**Daimler Trucks & Buses Tech and Data Hub**

**Big Data Technical Challenge**

Carlos Godinho

[cma.godinho@gmail.com](mailto:cma.godinho@gmail.com)

Version 1.0, April 2019

# Answers

Analyze 3 datasets to produce a dataset that answers the question:

**Which doctors from which medical school prescribe drugs of a certain family and type?**

And answer 3 proposed questions:

**1 - The following table from the above 3 datasets. Please compile the data from the above 3 data sets.**

Read chapter 3 - Exploratory Data Analysis for the detailed data analysis.

Check the proposal for the consolidated dataset in chapter 3.6 - Final Dataset.

A Spark application (Consolidation) is available to implement the proposal and is described in chapter 4 - Solution.

**2 - In the case that the data was available as a web download (not as a downloaded file), modify the program to read from a HTTP source (S3 / Blob storage). Is it possible to process the file without local storage / staging in HDFS?**

Data is available as a web download, as described in chapter 2.4 - Other Data Availability.

As available in Spark Scala doc:

<https://spark.apache.org/docs/latest/api/scala/index.html#org.apache.spark.SparkContext>

Spark reads directly from HDFS, S3 or a local filesystem. Direct reading as HTTP(S) is not supported.

A specific implementation is added to Consolidation application to parse HTTP(S) input files. The implementation is available in class Manager, method webFile. The solution is working as described in chapter

4.5 - Execution. However, this solution is not recommended for large files (> 1 million records).

An alternative solution is presented in Figure 1. Data is downloaded, parsed and an injected into Kafka. Spark Streaming read records from Kafka and processes data. Final data is stored in a final device.



Figure 1 – Alternative solution

Therefore, it is possible to process the file without local storage / HDFS.

**3 - How can the original data be downloaded and deflated directly from spark? Write a spark job for this?**

Spark application (Consolidation) execution and tests are described in chapter 5 - Tests.

# Datasets

## Dataset Drugs

**Content:** The primary data source for these data is the CMS Chronic Condition Data Warehouse (CCW), a database with 100% of Medicare enrollment and final-action Part D prescription drug event (PDE) data.

**Location:** <https://data.cms.gov/Medicare-Part-D/Part-D-Prescriber-National-Summary-Report-Calendar/2n5w-7ghf> is the base directory for Drugs.

<https://download.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/Medicare-Provider-Charge-Data/Downloads/PartD_Prescriber_PUF_Drug_Ntl_15.zip>, holds the data.

**Format:** Microsoft Excel Open XML Spreadsheet (XLSX).

**Data Dictionary:** In file, tab Data Dictionary

## Dataset Physicians

**Content:** This file contains general information about individual eligible professionals (EPs) such as demographic information and Medicare quality program participation.

**Location:** <https://data.medicare.gov/data/Physician-Compare> is the base directory for Physicians.

<https://data.medicare.gov/Physician-Compare/Physician-Compare-National-Downloadable-File/mj5m-pzi6> holds the data.

**NOTE:** that there is also a link for the register 2015 Physicians: <http://medicare.gov/download/PhysicianCompare/2015/Refresh_Data_Archive_November_2015_1.zip>

this is the used link!

**Format:** ZIP with Comma Separator Values. Commas may exist within fields. In such case, fields are quoted.

**Data Dictionary:** In the page

## Dataset Prescriptions

**Content:** The Part D Prescriber PUF is organized by National Provider Identifier (NPI) and drug name and contains information on drug utilization (claim counts and day supply) and total drug costs.

**Location:** <http://download.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/Medicare-Provider-Charge-Data/Downloads/PartD_Prescriber_PUF_NPI_DRUG_15.zip>

**Format: ZIP with Tab Separator Values.**

**Data Dictionary:** <https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/Medicare-Provider-Charge-Data/Downloads/Prescriber_Methods.pdf>

## Other Data Availability

**Data.Medicare.gov** data is supported by the **Socrata Open Data platform (SODA)**, which provides an API to allow software developers to access it.

The description link is presentation here: <https://data.medicare.gov/developers>

The SODA API supports formats like JSON, XML and CSV. Each dataset has a specific endpoint to access the data.

