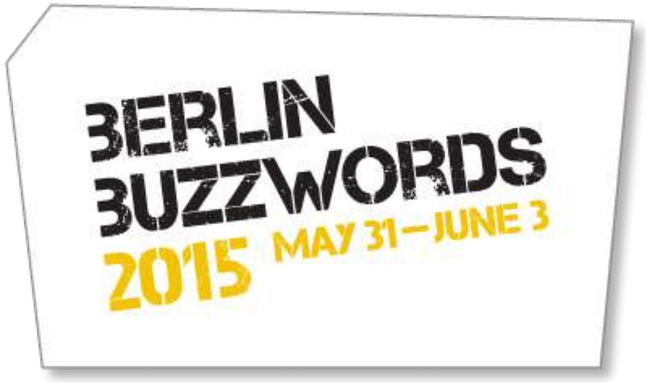
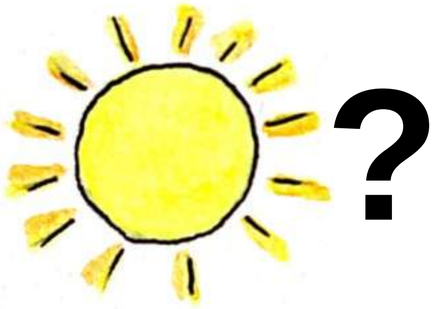
Analytics in the age of the Internet of Things

Ludwine Probst @nivdul



Thank you!

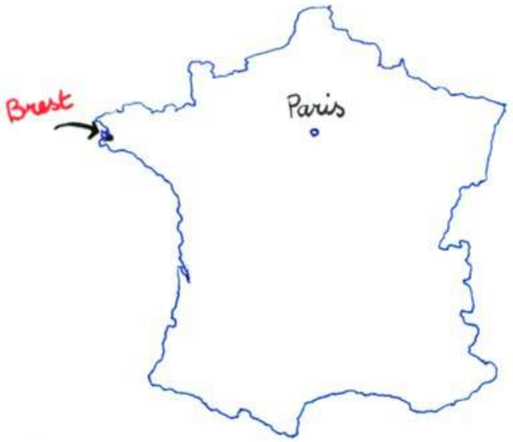


?

me

Data Engineer

Cityzen Data



@nivdul
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Women in Tech

Duchess France

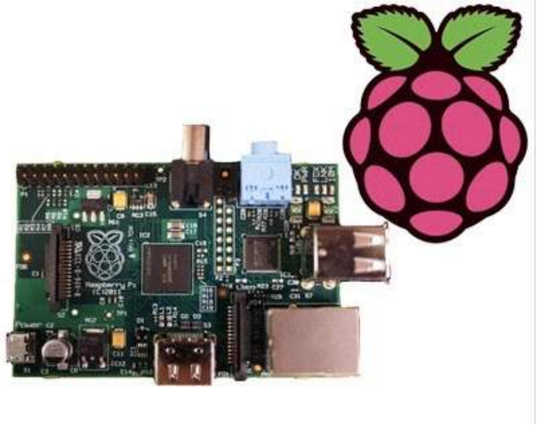
@duchessfr
duchess-france.org

Paris chapter Leader

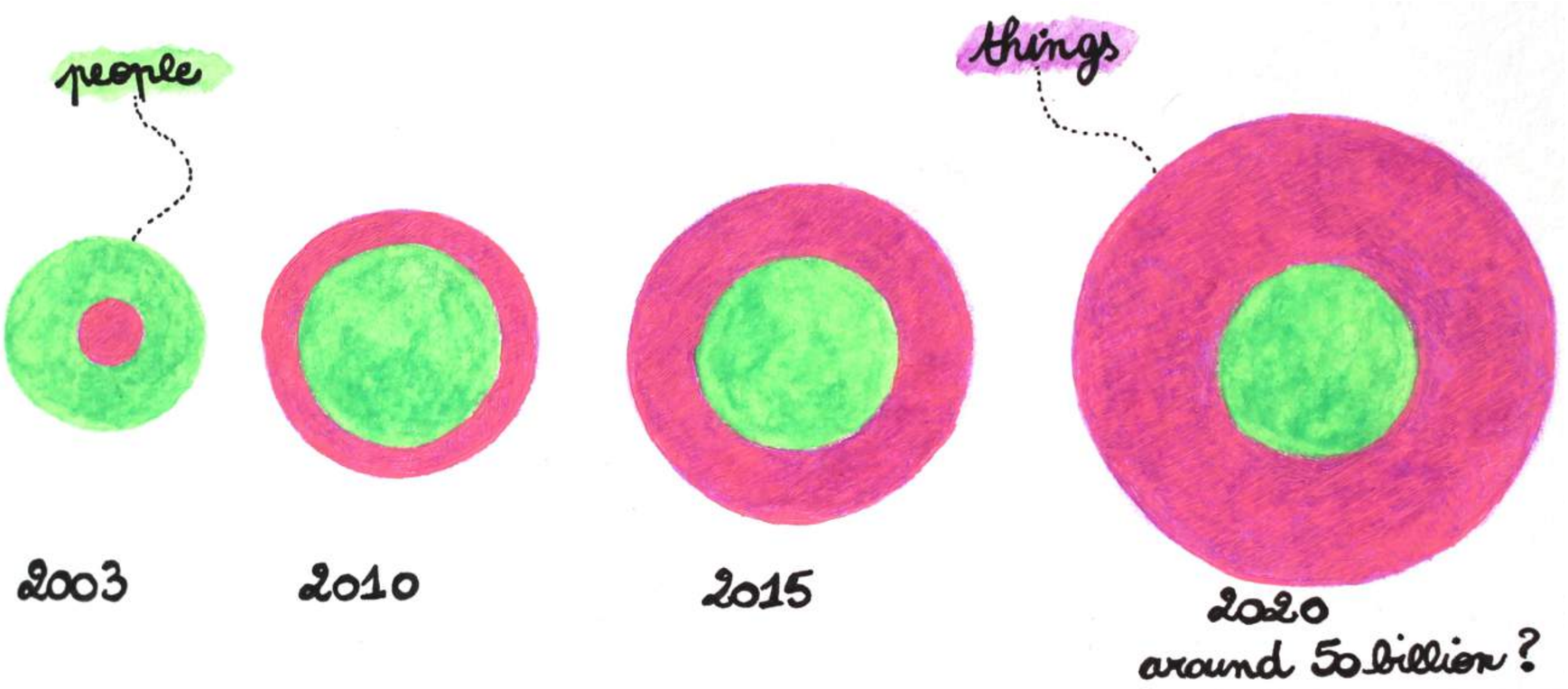
LADIES who CODE

Internet of Things (IoT)

ARDUINO™



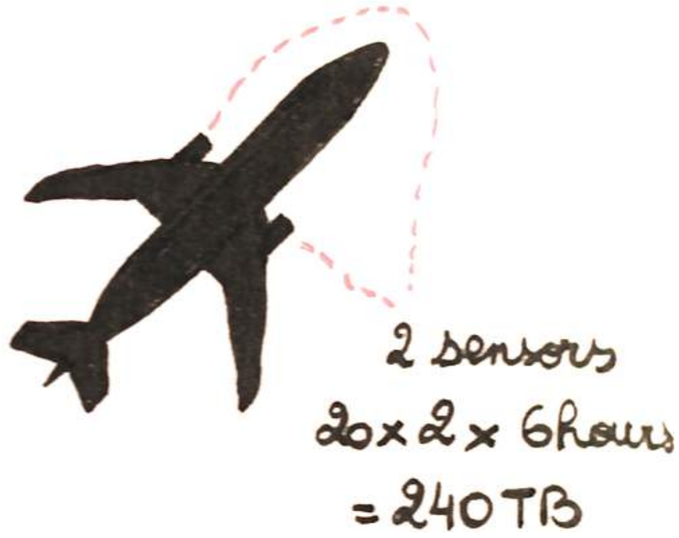
more and more



aircraft

use case: sensor data from a cross-country flight
data points: several terabytes every hour per sensor
data analysis: batch mode or real time analysis

applications:
- flight performance (optimize plane fuel consumption,
- reduce maintenance costs…)
- detect anomalies
- prevent accidents



insurance

use case: data from a connected car key

applications:
- monitoring
- real time vehicle location
- drive safety
- driving score

