Leveraging Data Preparation, HBase NoSQL Storage, and HiveQL Querying for COVID-19 Big Data Analytics Projects

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Abstract. Epidemiologist, Scientists, Statisticians, Historians, Data engineers and Data scientists are working on finding descriptive models and theories to explain COVID-19 expansion phenomena or on building analytics predictive models for learning the apex of COVID-19 confirmed cases, recovered cases, and deaths evolution curves. In CRISP-DM life cycle, 75% of time is consumed only by data preparation phase causing lot of pressions and stress on scientists and data scientists building machine learning models. This paper aims to help reducing data preparation efforts by presenting detailed schemas design and data preparation technical scripts for formatting and storing Johns Hopkins University COVID-19 daily data in HBase NoSQL data store, and enabling HiveQL COVID-19 data querying in a relational Hive SQL-like style.

Key words: Coronavirus, SARS-CoV-2, COVID-19, 2019-nCoV, Data Engineering, NoSQL, HBase, Hive.

1 Introduction

Johns Hopkins University has provided a github repository with, among others, daily fresh data about COVID-19 pandemy confirmed cases, recovered cases, and deaths evolution [1]. Epidemiologist, Scientists, Statisticians, Historians, Data engineers and Data scientists are working on finding models and theories to explain and predict COVID-19 expansion phenomena. Our paper aims to help reducing data preparation efforts by presenting detailed schemas design and data preparation technical scripts for formatting and storing Johns Hopkins University COVID-19 daily data in HBase [2] NoSQL data store, and enabling HiveQL COVID-19 data querying in a relational Hive [3] SQL-like style. Our data
integration and analytics approach for this paper, and for handling COVID-19 crisis in general is building Minimum Viable Model, Platform, and Data Product through agile analytics [4].

2 Prerequisites

(1) Hadoop or YARN [5] with HBase, Hive need to be installed\(^1\). (3) A Linux/Unix environment is requested for running the given shell scripts. (4) git tools are necessary for pulling data.

```
Listing 1.1: Targeted Datalake Hadoop ecosystem starting
1 ./start.sh hadoop
2 ./start.sh hbase
3 ./start.sh hive
```

This step depends on the Hadoop/YARN environment specificities. Ambari [6] may be used to start those services.

3 COVID-19 Data Preparation

3.1 Data Collection

COVID-19 Data can be collected each day from Johns Hopkins University Center for Systems Science and Engineering (JHU CCSE) github repository around 2.00 am GMT+1.

```
Listing 1.2: Pulling COVID-19 Data
1 #kbaina is my local home directory, change it to your home
directory or another directory
2 cd /home/kbaina/
3 4 git clone https://github.com/CSSEGISandData/COVID-19.git
   COVID-19/
5
6 cd ./COVID-19/
7
8 git pull
```

\(^1\) In this paper, a minimal IBM BigInsights quick start VM is used as a DEV on-premises Big Data platform, however, scripts are compatible with every on-premises Hadoop Apache compliant Big Data distributions (like Cloudera/Hortonworks HDP, IBM Open Platform, MapR, etc.), or Hadoop Apache compliant Cloud Analytics Solutions (like Google Cloud Big Data Analytics Solutions, Microsoft Azure HDInsight, Amazon AWS EMR, IBM Analytics Engine on IBM Watson, etc.)
3.2 Data Formatting

`ingest_and_clean.sh` data formatting Shell script removes ",", '*' characters, and replaces non separator ',' by '-' character (e.g. in "Korea, South"), formats column dates into "%m/%d/%Y" format (e.g. 3/2/20 becomes 03/02/2020) enabling dates operations, keeps only not null values from the sparse matrix, and merges the two first columns to form a composite key separated by a '-' character.

Listing 1.3: Data Formatting Shell Script (`ingest_and_clean.sh`)

```bash
#!/bin/sh
specific=$1

sed "s/, /-/" ./COVID-19/csse_covid_19_data/csse_covid_19_time_series/time_series_covid19_${specific}_global.csv | sed "s//\"/g" | sed "s/\*/" | sed -E "s/\(//,\1\)/g" | sed -E "s/\)/,\1\)/g" | sed -E "s/\20\[^/]/\2020\1/g" | sed -E "s/,($)/,0\1/g" | sed "s/,0,/,,/g" | sed -E "s/([\[\],]+)0,/\1,/g" | sed "s/,0$/,,/g" | sed "s/,/^-/g" | tail -n +2 time_series_covid19_${specific}_global-sparse-with-formatted-column-names.csv
```

