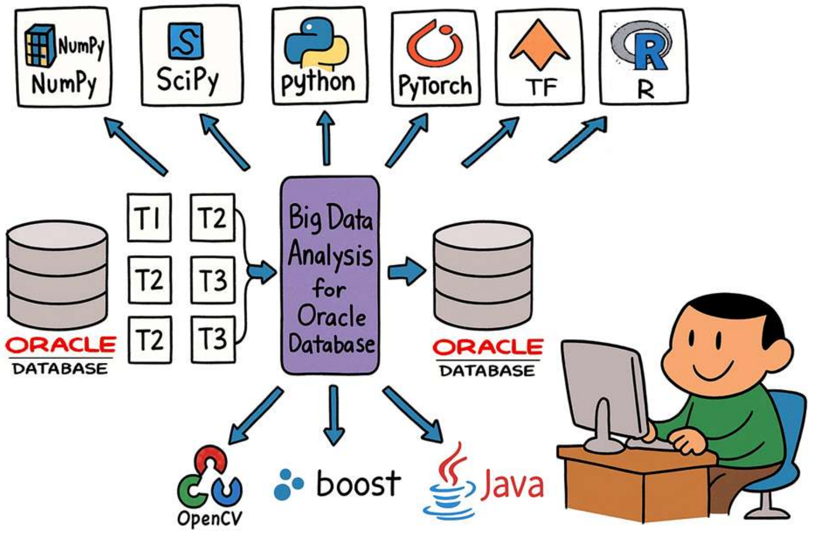
Big Data Analysis Enabler(BDAE^{TM})

Introduction Summary

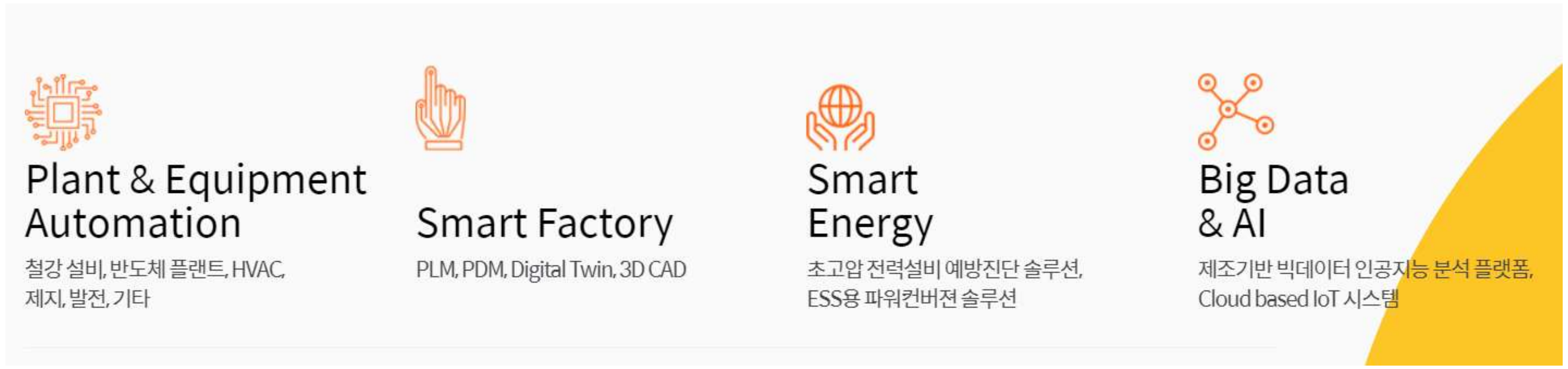


Raymond,

2025/05/16

1 General

BDAE(TM) can be used in most fields that use Oracle Database(TM) , Non-stop installation/patching, algorithms or logic can be applied immediately to existing solutions without any downtime.



Plant & Equipment Automation
철강 설비, 반도체 플랜트, HVAC, 제지, 발전, 기타

Smart Factory
PLM, PDM, Digital Twin, 3D CAD

Smart Energy
초고압 전력설비 예방진단 솔루션, ESS용 파워컨버전 솔루션

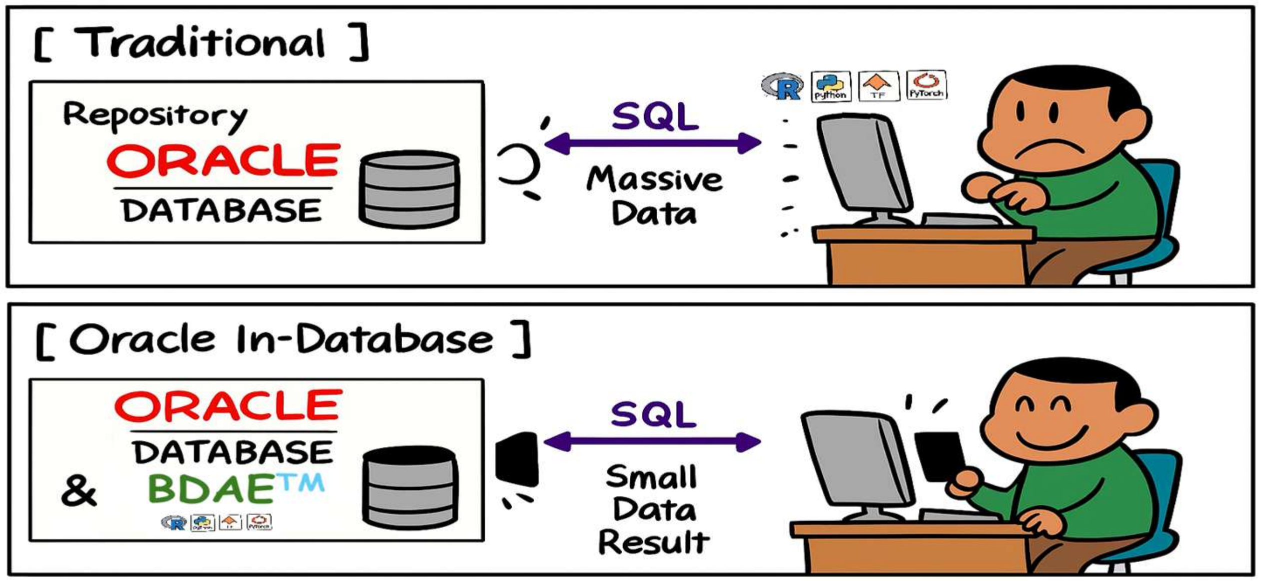
Big Data & AI
제조기반 빅데이터 인공지능 분석 플랫폼, Cloud based IoT 시스템

BDAE(TM) is executed as a SQL statement and the results are retrieved like the results of a general SQL statement, so a separate application server is unnecessary, and all logic (including the backend) can be implemented in Python and R.