Zubie

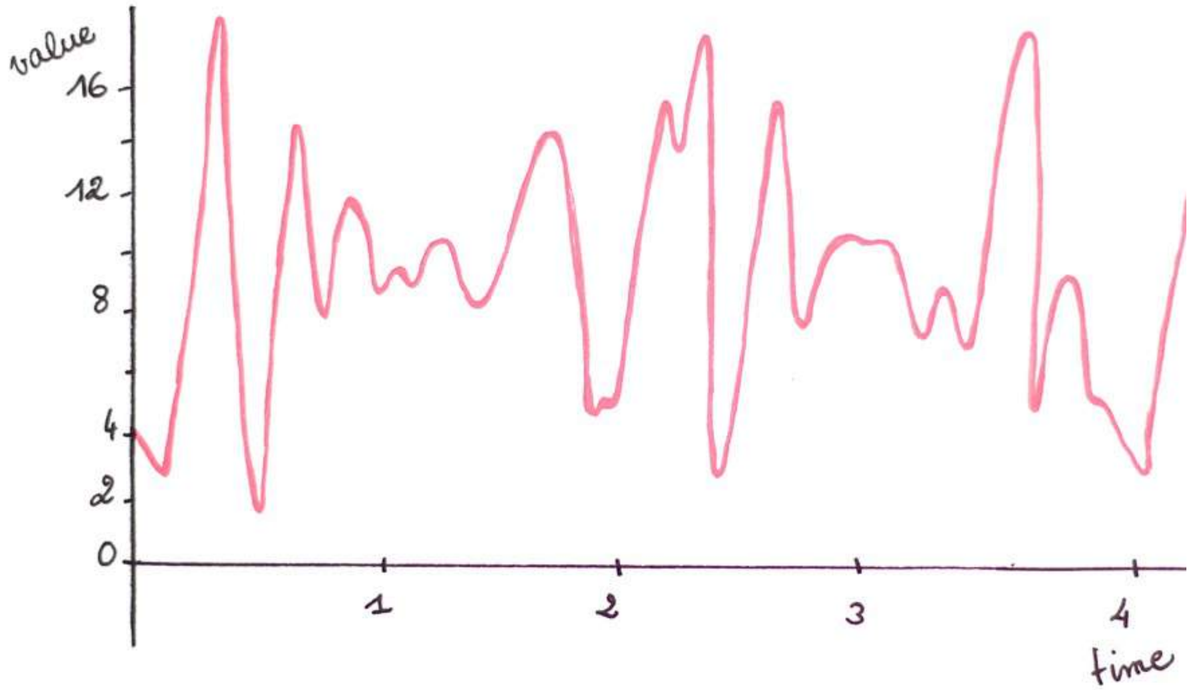
Why should I care?

Because it can affect & change our business, our everyday life?

Collecting

Time series

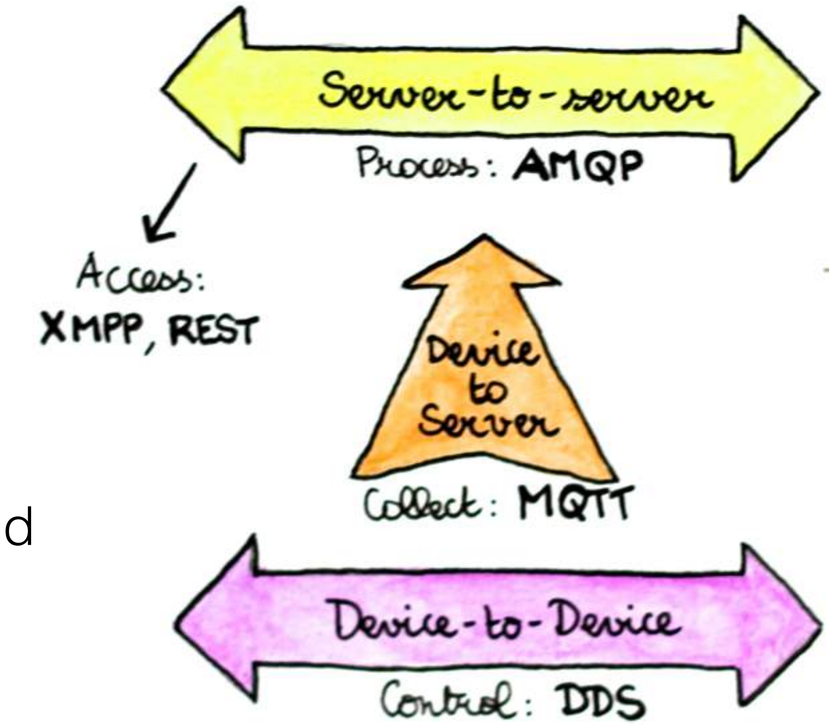
112578291481000	-5.13
112578334541000	-5.05
112578339541000	-5.15
112578451484000	-5.48
112578491615000	-5.33



Some protocols…

- DDS – Device-to-Device communication – real-time
- MQTT – Device-to-Server – collect telemetry data
- XMPP – Device-to-Server – Instant Messaging scenarios
- AMQP – Server-to-Server – connecting devices to backend

…



Challenges

limited CPU
&
memory resources

low energy communication network

Storing

Storing TS

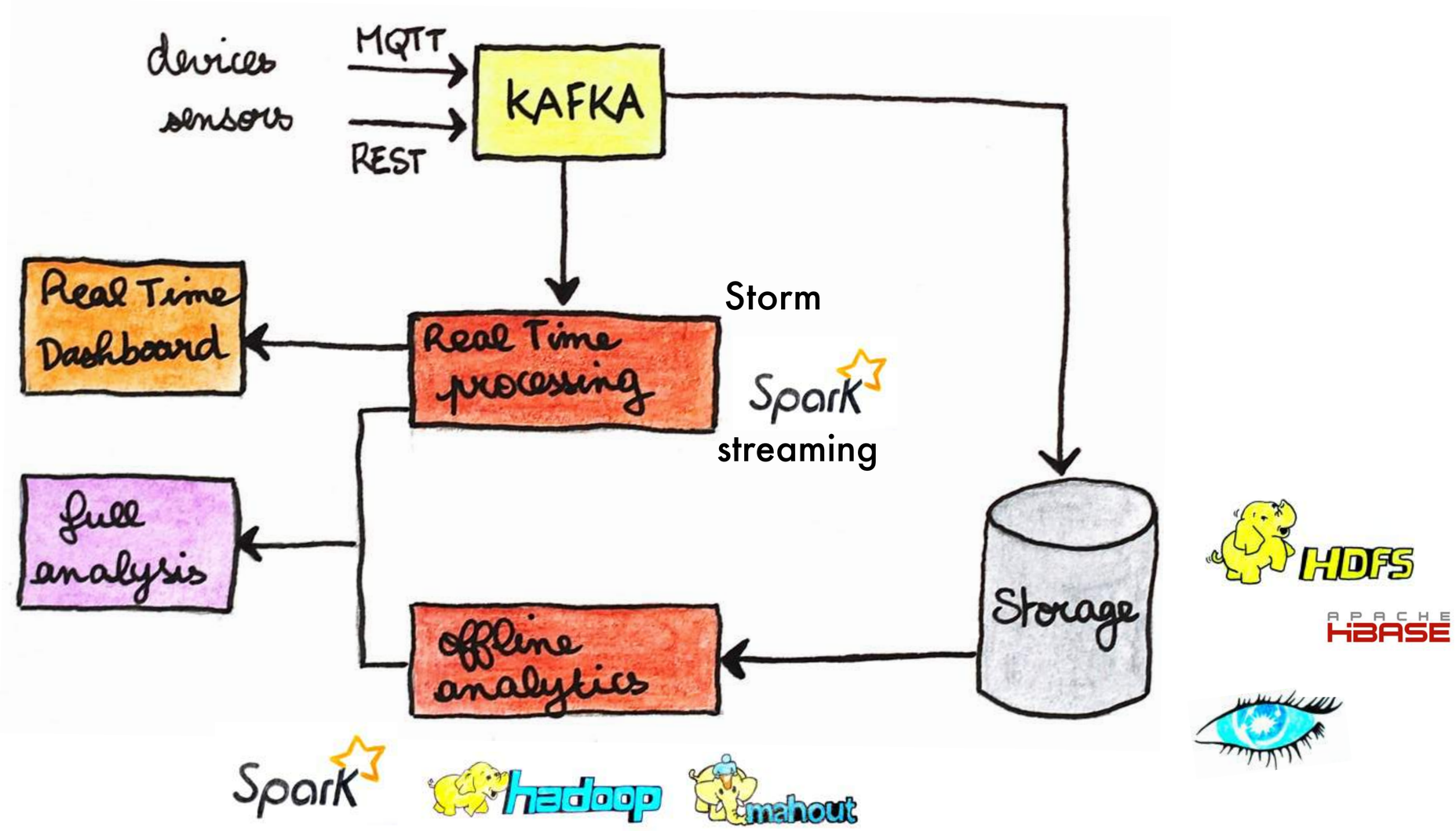
- flat file:
  - limited utility
- relational database:
  - limited design
  - rigidity
- NoSQL database:
  - scalability
  - faster & more flexible