Examples on how to us the API: <https://dev.socrata.com/>

For the drugs we have as example:

<https://data.cms.gov/Medicare-Part-D/Part-D-Prescriber-National-Summary-Report-Calendar/2n5w-7ghf>

With data end points like:

<https://data.cms.gov/resource/5m6j-9i3f.json>

<https://data.cms.gov/resource/5m6j-9i3f.csv>

# Exploratory Data Analysis

## Introduction

To make an effective exploratory data analysis to the provided data, [R](https://www.r-project.org/) language is used. Besides basic R the following components are required:

* RStudio for IDE support;
* R Packages (dplyr, readr and stringr) to increase R productivity.

The R script is available as /code/data\_analysis.R.

## Entities

3 entities are identified:

* **Drug** – lists a set of drugs with prices and properties;
* **Physician** – Defines a set of Physicians, with specialties, training, alma-mater and other personal details;
* **Prescription** – Records of drug prescriptions made by physicians during 2015.

Each entity is available as a dataset (tabular format).

## Size and Keys

Dataset size and leys are presented in Table 1.

|  |  |  |
| --- | --- | --- |
| **Dataset** | **Size** | **Primary KEY** |
| Drug | 3 395 x 19 | Drug Name + Drug Generic Name |
| Physician | 2 013 843 x 43 | NPI is the key, although multiple updates are available  There are other identifiers with no applicability for this use case |
| Prescription | 24 524 894 x 21 | As stated in data dictionary, it is an aggregation of:  NPI + Drug Name + Drug Generic Name |

Table 1 – Dataset size and keys

## Findings

In **Drug**:

* Drugs dataset has a composite key of Drug Name + Generic name. In fact, there are only 190 repetitions of field Drug Name. In a real scenario a discussion with a domain expert would be recommended;
* Considering both Drug Name and Generic Name, all fields are available.

In **Physician**:

* Using file form 2015;
* Entries related to the same Physician is repeated, due to updates in its descriptions;
* The pair <NPI, Medical school name> can be aggregated as it never changes.

In **Prescription**:

* Field bene\_count has ~3 million empty records. According to the data dictionary, counts fewer than 11 are suppressed and are indicated by a blank;
* Key fields are always available;
* There are 1 208 entries of empty field nppes\_provider\_first\_name, which corresponds to providers registered as organizations. This is a very low rate;
* Holds references to Prescribers (by field npi);
* Holds references to Drugs (by field drug\_name and generic\_name);
* Besides individual providers, attribute NPI includes organizational providers, nursing homes, group practices, non-physician practitioners, residential facilities, ambulatory surgery centers, and other providers.

Between entities:

* There are 336 092 prescriptions pointing to unavailable Physicians. According to the data description not all the Physicians are available. Also, some Prescribers are not Physicians (although they have npi);
* All Drugs reported in Prescriptions are available in Drugs dataset.

## Relationships

The relationships between entities are presented in Figure 2.

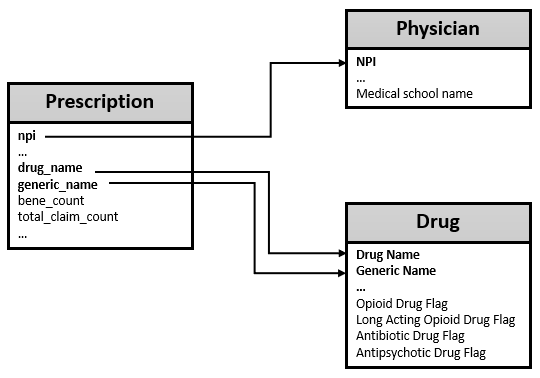


Figure 2 - Relationship between entities. Keys are represented in bold.

## Final Dataset

The final dataset purposed is presented in Table 2, together with the data source location. A markdown file is available with the data dictionary as /doc/consolidated\_prescription.md.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **New Dataset** | | **Original Entity** | | | **Notes** |
| **Name** | **#** | **Entity** | **Name** | **#** |
| npi | 1 | Physician  Prescription | NPI  npi | 1  1 | Numeric |
| drug\_simple\_name | 2 | Drug  Prescription | Drug Name | 1  8 | String |
| drug\_generic\_name | 3 | Drug  Prescription | Generic Name | 2  9 | String |
| bene\_count | 4 | Prescription | bene\_count | 10 | Numeric, Not always available  May be useful for data scientists |
| total\_claim\_count | 5 | Prescription | total\_claim\_count | 11 | Numeric,  May be useful for data scientists |
| medical\_school | 6 | Physician | Medical school name | 10 | String |
| drug\_opioid\_flag | 7 | Drug | Opioid DF | 16 | Boolean  Drug type descriptor |
| drug\_long\_acting\_opioid\_flag | 8 | Drug | Long Acting Opioid DF | 17 | Boolean  Drug type descriptor |
| drug\_antibiotic\_flag | 9 | Drug | Antibiotic DF | 18 | Boolean  Drug type descriptor |
| drug\_antipsychotic\_flag | 10 | Drug | Antipsychotic DF | 19 | Boolean  Drug type descriptor |