Available for use in all MES, SPC, FDC, YMS and Smart Factory configuration systems in manufacturing, finance, energy, etc.

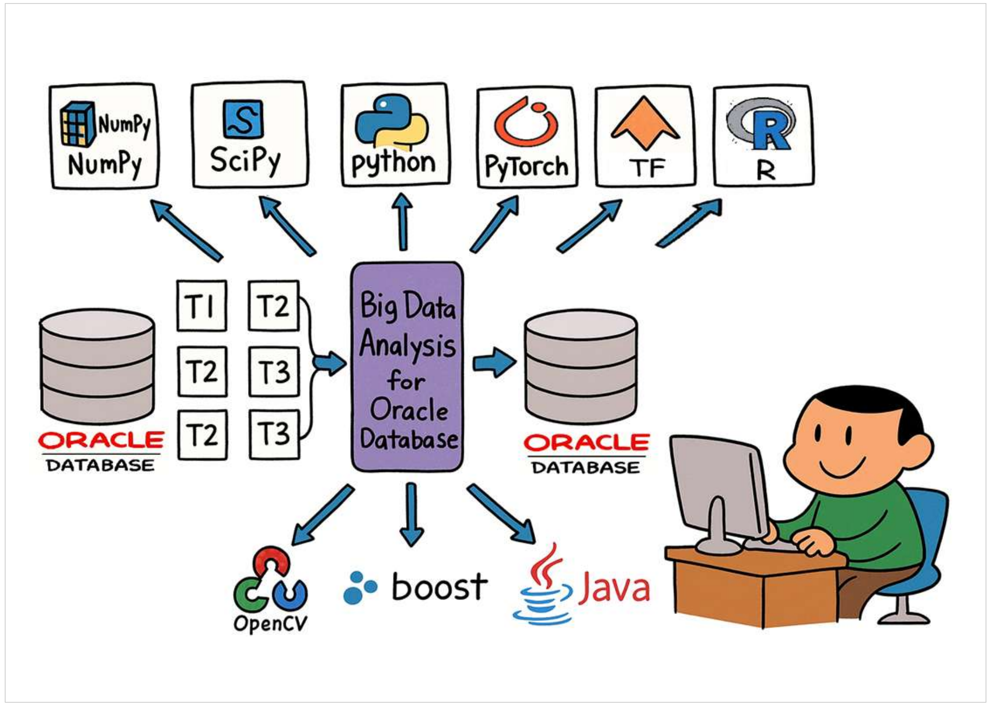
2 BDAE(TM) for What

BDAE(TM) is built on Oracle In-Database technology and has platform features that enable Oracle Database(TM) to be used not only as a simple storage for general AI tasks, but also as a non-stop operating environment without the overhead of data movement during learning and inference.



※ BDAE(TM) advantages include development productivity (Python, R), parallel processing, and bringing performance into the real-time domain.

3 BDAE(TM) SW Configurations & Architecture

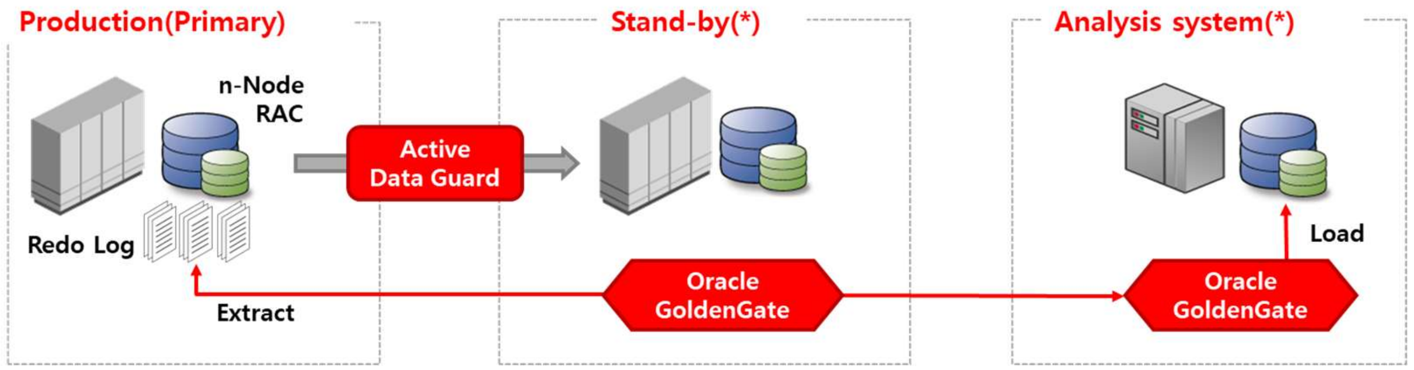


Left Image Shows the operating location of BDAE(TM) in the form of **Oracle In-Database.**

Parallel distributed processing is a feature of **Oracle In-Database**, and analysts do not need to consider it in their modules, which increases the reusability of logic.

In addition, the fact that it can be integrated with various analysis engines can be seen as an advantage of BDAE(TM) .