OpenTSDB

APACHE HBASE

cassandra

IoT data pipeline



Now, the example!

WISDM Lab's study

http://www.cis.fordham.edu/wisdm/index.php
http://www.cis.fordham.edu/wisdm/includes/files/sensorKDD-2010.pdf

The example

Goal: identify the physical activity that a user is performing

inspired by WISDM Lab's study http://www.cis.fordham.edu/wisdm/index.php

The situation

The labeled data comes from an accelerometer (37 users)

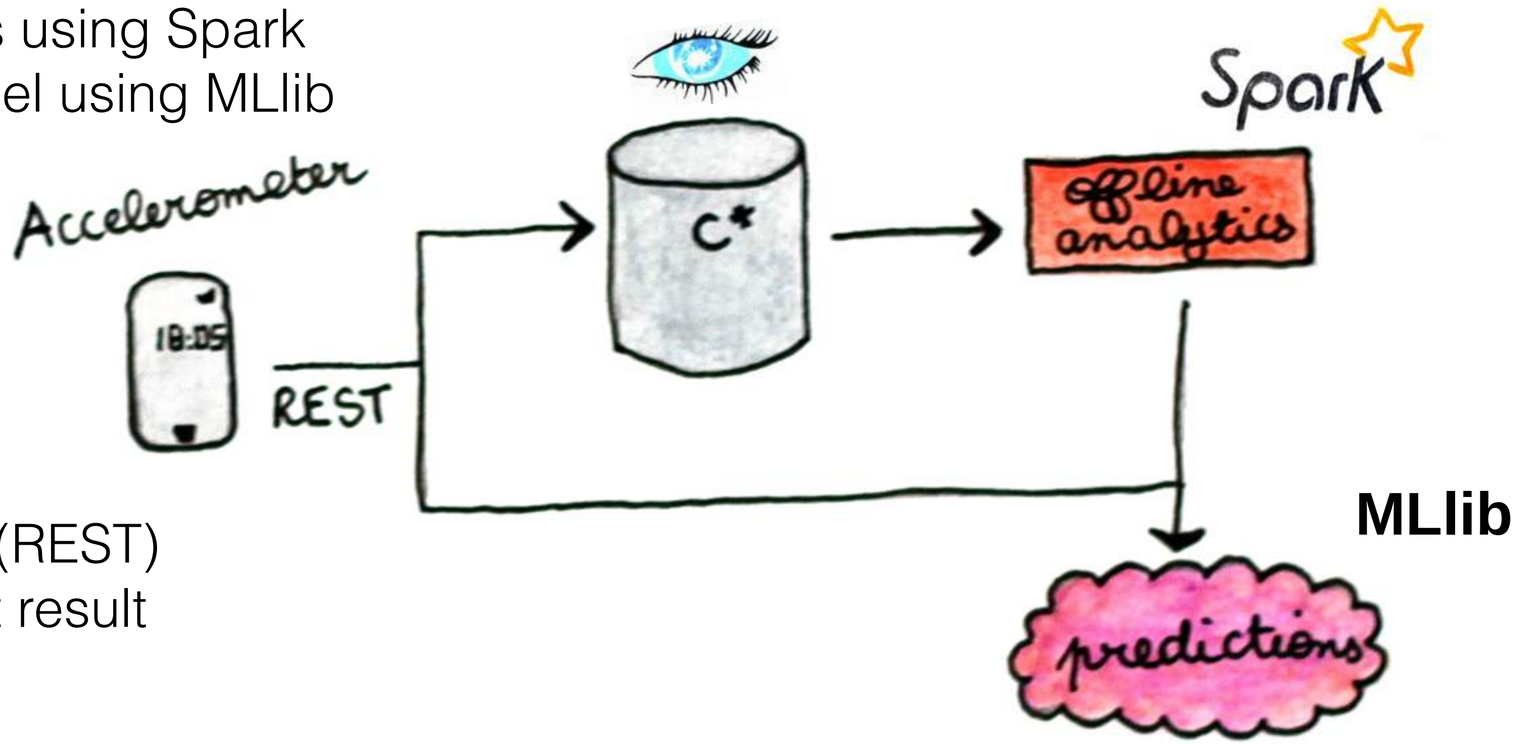
Possible activities are:
walking, jogging, sitting, standing, downstairs and upstairs.

This is a **classification** problem here!

Some algorithms to use: Decision tree, Random Forest, Multinomial logistic regression...

How can I predict the user's activity?

1. **analyzing part**:
   - collect & clean data from a csv file
   - store it in Cassandra
   - define & extract features using Spark
   - build the predictive model using MLlib



2. **predicting part**:
   - collect data in real-time (REST)
   - use the model to predict result

https://github.com/nivdul/actitracker-cassandra-spark

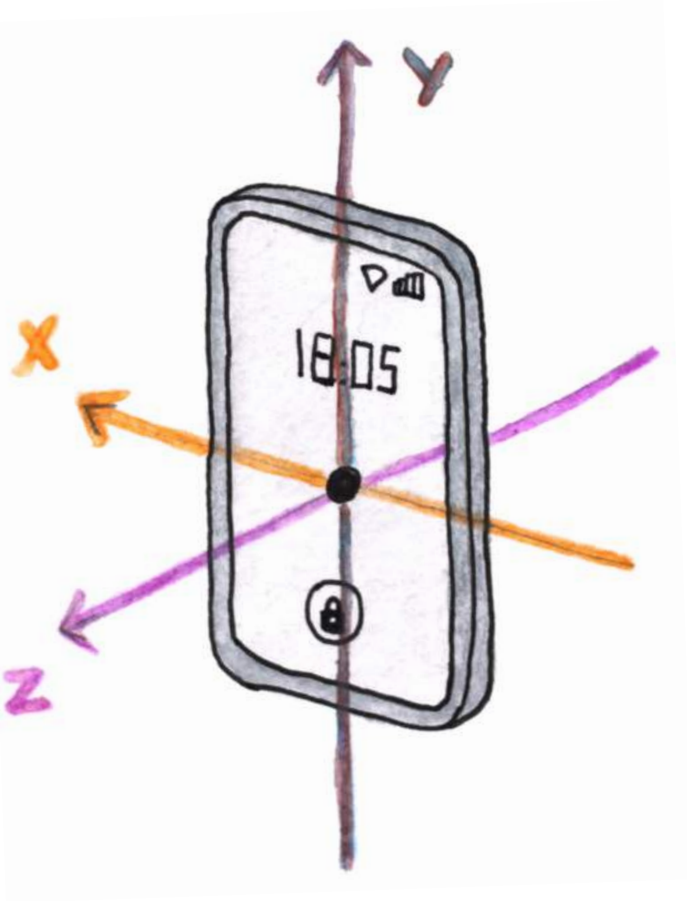
Collect
&
store the data

The accelerometer

A sensor (in a smartphone)
compute acceleration over X,Y,Z
collect data every **50ms**

