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Data Science Project

Assessment of Database Performance Degradation

Conceptual Design Report

22nd September 2019

ABSTRACT

Today's commercial data management systems (short: database) often operate in complex application environments, with the databases generally being the pivotal component. Thus, if the database performance degrades, then the system's overall performance is at stake. Tight monitoring of the database's performance is mandatory in such an environment. To facilitate database monitoring, every commercial database system is equipped with an impressive number of system statistics, allowing to look at every aspect of the database's operation.

For the data science project I will describe on the following pages, I use database statistics to assess a suspected performance degradation, which occurred after an upgrade of the database infrastructure on the hosting server. After the upgrade we noticed deteriorations of the response times of several application components. In order to held responsible the database manufacturer and the provider of the hosting server, we have to provide evidence that the deteriorations indeed originate on the database.

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OBJECTIVE

The database examined is the integration database of the Swiss Federal Railways (SBB) CUS platform. CUS is the acronym for Customer Service. It is a datahub for real-time data of swiss public transport.

The data is provided by the participating transport companies, a few tens, from Switzerland and the neighboring countries. It is enriched with data taken from internal and external information system. The compiled data is made available to our partners, and also to various traveler information systems; e.g. screen displays in stations and in vehicles; announcements by loudspeakers; internet websites and applications, etc.

The integration and the production database each run on their own, dedicated platform; an Oracle Database Appliance (ODA). And each database consists of two instances which run in cluster mode (Oracle Real Application Cluster RAC). The integration environment’s main purpose is to enable tests of a new release before it is deployed onto the production platform. A new release must be tested for functional and technical correctness, and for its performance under high load.

After an upgrade in spring 2019 of the grid infrastructure of the integration database’s hosting server, this database suffered from serious performance problems. The performance issues mostly manifested themselves as significantly increased response times of several application components on the one hand. And by massively increased waits related to the cluster operation of the databases, on the other hand. With this degradation the release tests were at risk.

In beginning of August 2019, a number of patches were applied to the hosting server, as a corrective action. The analysis' goal is to test if the patching resolved the performance degradation. Or if it prevails, in which case the release tests would be compromised. As I cannot use gathered system statistics from pre-upgrade days, I will compare selected performance statistics of the integration database to the production database.

METHODS

Environment

The analysis was executed in an Anaconda environment:

- Anaconda Navigator 1.9.7
- JupytherLab 1.0.2
- Conda Packages
    - r 3.6.0 (R 3.6.1)
    - r-irkernel 0.8.15
    - r-data.table 1.12.2
    - r-broom 0.5.2
    - stats 3.6.1 (r-essentials 3.6.0)
    - r-ggplot2 3.1.1
    - r-reshape2 1.4.3

The computations have been performed on my Lenovo P50 notebook

- Intel Core i7-6820HQ (x64-based)
- 32 GB RAM
- Windows 10 Enterprise, Version 1803

As I have unpaired samples and cannot presume any distribution of the data, I have to rely on non-parametric tests. I have chosen the Wilcoxon Rank Sum Test (one-tailed and two-sided).

Procedure

Compare Waiting Classes: Every database event causing a session to wait, is assigned to a waiting class. A waiting class aggregates all waiting times of events assigned to it. They provide a high level view to database activities, showing were sessions spend and loose time. Comparison is done between waiting classes within one database on the one hand, and between the databases on the other hand.
The main waiting classes are application, concurrency, cluster and user I/O.

Compare Database Load: Some system statistics are indicators for database load, e.g. the number of data blocks changed, or the number of calls that executed a SQL statement. The statistics are compared between the databases.

Compare Cluster Statistics: Cluster statistics are related to operations due to the RAC setup of the databases. Both instances of each database have to share the data. When one database instance requests a data block, and this data block is currently held in the local cache of the other database instance, a complex protocol is followed. The main concept

behind this protocol is the so-called global cache.
I compare statistics between the databases measuring the global cache load, and statistics measuring the waiting times spent during global cache-related activities.