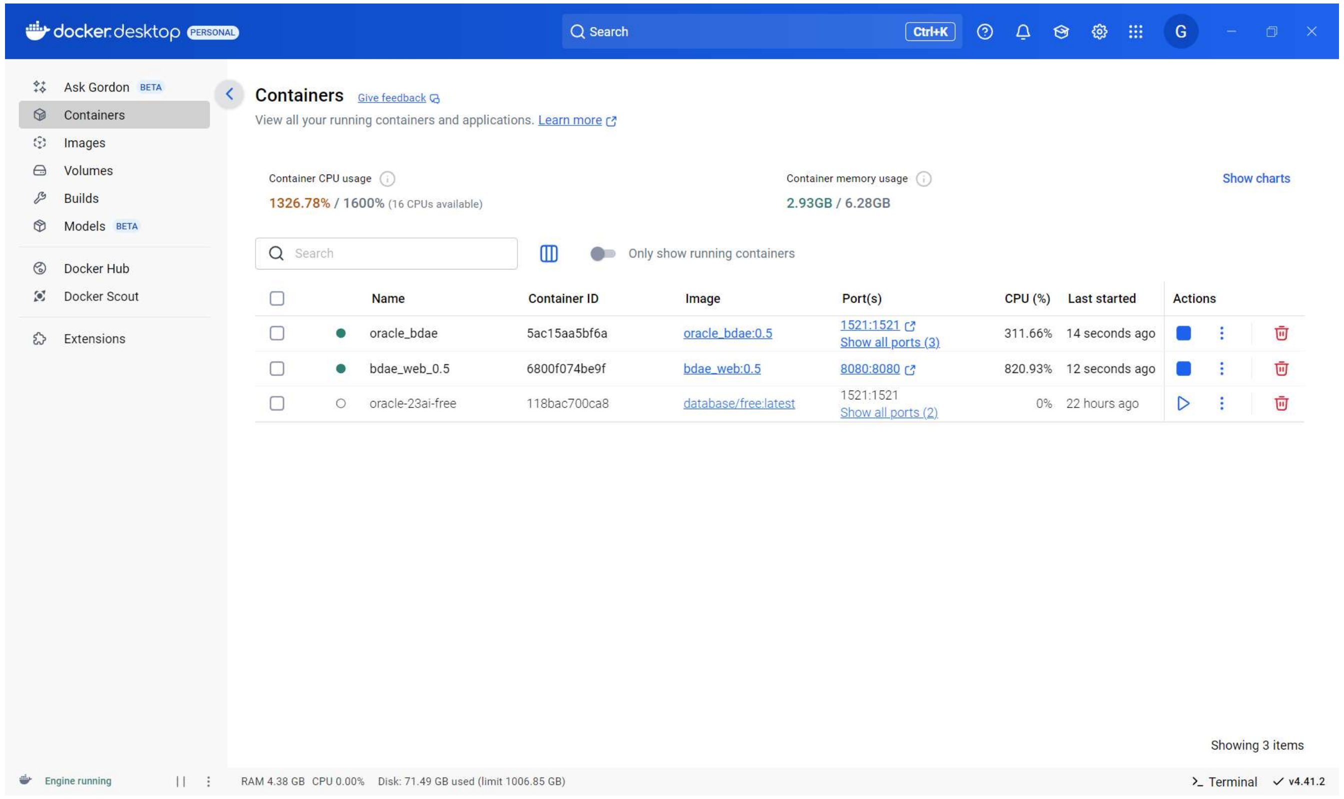
BDAE(TM) can operate on any architectural configuration of Oracle Database(TM) .



4 BDAE(TM) Docker-based Demo environment

BDAE(TM) consists of two parts: oracle_bdae and bdae_web.

bdae_web is made with Spring Boot + JSP, and oracle_bdae is installed with BDAE(TM) on the image distributed by Oracle, and then distributed to customers as an export file. (It can be delivered via USB storage device)



Containers Give feedback

View all your running containers and applications. Learn more

Container CPU usage
1326.78% / 1600% (16 CPUs available)

Container memory usage
2.93GB / 6.28GB

Show charts

Only show running containers

	Name	Container ID	Image	Port(s)	CPU (%)	Last started	Actions
●	oracle_bdae	5ac15aa5bf6a	oracle_bdae:0.5	1521:1521 Show all ports (3)	311.66%	14 seconds ago	
●	bdae_web_0.5	6800f074be9f	bdae_web:0.5	8080:8080	820.93%	12 seconds ago	
○	oracle-23ai-free	118bac700ca8	database/free:latest	1521:1521 Show all ports (2)	0%	22 hours ago	

Showing 3 items

Engine running RAM 4.38 GB CPU 0.00% Disk: 71.49 GB used (limit 1006.85 GB) Terminal v4.41.2

※ If necessary, please request to gracesjy@naver.com. I will provide you with the Google Cloud shared file URL.

5 BDAE(TM) Build, Packages

BDAE(TM) is built on Oracle Linux(TM) (OL, formerly OEL: Oracle Enterprise Linux(TM)).
BDAE(TM) can run on any Linux or UNIX environment supported by Oracle Database(TM).

As of now, BDAE(TM) has been built on versions 6, 7, 8, and 9 of the RedHat series (including Oracle Linux). Once built, it is provided in the form of a library file along with PL/SQL, etc., and can be installed.

Oracle In-Database Programs(including BDAE(TM)) must be written in C with PL/SQL, Type, Function, etc., so it needs to be built. Engines such as R and Python are all written in C, and can be viewed as being similar to the device driver of the operating system. (Oracle Database is guaranteed by OL/OEL and is related to the GLIBC version.)

※Customers can install Python and R packages themselves, and on Nexus-based systems, the package location can be changed to Private Network.

※Setting up parallel processing for a specific schema is as simple as creating a BDAE(TM) Oracle Function, and you can refer to the existing built-in examples. (This will be explained in the future when introduced.)

6 BDAE(TM) Docker Installation

In a Windows environment, install Docker Desktop first and then proceed as follows.
For Docker Desktop installation, refer to the relevant Internet document.

Import two Docker Images: Oracle Database(TM) + BDAE(TM) , BDAE(TM) Web and run them respectively.

```
docker load -i oracle_bdae.tar   # Oracle Database(TM) + BDAE(TM)
docker load -i bdae_web.tar      # BDAE(TM) Web

# check docker images above, and run belows
docker run --name oracle_bdae -p 1521:1521 -p 5500:5500 -p 8888:8888 oracle_bdae:0.5
docker run --name bdae_web -p 8080:8080 bdae_web:0.5
```

Oracle Database Access :

> Oracle Service Name : FREE, TNS Port : 1521, IP : 127.0.0.1

Web Server Access :

> http://127.0.0.1:8080

7 Before using BDAE(TM) ..

Oracle R Enterprise(TM) , a commercial product from Oracle Corporation, supports only the R language. Of course, great analysts have built their main algorithms into R packages, but the reality is that a lot of code needs to be written.
And the written code must be stored as a DB table and does not provide a GUI.

On the other hand, BDAE(TM) supports for Python, R, and JAVA for ETL (mainly Hadoop, etc.), has a simple web screen, and inputs the customer's algorithm into the DB through this web editor.