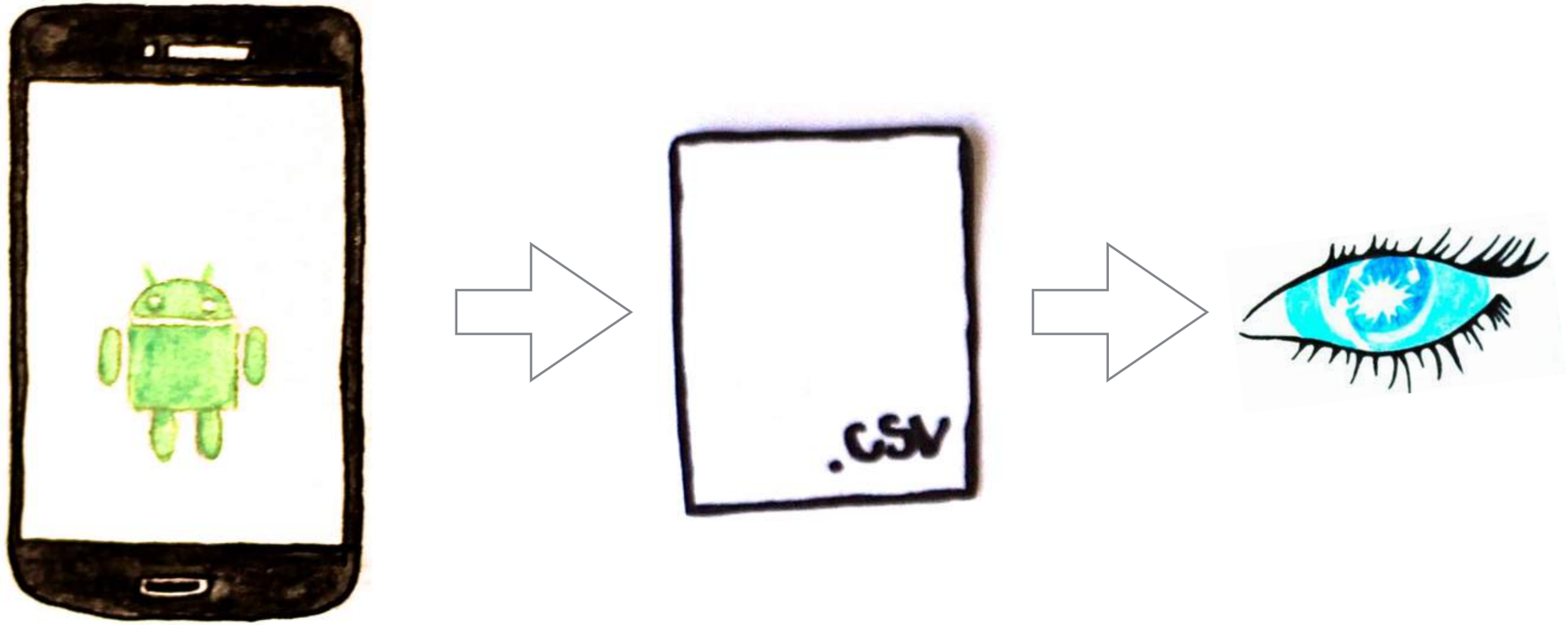
Each acceleration contains:

- a timestamp (eg, 1428773040488)
- acceleration along the X axis (unit is m/s^2)
- acceleration along the Y axis (unit is m/s^2)
- acceleration along the Z axis (unit is m/s^2)



Accelerometer Android app

REST Api collecting data coming from a phone application



Accelerometer Data Model

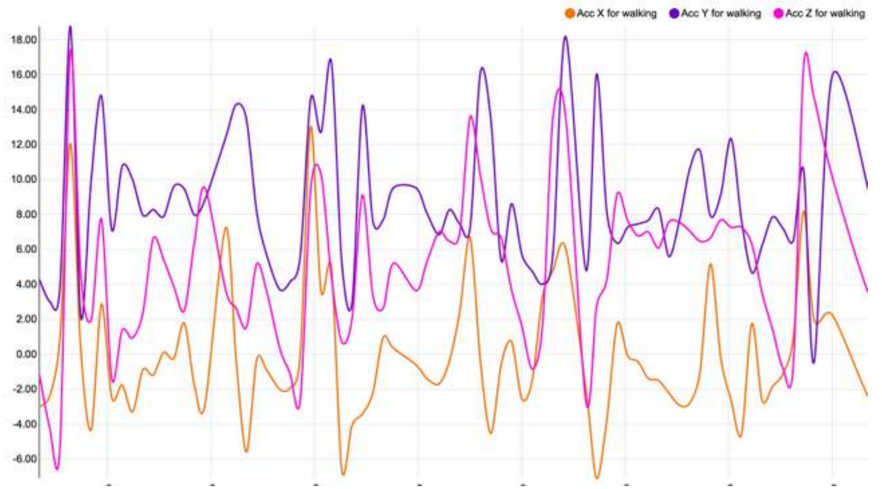
```
CREATE KEYSPACE actitracker WITH replication = {'class': 'SimpleStrategy', 'replication_factor': 1 };

CREATE TABLE users (user_id int,
                    activity text,
                    timestamp bigint,
                    acc_x double,
                    acc_y double,
                    acc_z double,
                    PRIMARY KEY ((user_id,activity),timestamp));

COPY users FROM '/path_to_your_data/data.csv' WITH HEADER = true;
```

Accelerometer Data Model: logical view

user_id	activity	timestamp	acc_x	acc_y	acc_z
8	walking	112578291481000	-5.13	8.15	1.31
8	walking	112578334541000	-5.05	8.16	1.31
8	walking	112578339541000	-5.15	8.16	1.36
8	walking	112578451484000	-5.48	8.17	1.31
8	walking	112578491615000	-5.33	8.16	1.18



graph from the Cityzen Data widget

Analyzing

https://github.com/nivdul/actitracker-cassandra-spark

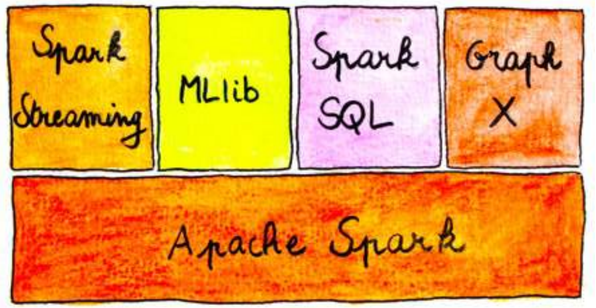
is a large-scale in-memory data processing framework

- big data analytics in memory/disk
- complements Hadoop
- faster and more flexible
- Resilient Distributed Datasets (RDD)

interactive shell (scala & python)

Lambda
(Java 8)