Table 2 - Selected fields and its origin

# Solution

## Introduction

A Spark solution validates and combines the datasets. As a result, the **Consolidation dataset** is created. To build the solution the following components are required:

* IntelliJ IDE with Scala extension;
* Scala 2.11.12
* Scala Test 3.0.5
* Spark 2.4.0
* sbt 1.2.8
* HDFS 2.9.2
* Apache HTTP server 2.2 (for simulating HTTP download)

The project is available as **Consolidation** and is available in/code/Consolidation.

## Architecture

The following points are the result of design/architecture decisions:

* The application executes in a Spark Cluster and accesses HDFS;
* For the use underlying data structures, RDDs are used. RDDs guarantee best performance in data processing. As an alternative the SQL/Dataset/Dataframe could also be used;
* The application is available as a jar to be launched in a cluster with spark-submit;
* For flexibility, the application receives a set of arguments when launched;
* It is recommended to have input data available in HDFS, as an alternative an URL may also be provided;
* Results are provided to an output directory in HDFS;
* Input data files have fields separators, but the field separator may also be used inside a file. In this case the fields are quoted. For simplification the output data uses “,” as single separator and removes quotes from fields. In the case “,” are used in a field, it is replaced by “;”;
* Scala test is used for testing a class and to show its potentiality;
* Each application execution produces a log in the output directory (consolidation.<date+time>.log**),** detailing its activities and timestamps;
* Data is joined by **inner join** concept, if no matching is found, entries are not considered.
* sbt script is available for producing the application.

## Spark Performance

The following performance improvements are available:

* **Kyro** serialization is activated to improve performance as data needs to be changed between executors;
* As Drugs have a small size compared to the other datasets, it is more efficient to transform Drugs data into a Map and use it as a lookup. Drugs data is Broadcasted into the executors as a name value Map;
* Filtering only relevant fields reduces the amount of data to be processed and shuffled in the cluster;
* As the application is working in a cluster, adding more resources (**horizontal scaling**) improves performance without the need of any changes in its internal implementation;
* Many physicians have its medical school reported as other, a possible performance improvement is to eliminate such elements during parsing (not implemented).

## Environment

Consolidation application runs in Spark cluster of 4 servers with the details presented in Figure 3.

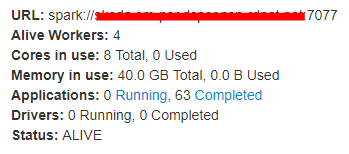


Figure 3 – Spark cluster

Each server has 2 cores, with 4 GB per core available. Total memory per server is 16 GB.

The cluster has a HADOOP cluster with 3 nodes as presented in Figure 4.

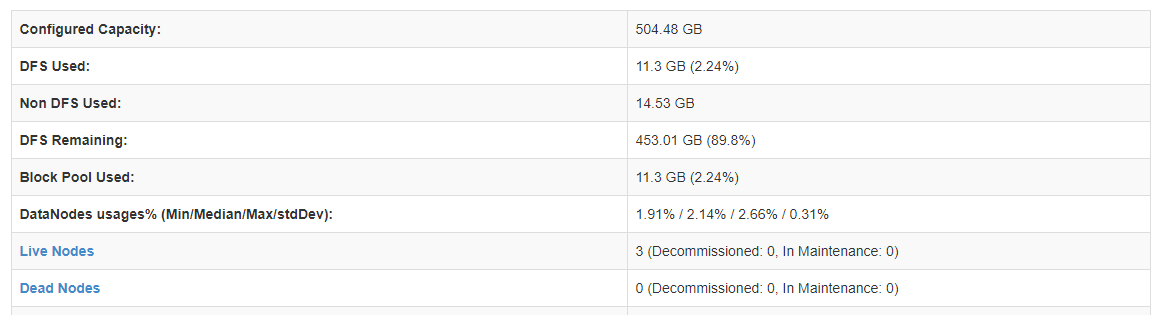


Figure 4 – HDFS cluster

Figure 5 presents the recommended directory tree in HDFS.