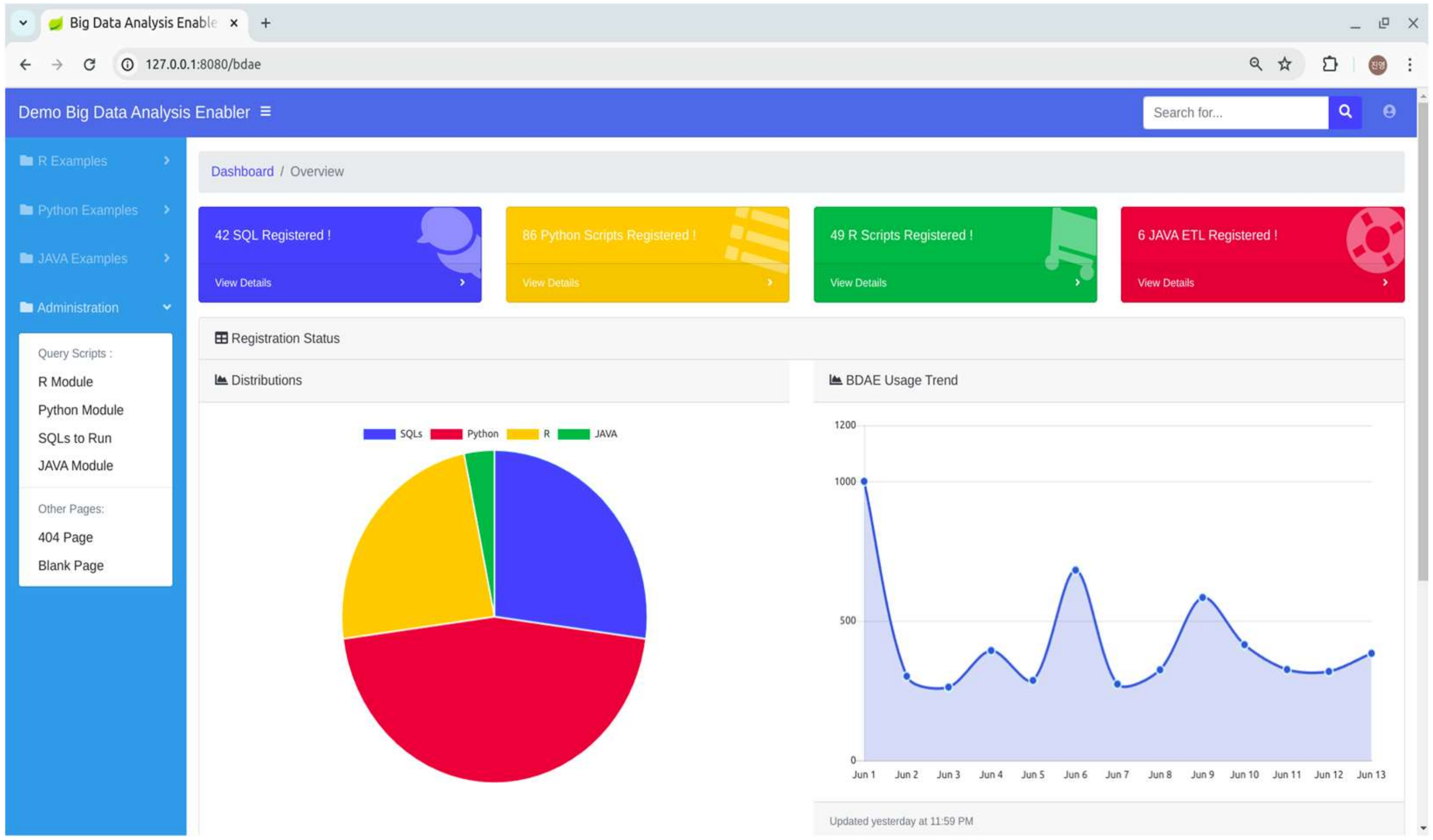
Normal development is often done in R Studio for R or Jupyter notebook for Python, and what is developed here can be copied and pasted into BDAE(TM) Web.

※ BDAE(TM) Web is a bundle, and it is intended for reference when building a basic CRUD function and a future customer-specific construction. (When used with Apache NIFI(TM), it is effective for real-time, batch work, scheduling, etc.)

8 BDAE(TM) Web

You can register, search, and delete R Modules and Python Modules mainly through the Administration menu on the left, and you can register data and SQL for calls and check the results by executing them immediately.

(※ The basic purpose of BDAE(TM) Web is to register and execute customers' algorithms in Python and R modules.)



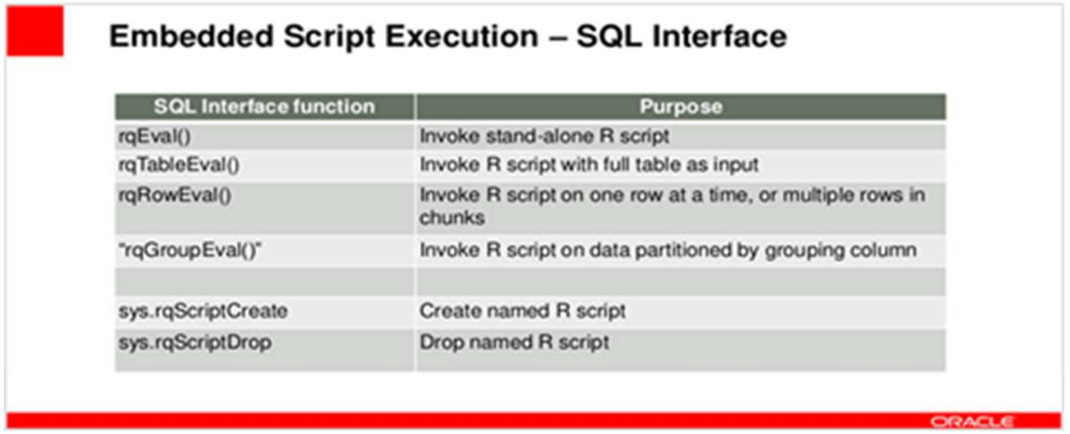
Oracle R Enterprise^{TM} SQL

Below is the Embedded Script Execution form provided by Oracle R Enterprise^{TM} .
The bottom two (sys.rqScriptCreate, rqScriptDrop) are for module input and deletion, which are a bit inconvenient.

In the case of BDAE$^{(TM)}$, creation, modification, and deletion are done in the Web Editor, so it is convenient.

※ Oracle R Enterprise^{TM} does not have version control capabilities for R code.
On the other hand, BDAE$^{(TM)}$ has a schema structure that allows version management and is customizable.