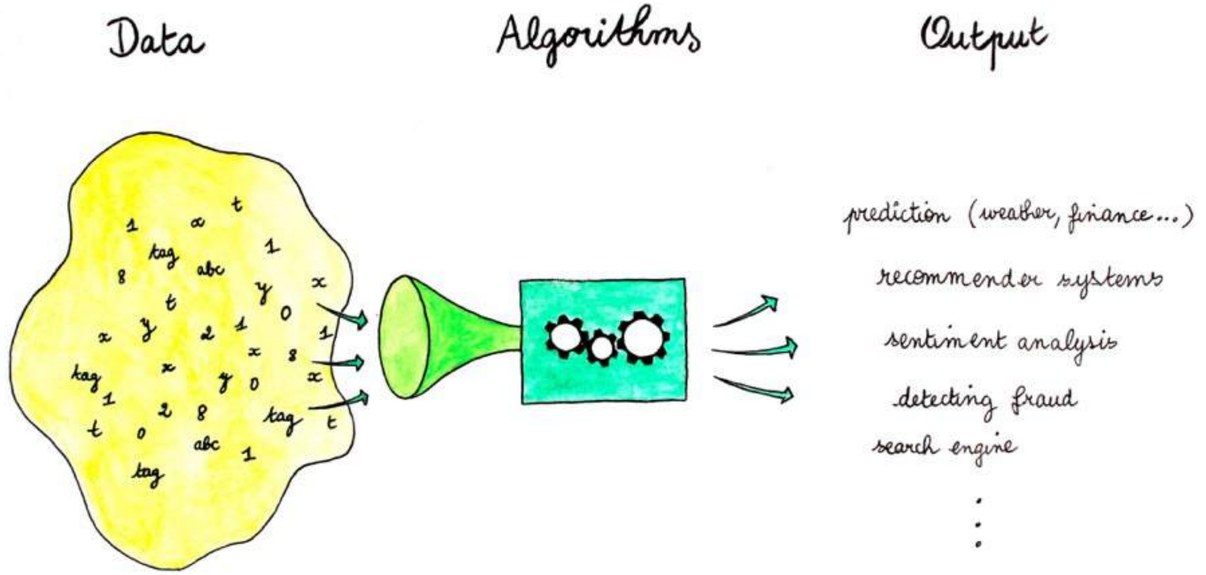
Spark ecosystem



MLlib

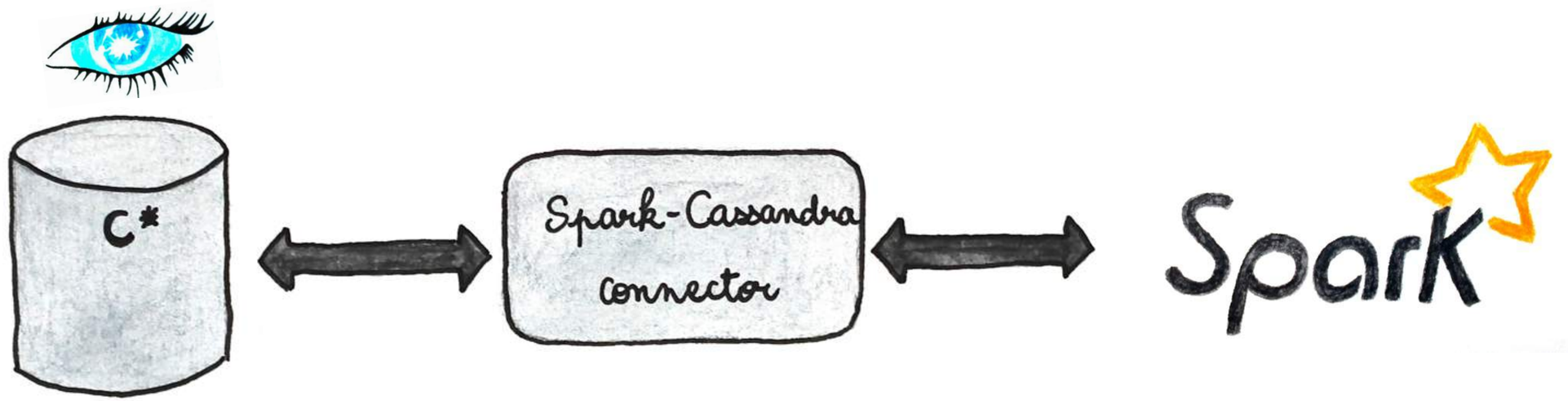
is Apache Spark's scalable machine learning library

- regression
- classification
- clustering
- optimization
- collaborative filtering
- feature extraction (TF-IDF, Word2Vec…)