DATA

Oracle measures hundreds of statistics in real time, and makes them available by so-called *dynamic performance views*. E.g. statistics related to the database system can be found in the view SYS.SYSSTAT. The values in these performance views are running sums. Upon restart of a database instance, all its statistics are reset to zero.

On every hour a snapshot of all dynamic performance views is made and stored in the *static performance views*. For SYS.SYSSAT the corresponding static view is SYS.DBA_HIST_SYSSTAT; see figure 1 DBA_HIST_SYSSTAT. Of this view I need the following columns:

snap_id: identifies a snapshot interval. Snapshots of all database instances, taken at the same hour, have identical snap_id

instance_number: id of the database instance for which a statistic was measured

stat_name: name of the statistics

value: value of the running sum of the statistic at the end of the snapshot interval.

To get the snapshot details, e.g. begin and end of the snapshot intervals, it must be joined with the DBA_HIST_SNAPSHOT view. This view provides all the snapshot details. I will just need the columns

begin_interval_time: timestamp of the beginning of the snapshot interval

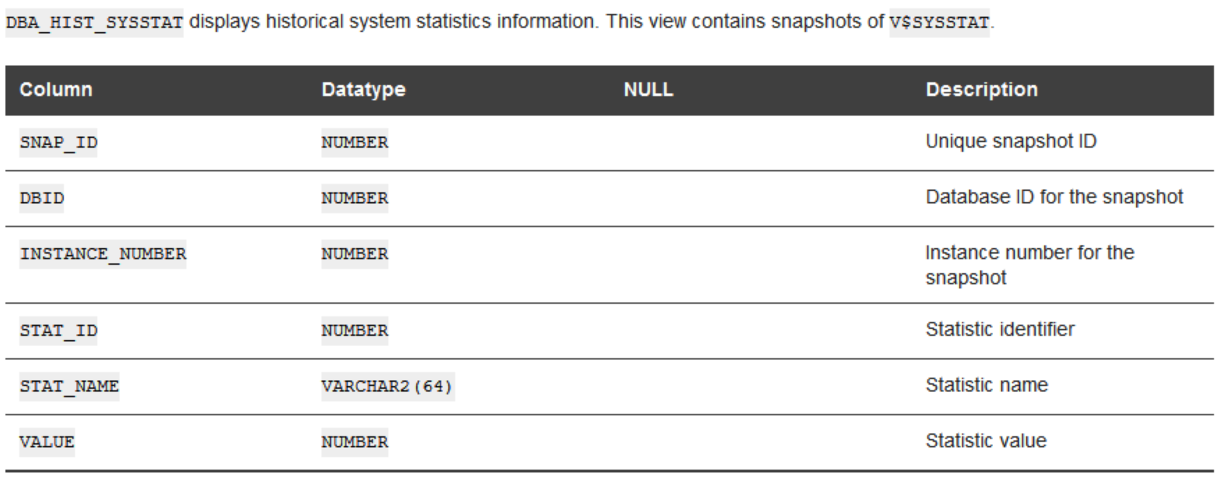
end_interval_time: timestamp of the end of the snapshot interval

The statistics data was selected using the SQL statement below:

```
alter session set nls_timestamp_format = 'YYYY-MM-DD HH24:MI:SS';

select begin_interval_time, end_interval_time, snap_id,
instance_number, stat_name, value
from dba_hist_sysstat
natural join dba_hist_snapshot
where begin_interval_time between
  timestamp '2019-08-22 00:00:00'
  and timestamp '2019-08-29 08:00:00'
order by begin_interval_time, instance_number, stat_name;
```

I have chosen the time range such that both the integration and production database have application version 5.11.1 1.180.1 (on August 29, 2019 at 09:00 CEST, application version 5.12.0 1.188.1 was installed on the integration environment).



`DBA_HIST_SYSSTAT` displays historical system statistics information. This view contains snapshots of `V$SYSSTAT`.