※ Looking at the contents of rqScriptCreate, it is INSERT INTO …, but indentation is very important in Python, and since both Python and R use " ", ' ', etc., it takes more time to write SQL INSERT distinctions. In particular, in the case of Python, since it mixes """, "", ' ', it is almost impossible with the INSERT syntax.



Embedded Script Execution – SQL Interface

SQL Interface function	Purpose
rqEval()	Invoke stand-alone R script
rqTableEval()	Invoke R script with full table as input
rqRowEval()	Invoke R script on one row at a time, or multiple rows in chunks
"rqGroupEval()"	Invoke R script on data partitioned by grouping column
sys.rqScriptCreate	Create named R script
sys.rqScriptDrop	Drop named R script

10 BDAE(TM) SQL

BDAE(TM) supports both R and Python, providing a total of 8 functions, twice that of Oracle R Enterprise™ . The arguments are the same and both Concept and Oracle In-Database follow the same architecture.

SQL Interface function	Description (Oracle R Enterprise™ 와 비교)
asEval()	Same rqEval()
asTableEval()	Same rqTableEval()
asRowEval()	Same rqRowEval()
asGroupEval()	Same rqGroupEval()
apEval()	Invoke stand-alone Python module
apTableEval()	Invoke Python module with full table as input
apRowEval()	Invoke Python module on one row at a time, or multiple rows in chunks
apGroupEval()	Invoke Python module on data partitioned by gr ouping column

11 Register and Run, Using BDAE(TM) Web

BDAE(TM) can be registered and executed in 3 steps below.

1. Registering R or Python modules (reusable)
2. Registering BDAE(TM) SQL statements for integration with DB data and registered R or Python modules.
3. Execute the registered SQL statement above and view the results.

That's all. It patches instantly in real time and doesn't affect existing versions that are running.

Since the data to be analyzed and output by both Oracle R Enterprise(TM) and BDAE(TM) exists within the **Oracle Database(TM)**, everything must be described in SQL statements.

That is, both input and output are in a table-like data format that Oracle Database(TM) can understand, but the temporary part inside can be composed of various formats and codes.

※ Normally, after performing large-scale analysis or Hadoop or file-based analysis, the results are put into RDBMS, but BDAE(TM) can automatically perform these tasks.

※ Because Oracle Optimizer uses statistical information and Data Dictionary for input and output when executing SQL and then determines a plan, you must explicitly inform it about input and output. This is why input and output are specified in Oracle R Enterprise(TM) or BDAE(TM) SQL format.

12 R Coding Style (#1)

There are two R coding styles for BDAE(TM) , the first of which is a functional form as follows:
BDAE(TM) automatically finds the function argument names data and args and calls them by inserting the data.
Therefore, the analyst can arbitrarily specify the data and args variable names.

```
function(data, args) {
    # Registering various dependent libraries
    library(xts)
    library(quantmod)
    library(RCurl)
    library(logr)
    library(xts)
    library(quantmod)
    library(RCurl)


    …
    … < Any data type, model, or algorithm code supported by R can be accommodated. > …
    …

     df <- data.frame(col1=c(...), col2=c(...), ... ,stringsAsFactors=FALSE)
     return (df)
}
```

12 R Coding Style (#2) - BDAE(TM) Unique Features

Another R coding style is descriptive, like this:

At this time, data is called by putting it in explicit variable names called **data** and **args** in BDAE(TM), so these two variable names are Read-Only and should not be used for other purposes.

Since there is no return at the end, you must write df, and this variable name (df) can be anything you want.

```
library(xts)
library(quantmod)
library(RCurl)
library(logr)
library(xts)
library(quantmod)
library(RCurl)

x <- data # The variable that contains the raw data to be processed is data.
y <- args # Data that contains additional data is args
...
... < Any data type, model, or algorithm code supported by R can be accommodated. > ...
...
df <- data.frame(col1=c(...), col2=c(...), ... ,stringsAsFactors=FALSE)
df
```

12 R Coding Style (#3)

Check for syntax errors and runtime errors:

Analysts do not need to handle exceptions in the BDAE(TM) analysis module (the analyst's R, Python code).

If there is a problem in BDAE(TM), it is returned as an SQL error code (ORA-20001 to 20500) and an R error message.

BDAE(TM) first performs a syntax check for R, and then processes the data and calls the module only if there are no problems. If there are problems, the analyst resolves them and reruns them.

※ R has poor exception handling compared to Python. The API of the R engine, which is written in C, has limitations.

13 Python Coding Style (#1)

Python Coding Style is different from R. Python requires a module name (usually a file name) and a start function name among many functions to be called. (Not the normal way to call __main__)

```
import pandas as pd
import numpy as np
import seaborn as sns
from StreamToLogger import StreamToLogger
import sys
import logging, logging.handlers

def describe(df):
    logger = logging.getLogger('TitanicDesc:describe')
     logger.setLevel(logging.DEBUG)
     socketHandler = logging.handlers.SocketHandler('localhost',
                        logging.handlers.DEFAULT_TCP_LOGGING_PORT)
     logger.addHandler(socketHandler)

     sys.stdout = StreamToLogger(logger,logging.INFO)
     sys.stderr = StreamToLogger(logger,logging.ERROR)

    print('----- start -----')
    colums_ = df.columns.tolist()
    print(str(colums_))
    df.columns = list(map(str.lower,colums_))
    df_desc = df.describe()
    print(str(df_desc))
    df_desc.reset_index(inplace=True)
    df_desc.columns = ['vars', 'passengerid', 'survived', 'pclass', 'age', 'sibsp', 'parch', 'fare']
    df_melt = pd.melt(df_desc, id_vars=['vars'])
    print('----- end -----')

     socketHandler.close()
     logger.removeHandler(socketHandler)

    return df_melt
```