# time_series_covid19_${specific}_global-sparse-with-formatted-column-names.csv
# contains date formatted columns useful for any further date arithmetics and manipulation
# (e.g. duration calculations, D0 of COVID-19, D0 of n'th death manipulation, etc.)

tail -n +2 time_series_covid19_${specific}_global-sparse-with-formatted-column-names.csv > time_series_covid19_${specific}_global-sparse.csv
Listing 1.4: Calling Data Fomatting Shell Script (ingest_and_clean.sh)

1. cd /home/kbaina/
2. chmod u+x ./ingest_and_clean.sh
3. ./ingest_and_clean.sh confirmed
4. ./ingest_and_clean.sh deaths
5. #next command will succeed but you should adapt next section
   scripts for creating, feeding, and querying recovered
   tables.
6. ./ingest_and_clean.sh recovered

4 NoSQL HBase Storage and Hive SQL/pure NoSQL
interoperability

In this section present NoSQL and relational schema design and detailed
technical scripts for storing JHU COVID-19 daily confirmed cases and deaths
data. For a more conceptual background on NoSQL databases, and NoSQL
design methodologies, here are are related author papers [7,8]

4.1 NoSQL HBase schema Design

Confirmed cases and deaths data will be stored respectively in HBase 'confirmed_covid19_cases' table, and 'deaths_covid19_cases' table. Mainly those tables are compliant to JHU CCSE files structure with the first two columns aggregation for database unique key property. Each covid-19 row, either for confirmed cases or for deaths, in HBase will store a country data structured as a composite string primary key (rowid) constituted from its eventual province/state concatenated with its country name/region and separated with ‘~’ character. The row then will store all columns values under the same column family ‘a’ (e.g. ‘a:lt’ represents latitude, ‘a:lg’ represents longitude, while remaining dynamic daily dated columns values will be named by convention as ‘a:d122’ meaning value at January 22nd, ‘a:d327’ meaning confirmed cases value of confirmed_covid19_cases table (respectively number of deaths of deaths_covid19_cases table) at March 27nd, etc.

---

2 without losing in generality, all scripts in this paper can be very easily adapted to take into account JHU CCSE recovered cases file (time_series_covid19_recovered_global.csv) from github repository.
3 time_series_covid19_confirmed_global.csv and time_series_covid19_deaths_global.csv under ./COVID-19/csse_covid_19_data/csse_covid_19_time_series/ directory.
The following HBase commands retrieve number of confirmed COVID-19 cases, and deaths at March 31st for Morocco (suffix before ‘ ’ is empty for all countries) and for British Columbia Canada (suffix before ‘ ’ is not empty for all states) from 'confirmed_covid19_cases' and 'deaths_covid19_cases' Hbase tables.

Listing 1.5: HBase get query examples

1. get 'confirmed_covid19_cases', '-Morocco', 'a:d331'
2. get 'deaths_covid19_cases', '-Morocco', 'a:d331'
3. get 'confirmed_covid19_cases', 'British Columbia-Canada', 'a: d331'
4. get 'deaths_covid19_cases', 'British Columbia-Canada', 'a: d331'

4.2 Relational Hive schema Design

Confirmed cases and deaths data will be respectively represented by two external tables in Hive 'confirmed_covid19_cases' table, and 'deaths_covid19_cases'. Those tables will be relational abstractions mapped (kind of shortcuts pointing) to their equivalent NoSQL tables in HBase (i.e. non managed Tables - stored physically only in Hbase).

Listing 1.6: Under HBase remove Confirmed cases Table

1. disable 'confirmed_covid19_cases'
2. drop 'confirmed_covid19_cases'

Listing 1.7: Under HBase remove Deaths Table

1. disable 'deaths_covid19_cases'
2. drop 'deaths_covid19_cases'

---

4 In the NoSQL/SQL interoperability between HBase and Hive, the Hive 'CREATE TABLE' command will create two tables one in HBase and another table in Hive (the latest is implicitly external).

5 You should add a new column to Hive/HBase confirmed cases, deaths and recovered schemas each day after March 31st, 2020 manually or generate the new schema automatically !.