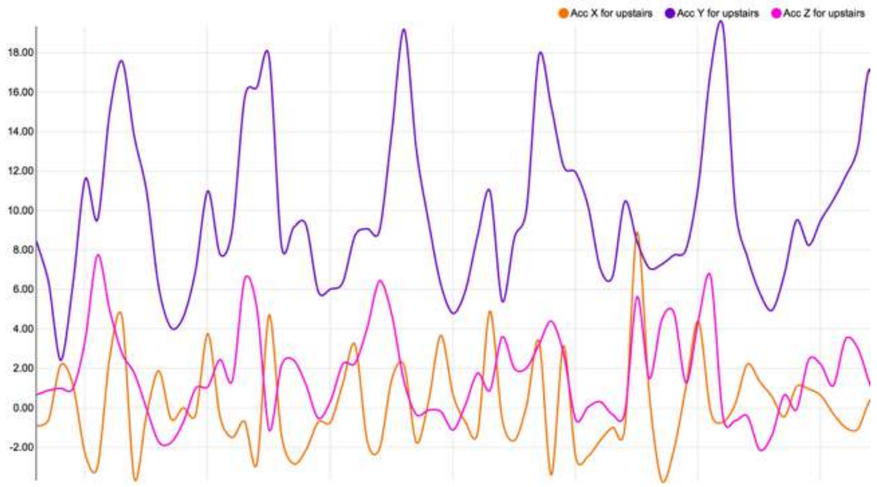
spark-cassandra-connector

Exposes Cassandra tables as Spark RDD



Identify features

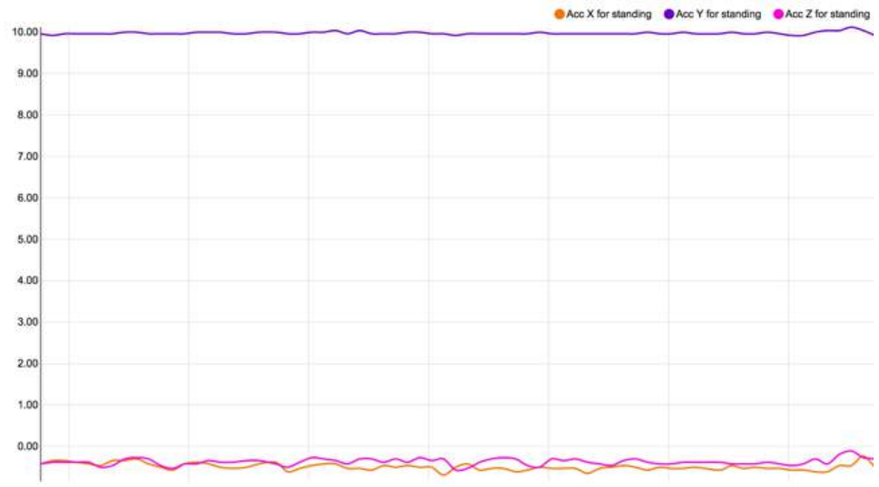
repetitive



walking, jogging, up/down stairs

VS

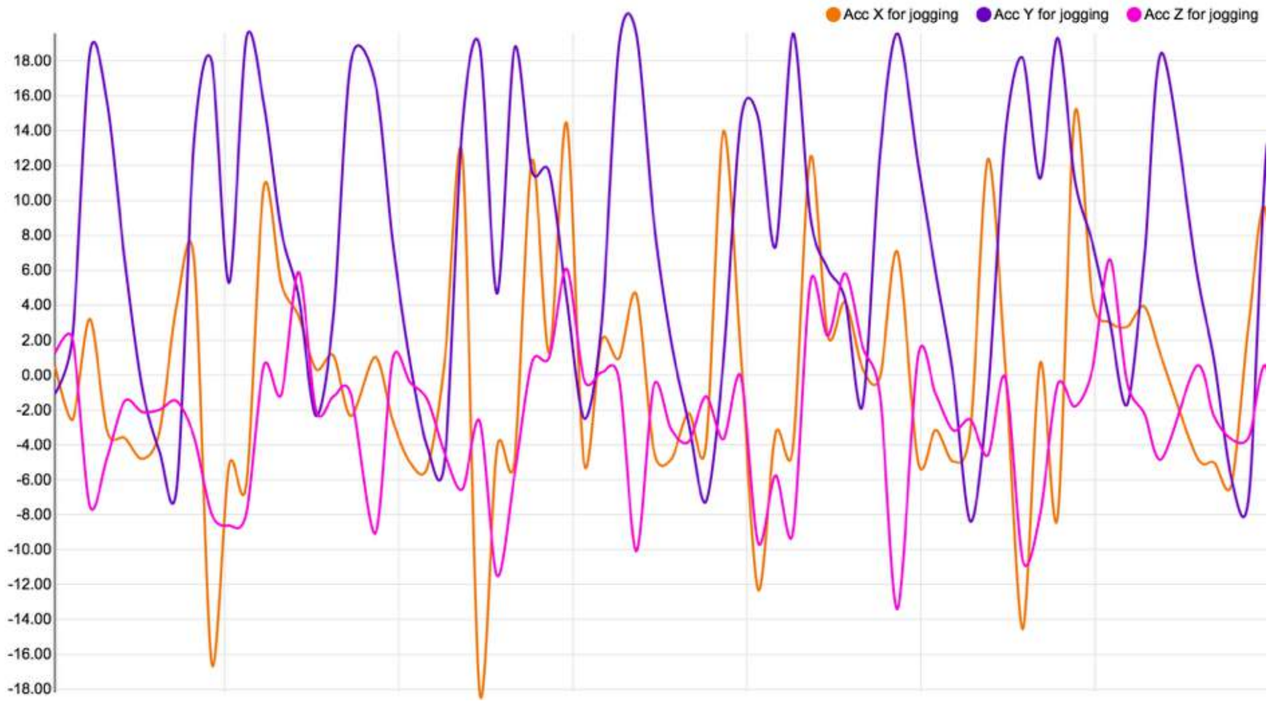
static



standing, sitting

graph from the Cityzen Data widget

The activities : jogging

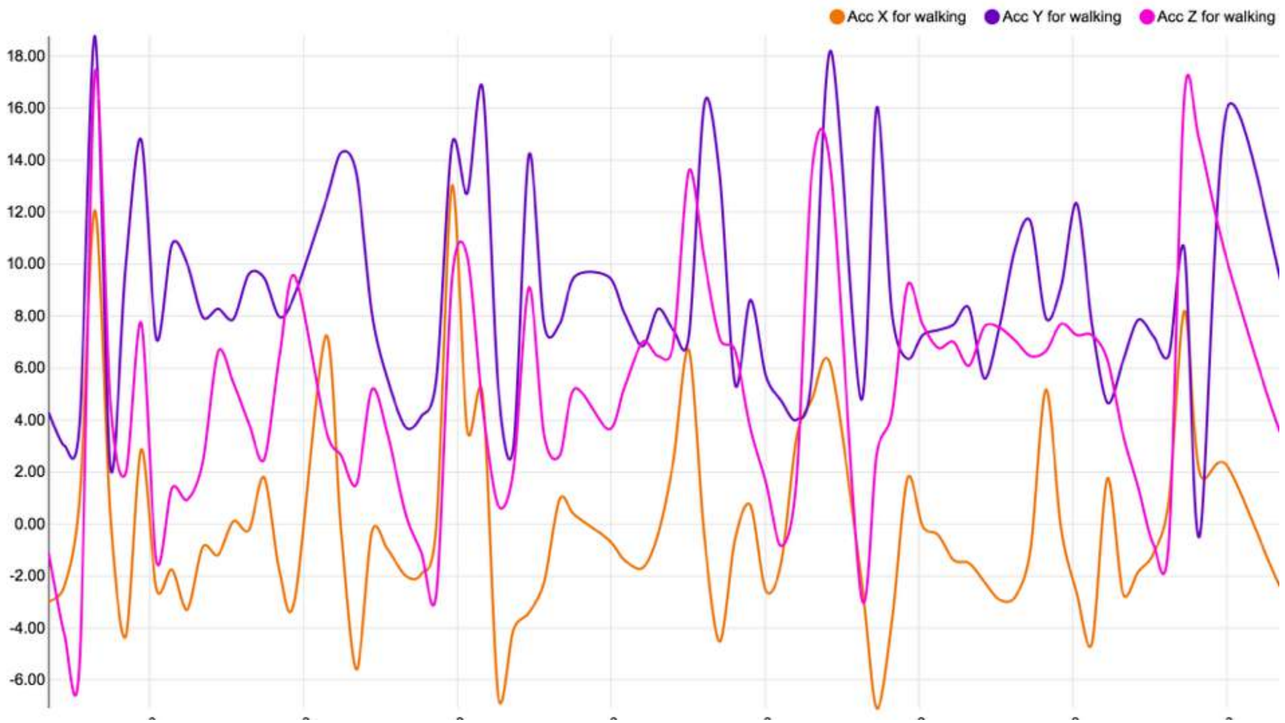


mean_x = 3.3
mean_y = -6.9
mean_z = 0.8

Y-axis: peaks spaced out about 0.25 seconds

graph from the Cityzen Data widget

The activities : walking



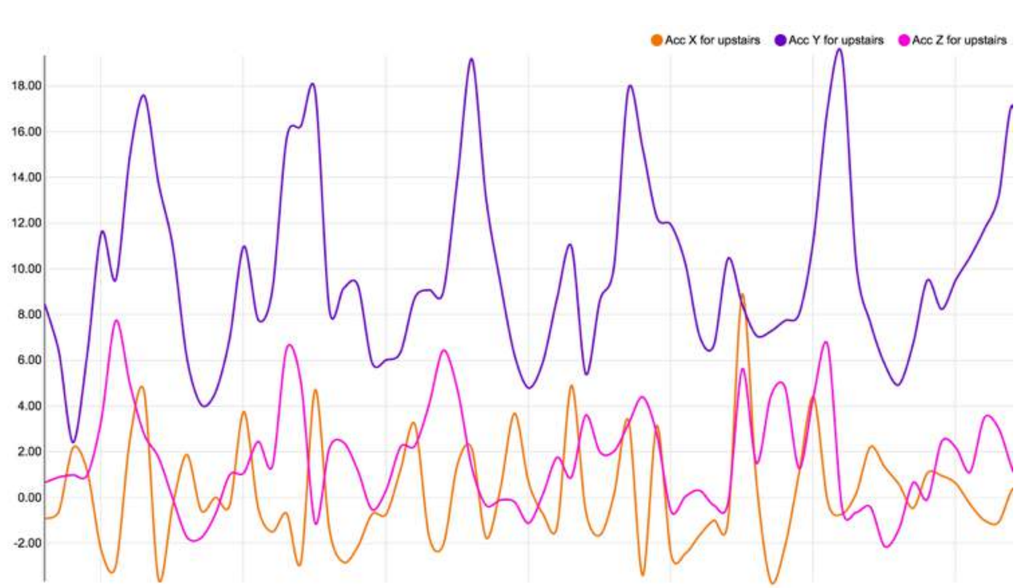
mean_x = 1
mean_y = 10