13 Python Coding Style (#2)

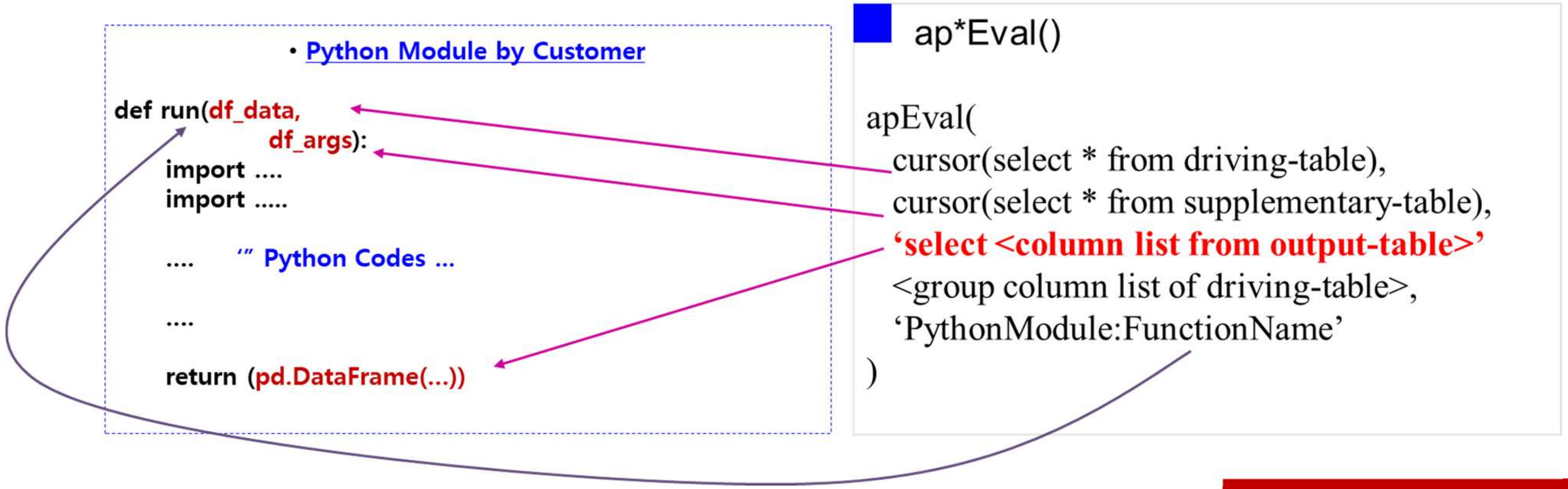
The arguments of the Python module's start function are the same as the R function coding style, and are the same as two. The first one is the input data, and the second one is additional data. You can name it as you like. Unlike R, it does not support descriptive form.

※ In the case of parallel processing, the function name (ap(s)GroupEval) is different, and the parallel processing column names must be provided.

※ It is necessary to understand the SQL execution mechanism of Oracle Database(TM) . The Oracle Optimizer creates a plan based on statistical information that is stored in the input and output format. Since Oracle does not automatically recognize the final Python output, you must inform it of this. (Red on the right)

※ If the output is complex, you can create it as an Oracle View and just write 'VIEW_NAME'. this is BDAE(TM) one of functionalities.

※ The part that automatically creates Python and R output as SELECT statements is on GitHub, and we will make it into a View.



• Python Module by Customer

```
def run(df_data,
              df_args):
    import ....
    import .....

    ....     ''' Python Codes ...

    ....

    return (pd.DataFrame(...))
```

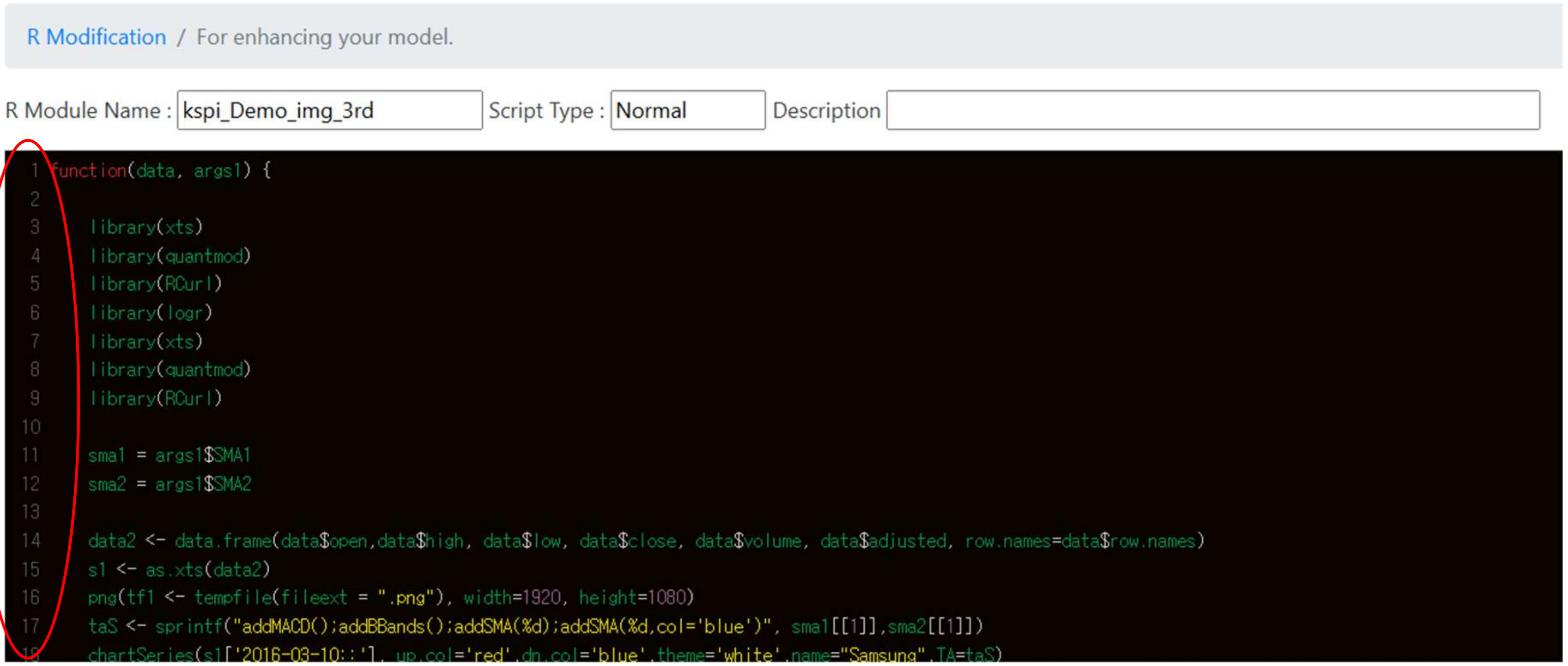
ap*Eval()

```
apEval(
  cursor(select * from driving-table),
  cursor(select * from supplementary-table),
  'select <column list from output-table>'
  <group column list of driving-table>,
  'PythonModule:FunctionName'
)
```

14 BDAE(TM) Web Editor

BDAE(TM) Web, the Web Editor part was imported and used as an open source package. It does not mean that you should develop it here. You can copy and paste what you developed in an existing development tool (R studio, Jupyter notebook, etc.).