Column	Datatype	NULL	Description
`SNAP_ID`	`NUMBER`		Unique snapshot ID
`DBID`	`NUMBER`		Database ID for the snapshot
`INSTANCE_NUMBER`	`NUMBER`		Instance number for the snapshot
`STAT_ID`	`NUMBER`		Statistic identifier
`STAT_NAME`	`VARCHAR2(64)`		Statistic name
`VALUE`	`NUMBER`		Statistic value

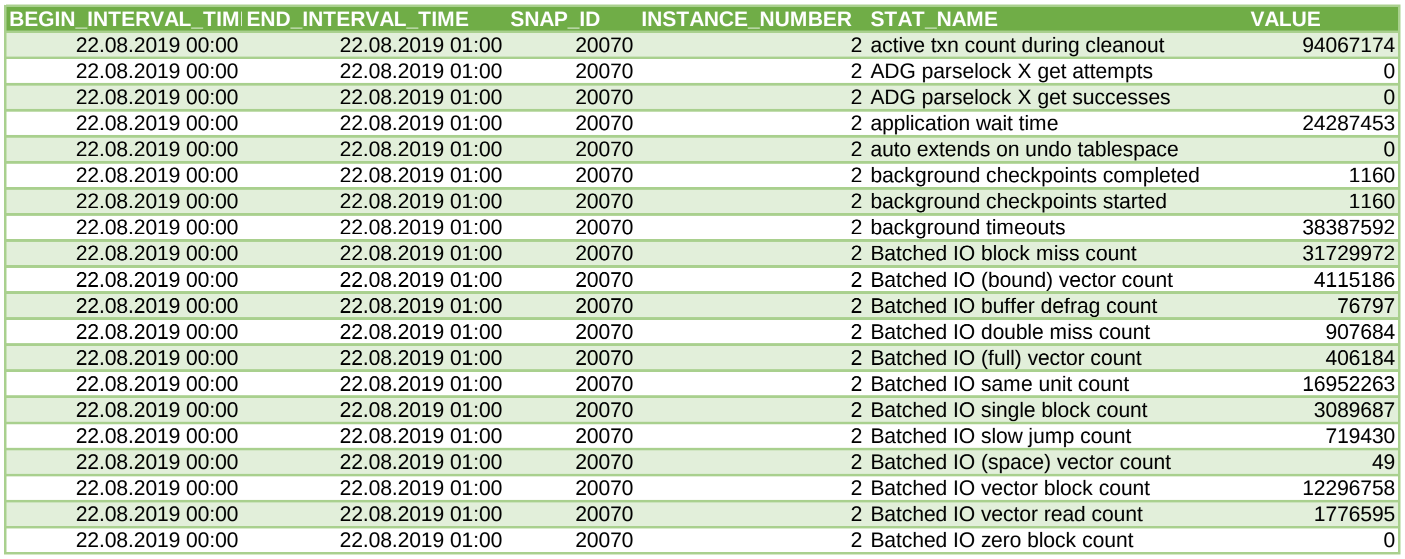
1 DBA_HIST_SYSSTAT

The data was exported to semicolon-separated text files:

- dba_hist_sysstat.inte.dsv for the integration database, and
- dba_hist_sysstat.prod.dsv for the production database.

The files are stored in the subdirectory Data-Science-Project\project.1\statistiken.2019-08-22T0000-bis-2019-08-28T1000\data of the GitHub repository mbassi1364/CAS-Applied-Data-Science. For the URL see section REFERENCES at the end of the document.

Extract from the integration statistics:



BEGIN_INTERVAL_TIM	END_INTERVAL_TIME	SNAP_ID	INSTANCE_NUMBER	STAT_NAME	VALUE
22.08.2019 00:00	22.08.2019 01:00	20070	2	active txn count during cleanout	94067174
22.08.2019 00:00	22.08.2019 01:00	20070	2	ADG parselock X get attempts	0
22.08.2019 00:00	22.08.2019 01:00	20070	2	ADG parselock X get successes	0
22.08.2019 00:00	22.08.2019 01:00	20070	2	application wait time	24287453
22.08.2019 00:00	22.08.2019 01:00	20070	2	auto extends on undo tablespace	0
22.08.2019 00:00	22.08.2019 01:00	20070	2	background checkpoints completed	1160
22.08.2019 00:00	22.08.2019 01:00	20070	2	background checkpoints started	1160
22.08.2019 00:00	22.08.2019 01:00	20070	2	background timeouts	38387592
22.08.2019 00:00	22.08.2019 01:00	20070	2	Batched IO block miss count	31729972
22.08.2019 00:00	22.08.2019 01:00	20070	2	Batched IO (bound) vector count	4115186
22.08.2019 00:00	22.08.2019 01:00	20070	2	Batched IO buffer defrag count	76797
22.08.2019 00:00	22.08.2019 01:00	20070	2	Batched IO double miss count	907684
22.08.2019 00:00	22.08.2019 01:00	20070	2	Batched IO (full) vector count	406184
22.08.2019 00:00	22.08.2019 01:00	20070	2	Batched IO same unit count	16952263
22.08.2019 00:00	22.08.2019 01:00	20070	2	Batched IO single block count	3089687
22.08.2019 00:00	22.08.2019 01:00	20070	2	Batched IO slow jump count	719430
22.08.2019 00:00	22.08.2019 01:00	20070	2	Batched IO (space) vector count	49
22.08.2019 00:00	22.08.2019 01:00	20070	2	Batched IO vector block count	12296758
22.08.2019 00:00	22.08.2019 01:00	20070	2	Batched IO vector read count	1776595
22.08.2019 00:00	22.08.2019 01:00	20070	2	Batched IO zero block count	0

As there are hundreds of statistics, I limited the analysis to a small subset, chosen such that I can address some conclusive aspects of database performance.

Waiting Classes

- application wait time
- cluster wait time
- concurrency wait time
- user I/O wait time

Database Load

- db block changes
- enqueue requests
- execute count
- global enqueue gets async
- global enqueue gets sync
- parse count (total)
- user calls

Global Cache Activity

- gc cr blocks received
- gc current blocks received
- gc local grants
- gc read waits
- gc remote grants
- gcs messages sent

Global Cache Wait Events

- gc cr block flush time
- gc cr block receive time
- gc current block flush time
- gc current block receive time
- gc current block send time
- gc read wait time
- global enqueue get time

METADATA

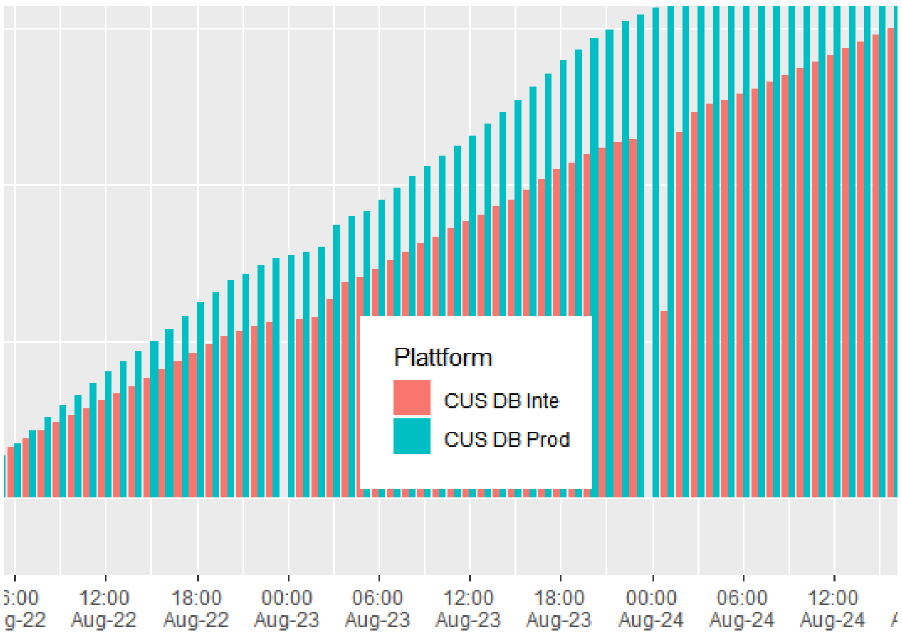
1. Both database platforms are Oracle Data Appliances X5-2-HA, with Oracle RDBMS Enterprise Edition 11.2.0.4.0 for Linux 64 bit, and Oracle Real Application Cluster.
2. On both databases the same application version 5.11.1 1.180.1 is installed.
3. None of the integration and production database instances was restarted in the period to be analysed. This precondition is not mandatory, but makes analysis more straightforward.
4. The statistics are described in the Oracle document Oracle Database Reference, 11g Release 2 (11.2), August 2015; section Statistics Descriptions. See References.
5. The Oracle dynamic performance views DBA_HIST_SYSSTAT (historicized system statistics) and DBA_HIST_SNAPSHOT (historicized snapshot intervals) are described in the same document, section Static Data Dictionary Views.