6 SQL Hive CREATE TABLE commands are may easily be adapted to other relational Big Data store compatible with HBase as Cloudera HDP Impala [9], IBM Db 2 Big SQL [10], etc.
Listing 1.8: Hive/Hbase Confirmed Cases tables creation

```
1 DROP TABLE confirmed_covid19_cases;
2
3 CREATE TABLE confirmed_covid19_cases (  
4   key struct<Province_State : string,Country_Region : string>,
5   Lat float,
6   Long float,
7   01_22_2020 int, 01_23_2020 int, 01_24_2020 int,
8   01_25_2020 int, 01_26_2020 int, 01_27_2020 int,
9   01_28_2020 int, 01_29_2020 int, 01_30_2020 int,
10   01_31_2020 int, 02_01_2020 int, 02_02_2020 int,
11   02_03_2020 int, 02_04_2020 int, 02_05_2020 int,
12   02_06_2020 int, 02_07_2020 int, 02_08_2020 int,
13   02_09_2020 int, 02_10_2020 int, 02_11_2020 int,
14   02_12_2020 int, 02_13_2020 int, 02_14_2020 int,
15   02_15_2020 int, 02_16_2020 int, 02_17_2020 int,
16   02_18_2020 int, 02_19_2020 int, 02_20_2020 int,
17   02_21_2020 int, 02_22_2020 int, 02_23_2020 int,
18   02_24_2020 int, 02_25_2020 int, 02_26_2020 int,
19   02_27_2020 int, 02_28_2020 int, 02_29_2020 int,
20   03_01_2020 int, 03_02_2020 int, 03_03_2020 int,
21   03_04_2020 int, 03_05_2020 int, 03_06_2020 int,
22   03_07_2020 int, 03_08_2020 int, 03_09_2020 int,
23   03_10_2020 int, 03_11_2020 int, 03_12_2020 int,
24   03_13_2020 int, 03_14_2020 int, 03_15_2020 int,
25   03_16_2020 int, 03_17_2020 int, 03_18_2020 int,
26   03_19_2020 int, 03_20_2020 int, 03_21_2020 int,
27   03_22_2020 int, 03_23_2020 int, 03_24_2020 int,
28   03_25_2020 int, 03_26_2020 int, 03_27_2020 int,
29   03_28_2020 int, 03_29_2020 int, 03_30_2020 int,
30   03_31_2020 int
31 )
32 ROW FORMAT DELIMITED
33 COLLECTION ITEMS TERMINATED BY '\~'
34 STORED BY 'org.apache.hadoop.hive.hbase.HBaseStorageHandler'
35 WITH SERDEPROPERTIES (  
36   "hbase.table.name" = "confirmed_covid19_cases",
37   "hbase.mapred.output.outputtable"="confirmed_covid19_cases",
38   "hbase.columns.mapping" = ":key,a:lt,a:lg,a:d122,a:d123,
39     a:d124,a:d125,a:d126,a:d127,a:d128,a:d129,a:d130,a:d131,
40     a:d201,a:d202,a:d203,a:d204,a:d205,a:d206,a:d207,a:d208,
41     a:d209,a:d210,a:d211,a:d212,a:d213,a:d214,a:d215,a:d216,
42     a:d217,a:d218,a:d219,a:d220,a:d221,a:d222,a:d223,a:d224,
43     a:d225,a:d226,a:d227,a:d228,a:d229,a:d230,a:d231,a:d232,
44     a:d304,a:d305,a:d306,a:d307,a:d308,a:d309,a:d310,a:d311,
45     a:d312,a:d313,a:d314,a:d315,a:d316,a:d317,a:d318,a:d319,
46     a:d320,a:d321,a:d322,a:d323,a:d324,a:d325,a:d326,a:d327,
47     a:d328,a:d329,a:d330,a:d331",
48   "hbase.composite.key.factory"="org.apache.hadoop.hive.hbase.  
SampleHBaseKeyFactory2");
49
50 DESCRIBE confirmed_covid19_cases;
```
Listing 1.9: Hive/Hbase Deaths table creation

```sql
DROP TABLE deaths_covid19_cases;
CREATE TABLE deaths_covid19_cases (  
key struct<Province_State : string,Country_Region : string>,  
Lat float,  
Long float,  
01_22_2020 int, 01_23_2020 int, 01_24_2020 int,  
01_25_2020 int, 01_26_2020 int, 01_27_2020 int,  
01_28_2020 int, 01_29_2020 int, 01_30_2020 int,  
01_31_2020 int, 02_01_2020 int, 02_02_2020 int,  
02_03_2020 int, 02_04_2020 int, 02_05_2020 int,  
02_06_2020 int, 02_07_2020 int, 02_08_2020 int,  
02_09_2020 int, 02_10_2020 int, 02_11_2020 int,  
02_12_2020 int, 02_13_2020 int, 02_14_2020 int,  
02_15_2020 int, 02_16_2020 int, 02_17_2020 int,  
02_18_2020 int, 02_19_2020 int, 02_20_2020 int,  
02_21_2020 int, 02_22_2020 int, 02_23_2020 int,  
02_24_2020 int, 02_25_2020 int, 02_26_2020 int,  
02_27_2020 int, 02_28_2020 int, 02_29_2020 int,  
03_01_2020 int, 03_02_2020 int, 03_03_2020 int,  
03_04_2020 int, 03_05_2020 int, 03_06_2020 int,  
03_07_2020 int, 03_08_2020 int, 03_09_2020 int,  
03_10_2020 int, 03_11_2020 int, 03_12_2020 int,  
03_13_2020 int, 03_14_2020 int, 03_15_2020 int,  
03_16_2020 int, 03_17_2020 int, 03_18_2020 int,  
03_19_2020 int, 03_20_2020 int, 03_21_2020 int,  
03_22_2020 int, 03_23_2020 int, 03_24_2020 int,  
03_25_2020 int, 03_26_2020 int, 03_27_2020 int,  
03_28_2020 int, 03_29_2020 int, 03_30_2020 int,  
03_31_2020 int  
) ROW FORMAT DELIMITED  
COLLECTION ITEMS TERMINATED BY '\~'  
STORED BY 'org.apache.hadoop.hive.hbase.HBaseStorageHandler'  
WITH SERDEPROPERTIES (  
"hbase.table.name" = "deaths_covid19_cases",  
"hbase.mapred.output.outputtable" = "deaths_covid19_cases",  
"hbase.columns.mapping" = "key, a:lt, a:lg, a:d122, a:d123,  
a:d124, a:d125, a:d126, a:d127, a:d128, a:d129, a:d130, a:d131,  
a:d201, a:d202, a:d203, a:d204, a:d205, a:d206, a:d207, a:d208,  
a:d209, a:d210, a:d211, a:d212, a:d213, a:d214, a:d215, a:d216,  
a:d217, a:d218, a:d219, a:d220, a:d221, a:d222, a:d223, a:d224,  
a:d225, a:d226, a:d227, a:d228, a:d229, a:d301, a:d302, a:d303,  
a:d304, a:d305, a:d306, a:d307, a:d308, a:d309, a:d310, a:d311,  
a:d312, a:d313, a:d314, a:d315, a:d316, a:d317, a:d318, a:d319,  
a:d320, a:d321, a:d322, a:d323, a:d324, a:d325, a:d326, a:d327,  
a:d328, a:d329, a:d330, a:d331",  
"hbase.composite.key.factory"="org.apache.hadoop.hive.hbase.  
SampleHBaseKeyFactory2");  
DESCRIBE deaths_covid19_cases;
```
4.3 NoSQL HBase Data Loading