※ If there is a line number in the case of a syntax error, you can use this, and the line number on the left is that line number.



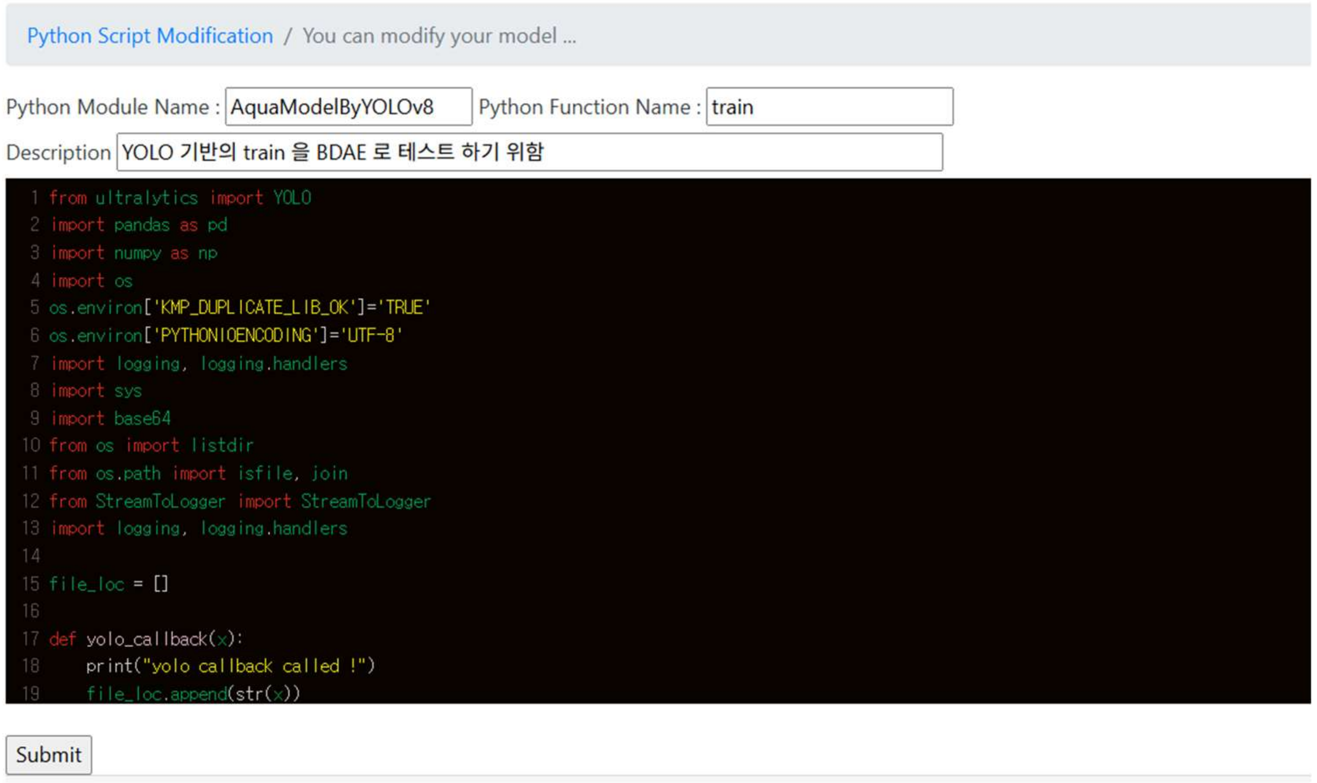
R Module Name : kspi_Demo_img_3rd Script Type : Normal Description

```
 1 function(data, args1) {
 2
 3     library(xts)
 4     library(quantmod)
 5     library(RCurl)
 6     library(logr)
 7     library(xts)
 8     library(quantmod)
 9     library(RCurl)
10
11     sma1 = args1$SMA1
12     sma2 = args1$SMA2
13
14     data2 <- data.frame(data$open,data$high, data$low, data$close, data$volume, data$adjusted, row.names=data$row.names)
15     s1 <- as.xts(data2)
16     png(tf1 <- tempfile(fileext = ".png"), width=1920, height=1080)
17     taS <- sprintf("addMACD();addBBands();addSMA(%d);addSMA(%d,col='blue')", sma1[[1]],sma2[[1]])
18     chartSeries(s1['2016-03-10::'], up.col='red',dn.col='blue',theme='white',name="Samsung",TA=taS)
```

15 BDAE(TM) Python CRUD

In the case of Python, Module Name and Function Name (start function) must exist, and BDAE(TM) executes both the case in DB and the file configuration, but DB is executed first.

That is, if it is not in DB, it means that the Module is searched in the PYTHONPATH location. (Customer sets it)



Python Script Modification / You can modify your model ...

Python Module Name : AquaModelByYOLOv8 Python Function Name : train

Description YOLO 기반의 train 을 BDAE 로 테스트 하기 위함

```
from ultralytics import YOLO
import pandas as pd
import numpy as np
import os
os.environ['KMP_DUPLICATE_LIB_OK']='TRUE'
os.environ['PYTHONIOENCODING']='UTF-8'
import logging, logging.handlers
import sys
import base64
from os import listdir
from os.path import isfile, join
from StreamToLogger import StreamToLogger
import logging, logging.handlers

file_loc = []

def yolo_callback(x):
    print("yolo callback called !")
    file_loc.append(str(x))
```

16 Python DataFrame, R data.frame

Since all RDBMS tables are 2D Tensors, we cannot escape from this. Therefore, both input and output values must be written in the Python Pandas DataFrame and R data.frame formats. (In the case of R, both data.frame and data.table outputs are supported.)

Input is done automatically by BDAE(TM) , but the output must be created and returned by the analyst when returning. The case is an issue when entering, but if you do it as below, you can also use columns with mixed case.

If SELECT is "col1", .., BDAE(TM) will pass the mixed case form as it is.
Analysts should be aware of this part. Be careful when using Pandas DataFrame columns.
It would be better to change all columns to uppercase or lowercase and then work on them.
(※ df['col1'] is used in Python, R, etc., and case is important at this time.)

If you say **SELECT "Passenger" as Passenger**, it will be capitalized. This is not something that BDAE(TM) does, but rather something that the Data Dictionary API does, so you should be aware of it.