The metadata is described in the markdown document metadata.readme.md, stored in the subfolder Data-Science-Project\project.1\statistiken.2019-08-22T0000-bis-2019-08-28T1000\about.data of the Github repository CAS-Applied-Data-Science. See section REFERENCES at the end of the document.

DATA QUALITY

Time Fuzziness

The real-time statistics are collected in the database's dynamic memory, i.e. for each database instance separately. The dynamic performance views, therefore, are not views defined on a database table, but only a convenient way to look at the data. This approach is fast; however, there is a major drawback: There is nothing like a *System Change Number (SCN)* enabling a consistent view of the data. Thus, if I want to compare statistics taken from two or more dynamic performance views, or the same statistic for two ore more database instances, there is no guarantee all data represent the database or database instance's state at the same moment. Monitoring of real-time data thus must take into account a certain amount time fuzziness. In times of high load, however, the time fuzziness may increase to a significant degree, which unfortunately cannot be assessed in a straightforward way.



2 Snapshot Creation

Snapshot Creation

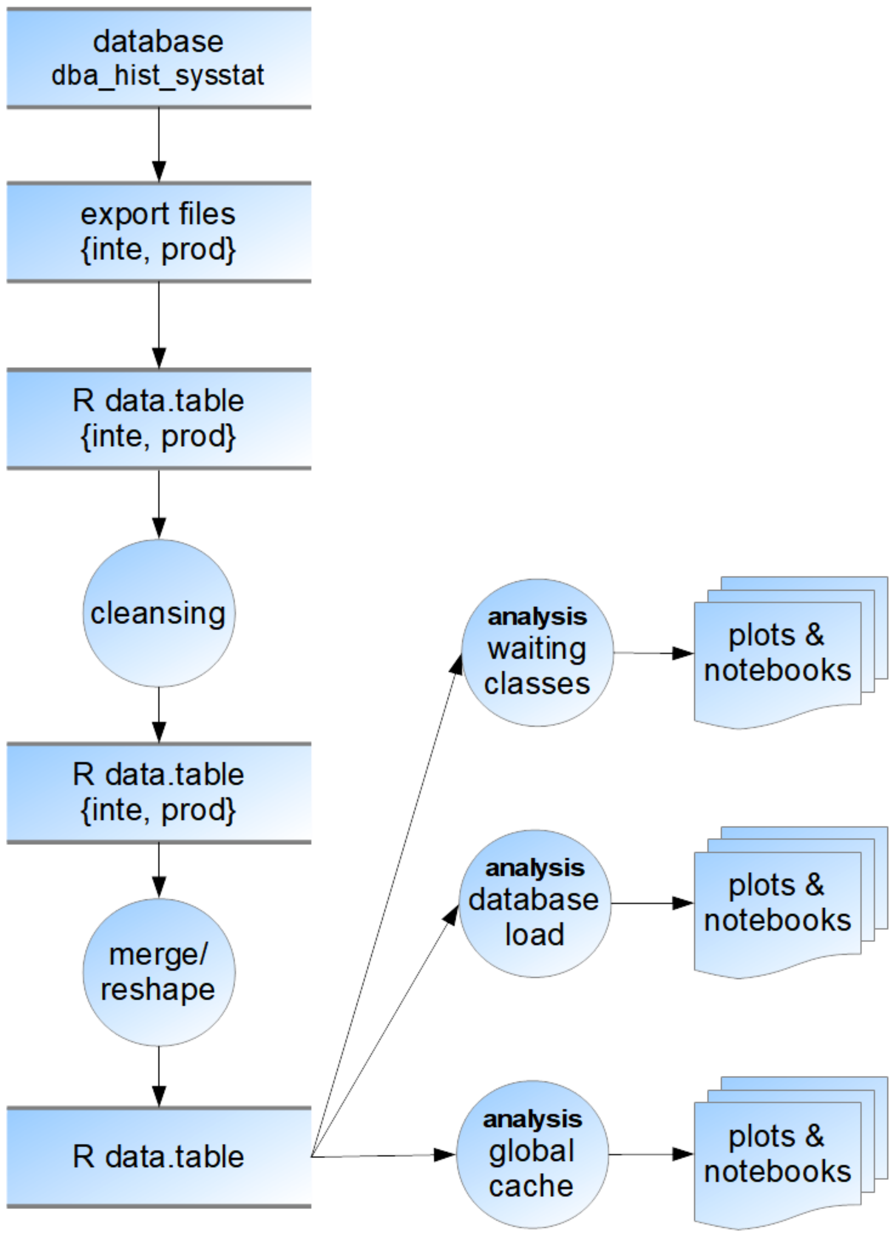
The problem of time fuzziness is mitigated when You work with hourly snapshots. But there is a new problem: Saving the snapshots is done by a database background process. This is a low-priority process. Therefore, in times of high database load, creating snapshots may be delayed for several minutes. In critical database situations lasting an hour or more, statistics data will be lost; see figure 2 Snapshot Creation.