Loading prepared COVID-19 data to HBase data store is achieved by (i) copying `time_series_covid19_confirmed_global-sparse.csv` and `time_series_covid19_deaths_global-sparse.csv` files generated by `ingest_and_clean.sh` script invocations into HDFS file system, and (ii) then performing bulk loading into HBase previously created schema.

Listing 1.10: HBase Feeding with Confirmed Cases data

```bash
# here biadmin is my HDFS user name change it to yours
hadoop fs -rm /user/biadmin/
time_series_covid19_confirmed_global-sparse.csv

hadoop fs -put /home/kbaina/
time_series_covid19_confirmed_global-sparse.csv /user/
biadmin/

hadoop fs -ls

# here /opt/ibm/biginsights/hbase/bin is my HBase binary directory change it to yours
/opt/ibm/biginsights/hbase/bin/hbase org.apache.hadoop.hbase.mapreduce.ImportTsv -Dimporttsv.separator=',' -Dimporttsv
.columns=HBASE_ROW_KEY,a:lt,a:lg,a:d122,a:d123,a:d124,a:
d125,a:d126,a:d127,a:d128,a:d129,a:d130,a:d131,a:d201,a:
d202,a:d203,a:d204,a:d205,a:d206,a:d207,a:d208,a:d209,a:
da210,a:d211,a:d212,a:d213,a:d214,a:d215,a:d216,a:d217,a:
da218,a:d219,a:d220,a:d221,a:d222,a:d223,a:d224,a:d225,a:
da226,a:d227,a:d228,a:d229,a:d301,a:d302,a:d303,a:d304,a:
da305,a:d306,a:d307,a:d308,a:d309,a:d310,a:d311,a:d312,a:
da313,a:d314,a:d315,a:d316,a:d317,a:d318,a:d319,a:d320,a:
da321,a:d322,a:d323,a:d324,a:d325,a:d326,a:d327,a:d328,a:
da329,a:d330,a:d331 -Dimporttsv.skip.bad.lines=true -
Dimporttsv.skip.empty.columns=true
confirmed_covid19_cases /user/biadmin/
time_series_covid19_confirmed_global-sparse.csv
```
5 Hive SQL/pure NoSQL interoperability and Querying