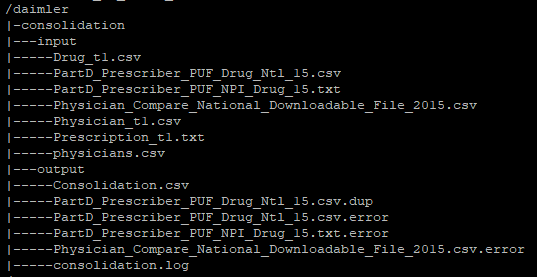


Figure 5 – Data structure in HDFS cluster

So, besides a base directory, the application expects an input and output directory.

Application jar file and launching scripts are available in NFS sharing point, accessible by all Spark nodes, as presented in Figure 6.

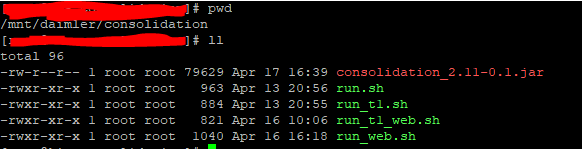


Figure 6 – Data structure in NFS

## Execution

To run the application, use the following command:

$SPARK\_HOME/bin/spark-submit --master spark://<spark address> consolidation\_2.11-\*.jar $1 $2 $3 $4 $5 $6

where:

$1 – HADOOP configuration files CSV list (core-site.xml and hdfs-site.xml are mandatory)

$2 – HADOOP base path

$3 – Drug file (must be inside HADOOP base path + input), if file in a web link, just provide an URL)

$4 – Physician file (must be inside HADOOP base path + input), if file in a web link, just provide an URL)

$5 - Prescription file (must be inside HADOOP base path + input), if file in a web link, just provide an URL)

$6 – Consolidation output file

Shell scripts are available in directory /tests/execution**.**

# Tests

## Introduction

The following test strategy is defined:

* Create a small data set to verify the consolidation business logic. Sample files are provided in /test/test\_data**.** This technique allows to identify and correct issues in business logic more efficiently. Different test cases may be created by duplicating these files in a text editor;
* Setup an HTTP server to test input data provided as HTTP requests. Each dataset is available by a direct web URL;
* Copy the 3 datasets to HDFS and execute the test with the complete data.

## Results

In /test/execution it is possible to find the shell scripts that launch the application and a set of pictures showing Consolidation application being executed in the cluster and using the its full capability.

Document /doc/execution\_times.xlsx gathers **10 executions** of Consultation application (with full data) in the available cluster. The statistics from the execution are resumed in Table 3. The total execution time expected is **~ 13 minutes**. Each execution log is available in /test/results/consolidation.<date-time>.log.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Statistic** | **Drugs Parse, Map & Broadcast** | **Physician Parse** | **Prescription Parse** | **Consolidation + Write to HDFS** | **Total** |
| Max | 01:50 | 00:49 | 05:14 | 07:00 | 14:42 |
| Min | 01:30 | 00:30 | 03:39 | 06:06 | 12:29 |
| Average | 01:41 | 00:38 | 04:17 | 06:36 | 13:16 |

Table 3 – Execution statistics, in mm:ss

The final Consolidation dataset produced has a size of **20 024 410 x 10**. This means that **82%** of the initial Prescription entries are enriched with the necessary Physician and Drugs data. The gap is explained per:

* Prescriptions from institutions and not individual Physicians;
* NPIs reported in Prescription, but not available in the Physicians
* Repeated Drugs removed during parsing.

A sample of 1000 entries from the produces Consolidation dataset is available in /test/results/.

Each issue in input data is reported to a specific log file in the output directory as presented in Table 4. Such files are available in /test/results/. The name of the input file is used to generate the error file, adding an extension error or dup accordingly to the error type.

|  |  |  |
| --- | --- | --- |
| **File / Source** | **Error Type** | **Physician Parse** |
| PartD\_Prescriber\_PUF\_Drug\_Ntl\_15.csv.dup | Duplicate | Key = [EYLEA,AFLIBERCEPT] x2 in lines [1394-1117]  Key = [ACTIVE OB,PNV NO.66/IRON;CARBONYL/FA/DHA] x2 in lines [34-1060] |
| PartD\_Prescriber\_PUF\_Drug\_Ntl\_15.csv.error | Format | Header, no real problem |
| PartD\_Prescriber\_PUF\_NPI\_Drug\_15.txt.error | Format | Header, no real problem |
| Physician\_Compare\_National\_Downloadable\_File\_2015.csv.error | Format | Header, no real problem |

Table 4 – Error logs