As a consequence, snapshot intervals must be examined closely before starting an analysis. There are several approaches:

1. Check begin, end and duration of snapshot intervals (view DBA_HIST_SNAPSHOT)
2. Plot a time series of selected statistics.
3. Check flush_elapsed and error_count (view DBA_HIST_SNAPSHOT).

Snapshots are created for each database instance separately. As a consequence snapshot interval checking must be performed separately for each database instance.

DATA FLOW



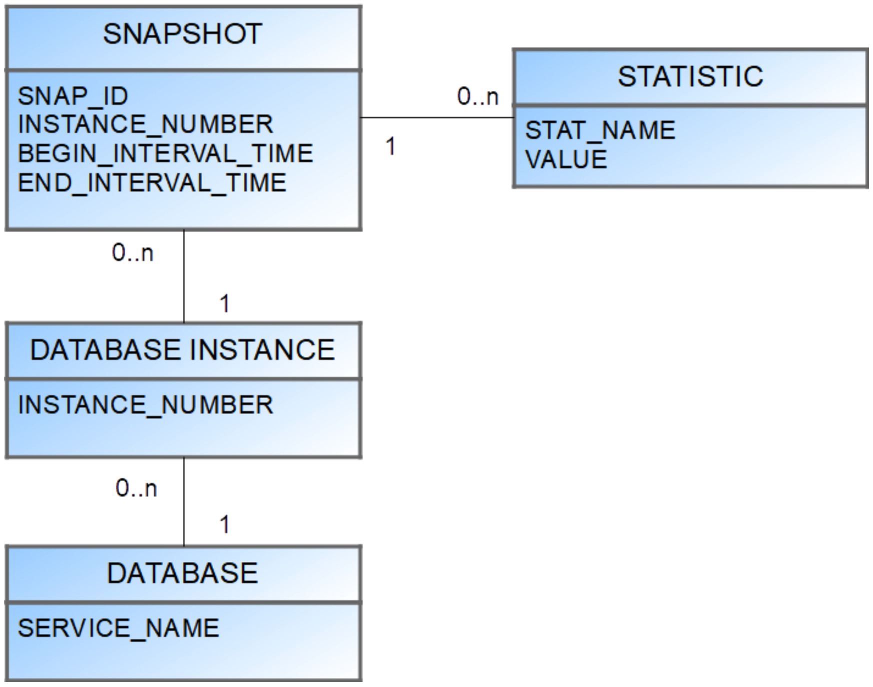
Procedure Followed for the Data Analysis