Instead of suffering from spreesheets limitations to exploit JHU COVID-19 data with regards to columns number for sorting, or integration of more tables, or versioning different hard coded sheets and workbooks for business users, and instead of coding complex reporting scripts for simple queries for data engineers and data scientists, one may express simple queries both using HBase and Hive command line interfaces or through APIs.

Listing 1.12: Visualise all confirmed cases and deaths directly from HBase

1. scan ‘confirmed_covid19_cases’
2. scan ‘deaths_covid19_cases’
Listing 1.13: HBase queries retrieving numbers concerning four countries on March 31st 2020

1. `get 'confirmed_covid19_cases', '~Morocco', 'a:d331'
2. `get 'deaths_covid19_cases', '~Morocco', 'a:d331'
3. `get 'confirmed_covid19_cases', '~Spain', 'a:d331'
4. `get 'deaths_covid19_cases', '~Spain', 'a:d331'
5. `get 'confirmed_covid19_cases', '~France', 'a:d331'
6. `get 'deaths_covid19_cases', '~France', 'a:d331'
7. `get 'confirmed_covid19_cases', '~Germany', 'a:d331'
8. `get 'deaths_covid19_cases', '~Germany', 'a:d331'

Listing 1.14: Hive query retrieving all confirmed cases data concerning Morocco

1. `SELECT *`
2. `FROM confirmed_covid19_cases`
3. `WHERE key.Country_Region='Morocco'`;

Listing 1.15: Hive Join query retrieving confirmed cases and deaths concerning Morocco on March 31st 2020

1. `SELECT d.key.Country_Region, c.03_31_2020, d.03_31_2020`
2. `FROM confirmed_covid19_cases c`
3. `JOIN deaths_covid19_cases d`
4. `ON c.key.Province_State = d.key.Province_State`
5. `AND c.key.Country_Region = d.key.Country_Region`
6. `WHERE c.key.Country_Region = 'Morocco'`;

Listing 1.16: Hive Join query retrieving confirmed cases and deaths concerning four countries on March 31st 2020

1. `SELECT d.key.Province_State, d.key.Country_Region, c.03_31_2020, d.03_31_2020`
2. `FROM confirmed_covid19_cases c`
3. `JOIN deaths_covid19_cases d`
4. `ON c.key.Province_State = d.key.Province_State`
5. `AND c.key.Country_Region = d.key.Country_Region`
6. `WHERE c.key.Country_Region in ('Morocco', 'France', 'Spain', 'Germany')`;
6 Conclusion

This paper presents detailed schemas design and data preparation technical HBase, Hive, shell and HDFS scripts for formatting and storing Johns Hopkins University COVID-19 daily data in HBase NoSQL data store, and enabling HiveQL COVID-19 data querying in a relational Hive SQL-like style. It aims to help scientists and data scientists shortening data preparation phase which is time consuming according to CRISP-DM life cycle specialists. This work is to be taken as a leveraging bootstrap for specific data preparation phase in COVID-19 analytics Big Data projects aiming for instance to integrate COVID-19 evolution time series with medical/biology best practices, COVID-19 mutations, scientific papers results, or to study correlations between COVID-19 curves with humidity data, people telco mobility during countries lockdown phases, or to analyse recurrent COVID-19 contamination causality; or to study similarities with other historical pandemics evolution data like SARS-CoV, MERS-COV, or to compare evolution with spreading information from social networks, etc. The more integration you do on the schema with other data sets (e.g. continents, median age, population, testing numbers, virus contamination rates, etc.), the more features you will have and the more this work will leverage your COVID-19 data experience. Hurry Up, and share your experience for the world scientists.

7 Appendix : How to download scripts of this paper ?

To download continuously data engineering models and scripts discussed in this paper, you can access, and clone the author gitlab repository at [11].

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