mean_z = -0.3

Y-axis: peaks spaced about 0.5 seconds

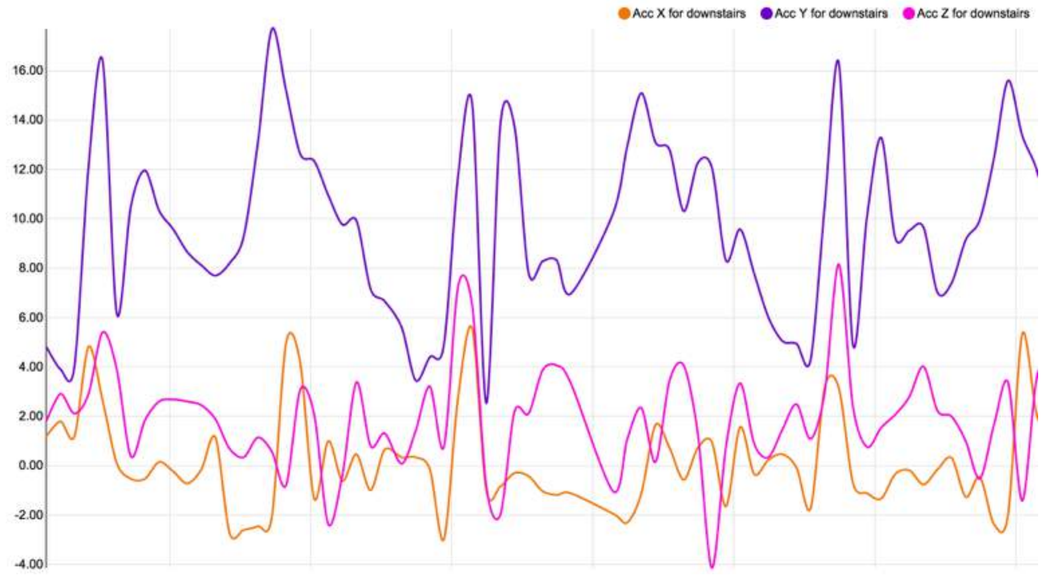
graph from the Cityzen Data widget

The activities : up/downstairs

up



down

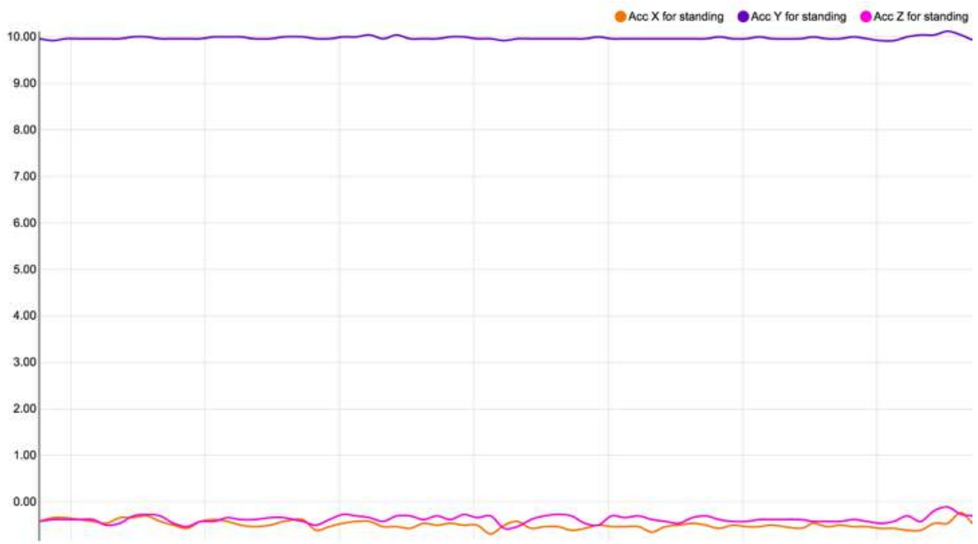


Y-axis: peaks spaced about 0.75 seconds

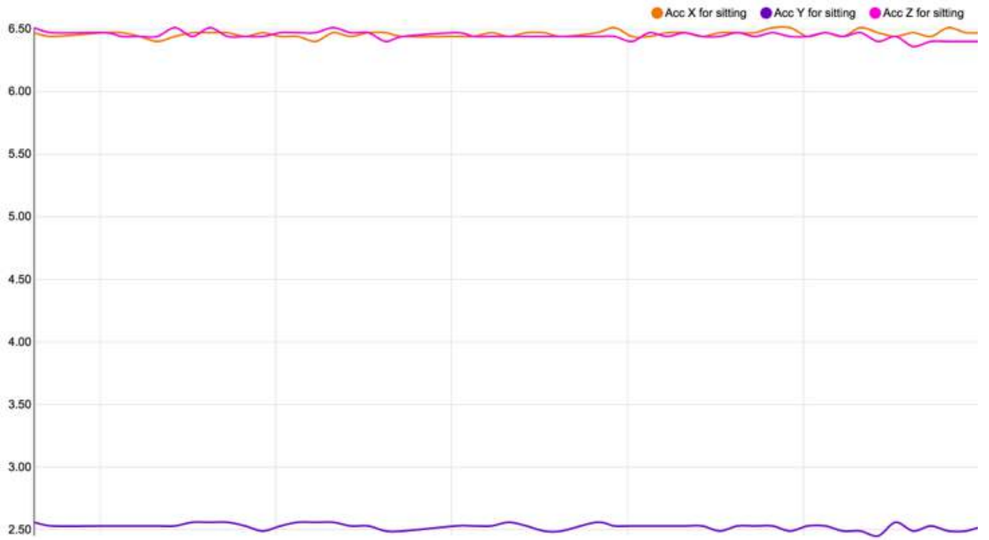
graph from the Cityzen Data widget

The activities : standing

standing



sitting



static activity: no peaks

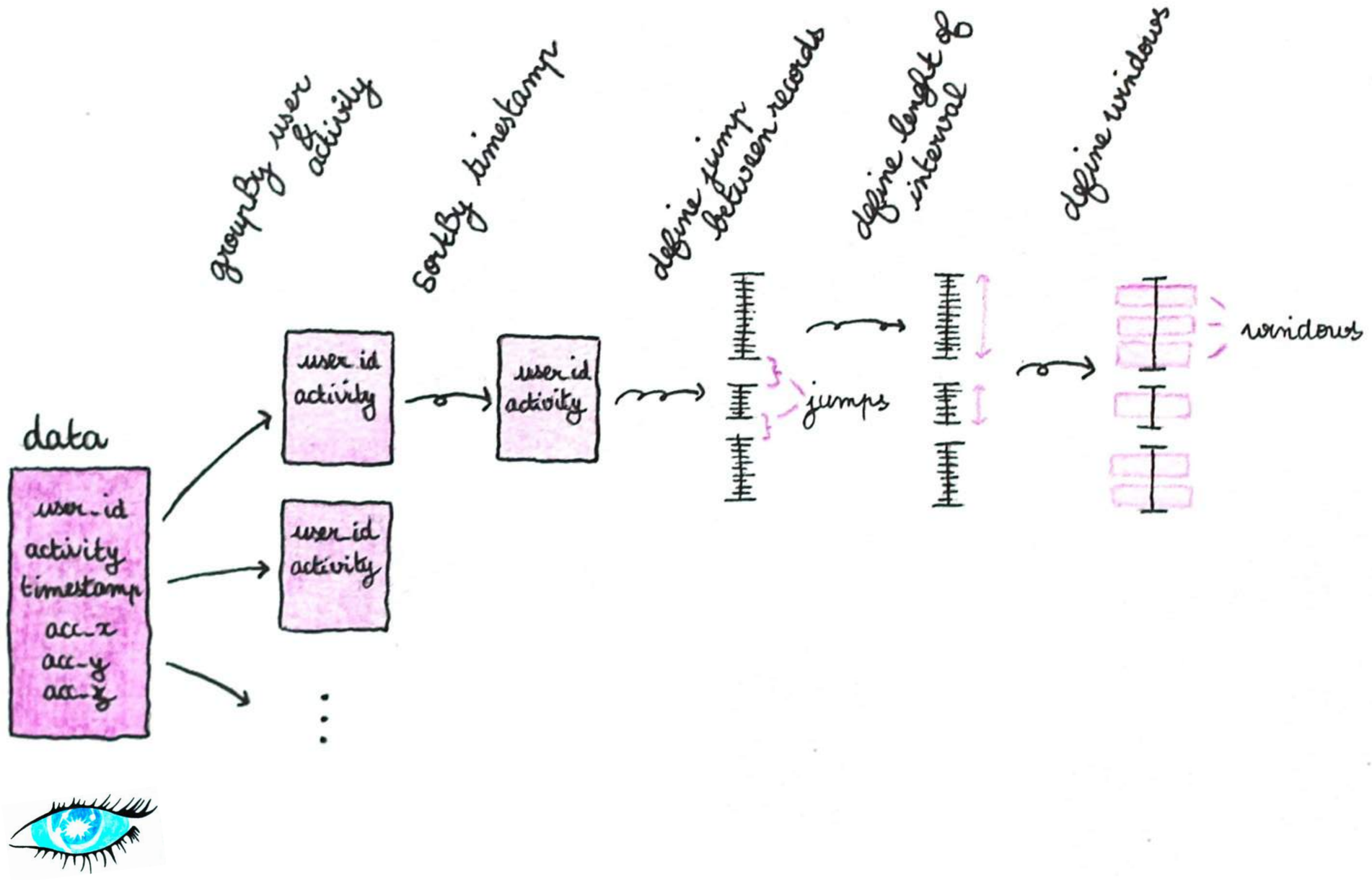
graph from the Cityzen Data widget

The features

Goal: compute these features for all the users (37) and activities (6) over few seconds window