1. export statistics from databases into CSV files
   separate files for integration and production data
2. import CSV files into R data.tables
   separate data.tables for integration and production data

3. data cleansing into new R data.tables
   separate cleansing for integration and production data
4. merge R data.tables for integration and production data into one R data.table, and reshape the data into long format.
5. perform separate data analysis for
   a. waiting time classes
   b. database load statistics
   c. global cache statistics

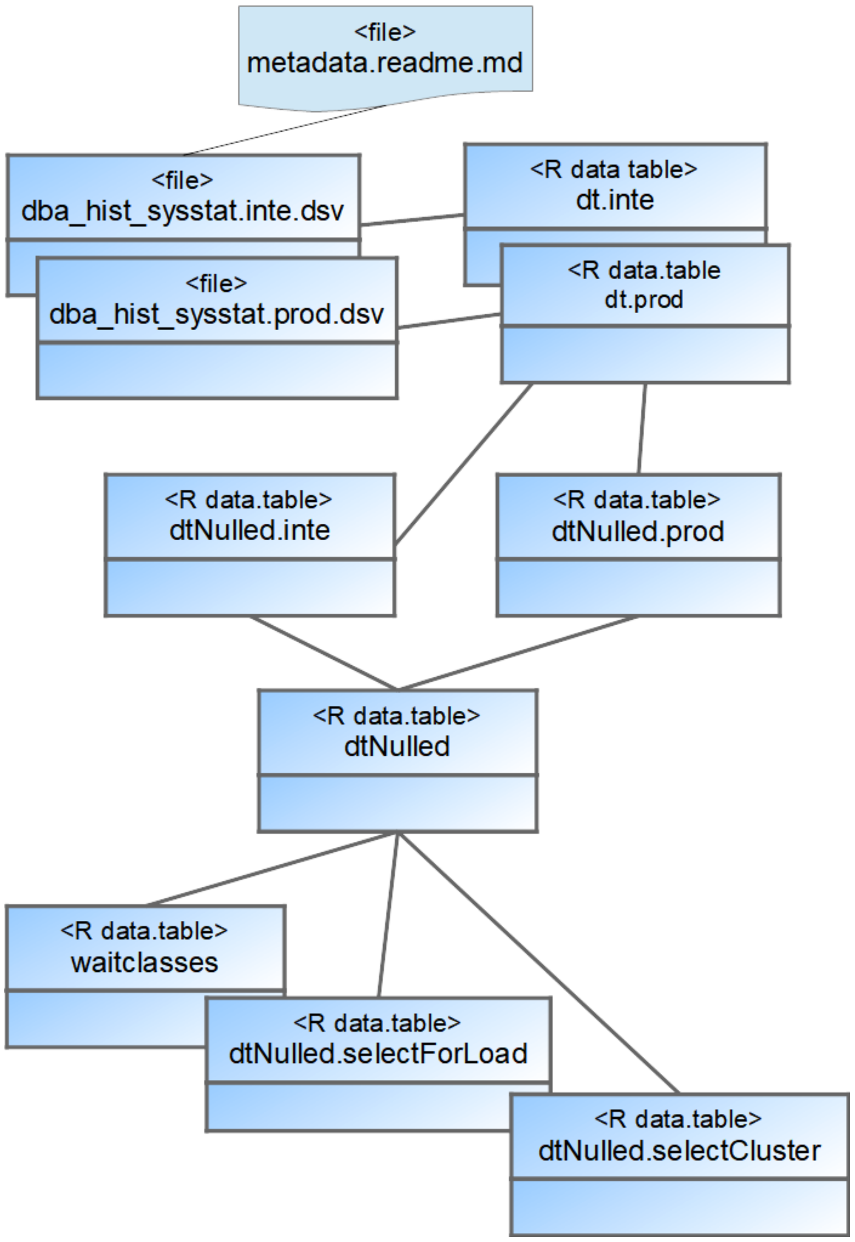
DATA MODELS

Conceptual Data Model



The conceptual mode is fairly simple. The central concept is the statistic, having a name and a value. A statistic instantiation is a concrete measurement. It must be assigned a snapshot instantiation, and so on …

Logical Data Model



The data is read from the data files (one for the integration database, and one for the production database) into R data.table objects, one for each database. Data cleansing results in new data.table objects, still one per database. The are then merged into one data.table object, and reshaped into long format.

For the various analyses, a dedicated data.table is created by subsetting the merged one.

The metadata is stored in an unstructured text file.

Physical Data Model

Export to File

- Export from integration database: 232898 Records
- Export file integration database: dba_hist_sysstat.inte.dsv (18.3 MB)
- Export from production database: 239009
- Export file production database: dba_hist_sysstat.prod.dsv (18.8 MB)

Data exported using Oracle SQL Developer 18.1.0 for Microsoft Windows 10 (x64)

Export Files

- Format: Text file
- Field separator: ";" (semicolon)
- First line: field names
- 2nd line and below: records
- Field 1: BEGIN_INTERVAL_TIME; timestamp YYYY-MM-DD HH24:MI:SS
- Field 2: END_INTERVAL_TIME; timestamp YYYY-MM-DD HH24:MI:SS
- Field 3: SNAP_ID; snapshot ID, non-negative integer
- Field 4: INSTANCE_NUMBER; ID of the database instance, non-negative integer
- Field 5: STAT_NAME; statistics' name
- Field 6: VALUE; statistics' value, integer

R Data Tables

- Import from export file production
```
239008 obs. of  6 variables:
BEGIN_INTERVAL_TIME: chr  "2019-08-22 00:00:14" "2019-08-22 00:00:14" ...
END_INTERVAL_TIME  : chr  "2019-08-22 01:00:16" "2019-08-22 01:00:16" ...
SNAP_ID            : int  35567 35567 35567 35567 35567 35567 35567 35...
INSTANCE_NUMBER    : int  1 1 1 1 1 1 1 1 1 1 ...
STAT_NAME          : chr  "active txn count during cleanout" "ADG pars...
VALUE              : num  5.11e+08 0.00 0.00 8.39e+07 1.19e+02 ...
```
- Import from export file integration
```
232897 obs. of  6 variables:
BEGIN_INTERVAL_TIME: chr  "2019-08-22 00:00:05" "2019-08-22 00:00:05"  ...
END_INTERVAL_TIME  : chr  "2019-08-22 01:00:22" "2019-08-22 01:00:22"  ...
SNAP_ID            : int  20070 20070 20070 20070 20070 20070 20070 20 ...
INSTANCE_NUMBER    : int  2 2 2 2 2 2 2 2 2 2 ...
STAT_NAME          : chr  "active txn count during cleanout" "ADG pars ...
VALUE              : num  94067174 0 0 24287453 0 ...
```
- Merged data table (long format) for analysis
```
114751 obs. of  4 variables:
snapHour  : POSIXct, format: "2019-08-22 00:00:00" "2019-08-22 00:00:00"  ...
```

```
STAT_NAME : chr  "ADG parselock X get attempts" "ADG parselock X get succ ...
sumValue_I: num  0 0 0 0 0 0 0 0 0 0 ...
sumValue_P: num  0 0 0 0 0 0 0 0 0 0 ...
```

Analysis Tools

- RGui 3.5.1
- Anaconda/Jupyter with Irkernel and R 3.6.0

Additional Comments

No considerations concerning CPU and memory consumption were made.

RISKS

No risks are known apart from those addressed by the data cleansing process. Outliers will be handled with during the data analysis process.

PRELIMINARY STUDIES

None

CONCLUSIONS

The analysis achieved its goal. It provided evidence that the integration database's performance is deteriorated in all cluster-related operations, when compared to the production database.

REFERENCES

1 Oracle® Database Reference 11g Release 2 (11.2), E40402-18, August 2015
https://docs.oracle.com/cd/E11882_01/server.112/e40402/toc.htm

2 GitHub Repository mbassi1364/CAS-Applied-Data-Science
https://github.com/mbassi1364/CAS-Applied-Data-Science

Appendix

Swiss National Science Foundation data management plan