- Average acceleration (for each axis)
- Variance (for each axis)
- Average absolute difference (for each axis)
- Average resultant acceleration
- Average time between peaks (max) (for Y-axis)

Clean
&
prepare the data


group by user & activity
sort by timestamp
define jump between records
define lenght of interval
define windows
data
user_id
activity
timestamp
acc_x
acc_y
acc_z
user_id
activity
user_id
activity
jumps
windows

retrieve the data from Cassandra

```
// define Spark context
 SparkConf sparkConf = new SparkConf()
                                    .setAppName("User's physical activity recognition")
                                    .set("spark.cassandra.connection.host", "127.0.0.1")
                                    .setMaster("local[*]");

 JavaSparkContext sc = new JavaSparkContext(sparkConf);


// retrieve data from Cassandra and create an CassandraRDD
  CassandraJavaRDD<CassandraRow> cassandraRowsRDD =
                                javaFunctions(sc).cassandraTable("actitracker", "users");
```

Compute the features

MLlib

Feature: mean

```
import org.apache.spark.mllib.stat.MultivariateStatisticalSummary;
import org.apache.spark.mllib.stat.Statistics;

private MultivariateStatisticalSummary summary;

public ExtractFeature(JavaRDD<Vector> data) {
    this.summary = Statistics.colStats(data.rdd());
}

// return a Vector (mean_acc_x, mean_acc_y, mean_acc_z)
public Vector computeAvgAcc() {
    return this.summary.mean();
}
```

Feature: avg time between peaks

```
// define the maximum using the max function from MLlib

double max = this.summary.max().toArray()[1];


// keep the timestamp of data point for which the value is greater than 0.9 * max
// and sort it !
// Here: data = RDD (ts, acc_y)

JavaRDD<Long> peaks = data.filter(record -> record[1] > 0.9 * max)
                          .map(record -> record[0])
                          .sortBy(time -> time, true, 1);
```

Feature: avg time between peaks

```
// retrieve the first and last element of the RDD (sorted)
Long firstElement = peaks.first();
Long lastElement = peaks.sortBy(time -> time, false, 1).first();

// compute the delta between each timestamp
JavaRDD<Long> firstRDD = peaks.filter(record -> record > firstElement);
JavaRDD<Long> secondRDD = peaks.filter(record -> record < lastElement);

JavaRDD<Vector> product = firstRDD.zip(secondRDD)
                                  .map(pair -> pair._1() - pair._2())
                                  // and keep it if the delta is != 0
                                  .filter(value -> value > 0)
                                  .map(line -> Vectors.dense(line));

// compute the mean of the delta
return Statistics.colStats(product.rdd()).mean().toArray()[0];
```

Choose algorithms

Goal: identify the physical activity that a user is performing

MLlib

Random Forests

Decision Trees

Multiclass Logistic Regression

Decision Trees

```
// Split data into 2 sets : training (60%) and test (40%)
JavaRDD<LabeledPoint>[] splits = data.randomSplit(new double[]{0.6, 0.4});
JavaRDD<LabeledPoint> trainingData = splits[0].cache();
JavaRDD<LabeledPoint> testData = splits[1];
```

Decision Trees

```
// Decision Tree parameters
Map<Integer, Integer> categoricalFeaturesInfo = new HashMap<>();
int numClasses = 4;
String impurity = "gini";
int maxDepth = 9;
int maxBins = 32;

// create model
final DecisionTreeModel model = DecisionTree.trainClassifier(
                                    trainingData, numClasses, categoricalFeaturesInfo, impurity, maxDepth, maxBins);

// Evaluate model on training instances and compute training error
JavaPairRDD<Double, Double> predictionAndLabel =
                                        testData.mapToPair(p -> new Tuple2<>(model.predict(p.features()), p.label()));

Double testErrDT = 1.0 * predictionAndLabel.filter(pl -> !pl._1().equals(pl._2())).count() / testData.count();

// Save model
model.save(sc, "actitracker");
```

Results

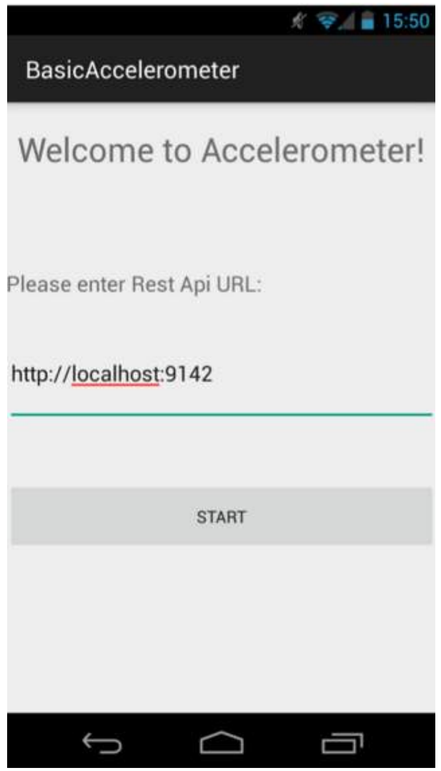
classes number	mean error (Random Forest)	mean error (Decision Tree)
4 (4902 samples)	1,3%	1,5%
6 (6100 samples)	13,4%	13,2%

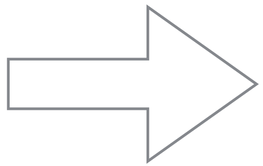
Predictions

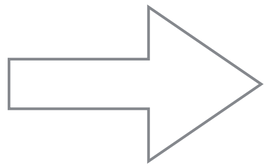
http://www.commitstrip.com/en/2014/04/08/the-demo-effect-dear-old-murphy/?setLocale=1

Accelerometer Android app

REST Api collecting data coming from a phone application







An example: https://github.com/MiraLak/accelerometer-rest-to-cassandra

Predictions!

```
// load the model saved before
DecisionTreeModel model = DecisionTreeModel.load(sc.sc(), "actitracker");

// connection between Spark and Cassandra using the spark-cassandra-connector
CassandraJavaRDD<CassandraRow> cassandraRowsRDD = javaFunctions(sc).cassandraTable("accelerations",
"acceleration");

// retrieve data from Cassandra and create an CassandraRDD
JavaRDD<CassandraRow> data = cassandraRowsRDD.select("timestamp", "acc_x", "acc_y", "acc_z")
                        .where("user_id=?", "TEST_USER")
                        .withDescOrder()
                        .limit(250);

Vector feature = computeFeature(sc);

double prediction = model.predict(feature);
```

How can I use my computations?

possible applications:

- adapt the music over your speed
- detects lack of activity
- smarter pacemakers
- smarter oxygen therapy

Conclusion

Thank you!

Some references

- http://cassandra.apache.org/
- http://planetcassandra.org/getting-started-with-time-series-data-modeling/
- https://github.com/datastax/spark-cassandra-connector
- https://github.com/MiraLak/AccelerometerAndroidApp
- https://github.com/MiraLak/accelerometer-rest-to-cassandra

- https://spark.apache.org/docs/1.3.0/
- https://github.com/nivdul/actitracker-cassandra-spark
- http://www.duchess-france.org/analyze-accelerometer-data-with-apache-spark-and-mllib/

http://www.cis.fordham.edu/wisdm/index.php