※ This part is not due to BDAE(TM) , but is a characteristic of the Oracle Database(TM) SQL engine.
※ If you do SELECT * FROM .., the column case at the time the table was created will be applied as is.

17 NA, NaN, Inf (#1)

In analysis, NA (Not Available), NaN (NULL), Inf (Infinity) are important.
However, in Oracle Database(TM), NA and NaN are the same value NULL,
and Inf is provided as follows. Infinity in R below is 1.0/0.0 is positive Infinity, -1.0/0.0 is negative Infinity.

1. In case of R

```
X <- c(1,2,3,NA,5)
Y <- c(1.1,-1.0/0,1.0/0,4.0,5.34)

df <- data.frame(X,Y)
df
```

2. In case of Python

```
import pandas as pd
import numpy as np

def returnNAN():
   df = pd.DataFrame([['motor type',1, np.inf],
                 [np.nan, 2, 3.2],
                 ['RF', np.nan, 4.5]],
                 columns = list('abc'))
   return df
```

17 NA, NaN, Inf (#2)

In Oracle, Infinity is returned as binary_double_infinity, but if you simply call this SQL in JAVA, an Overflow will occur, so be careful. (This is not an Oracle Database(TM) or BDAE(TM) problem.)

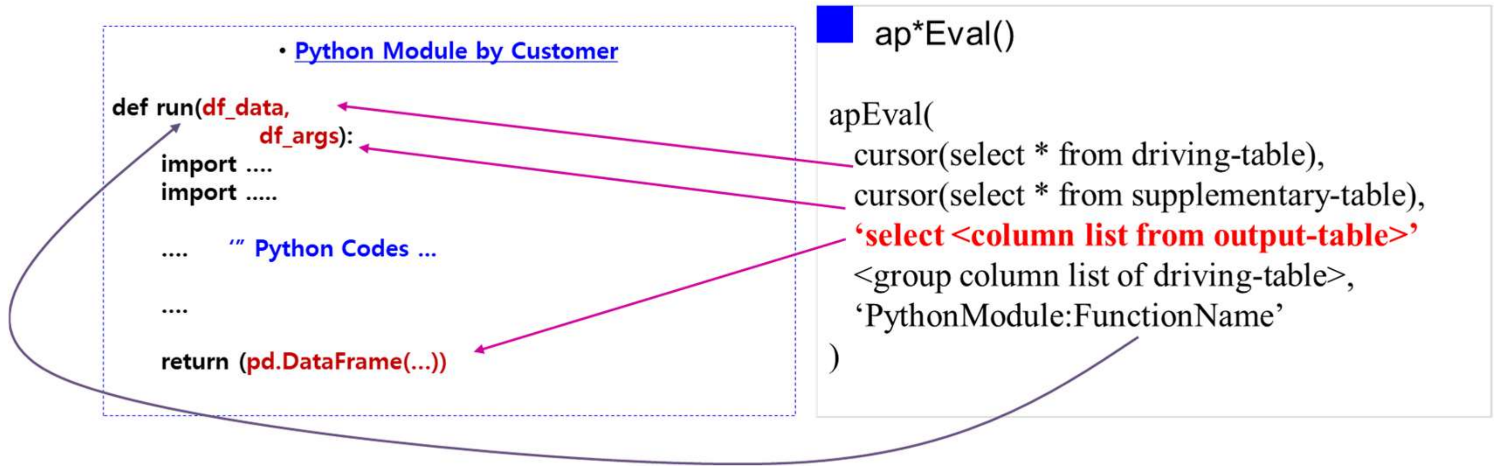
```
SELECT A, case when B=-binary_double_infinity
                 then '-Infinity'
                 when B=binary_double_infinity
                      then '+Infinity'
              else TO_CHAR(B) end AS B
FROM (
        SELECT *
          FROM
          table(asEval(
          NULL,
          'SELECT 1 as A, 1.0 as B FROM dual',
          'R_infinity'))
);
```

18 Output DataFrame vs Oracle Type Matching

The red 'select <column list from output-table>' part on the right usually uses dual as follows. However, if there are many columns like below, it is annoying. Therefore, it is convenient to use it by making it a View. Just input 'V_OUTPUT1'. (※ This part is a function of BDAE(TM))

```
'SELECT  CAST(''AA'' AS VARCHAR2(40)) EQP,
         CAST(''AA'' AS VARCHAR2(40)) UNIT,
         CAST(''AA'' AS VARCHAR2(40)) LOT,
         CAST(''AA'' AS VARCHAR2(40)) WAFER,
         CAST(''AA'' AS VARCHAR2(40)) RECIPE,
         CAST(''AA'' AS VARCHAR2(40)) PARAM,
         CAST(''AA'' AS VARCHAR2(100)) LOCATION
         FROM DUAL'
```

```
CREATE VIEW V_OUTPUT1  AS
SELECT  CAST(''AA'' AS VARCHAR2(40)) EQP,
         CAST(''AA'' AS VARCHAR2(40)) UNIT,
         CAST(''AA'' AS VARCHAR2(40)) LOT,
         CAST(''AA'' AS VARCHAR2(40)) WAFER,
         CAST(''AA'' AS VARCHAR2(40)) RECIPE,
         CAST(''AA'' AS VARCHAR2(40)) PARAM,
         CAST(''AA'' AS VARCHAR2(100)) LOCATION
         FROM DUAL;
```



• Python Module by Customer

```
def run(df_data,
            df_args):
    import ....
    import .....

    ....    "" Python Codes ...

    ....

    return (pd.DataFrame(...))
```

ap*Eval()

```
apEval(
  cursor(select * from driving-table),
  cursor(select * from supplementary-table),
  'select <column list from output-table>'
  <group column list of driving-table>,
  'PythonModule:FunctionName'
)
```

19 Real Time Logging

If there is a system error, you cannot see the logs in the Python or R modules.
(※ BDAE(TM) is not executed one line at a time like the Python or R development environment.)

BDAE(TM) transmits the error in the form of Description defined in ORA-20000 when there is a Python or R error.

If there is no error and you want to debug, it is better to use remote logging during development rather than doing it every time with a file. This part is included in GitHub.

In the case of Python, you can run the LogServer.py.

20 | Python Module Development (Input)

In a development environment without BDAE(TM), it is possible to use the Python sqlalchemy package.   It does not work if you only install pip install sqlalchemy, cx_Oracle.
You need an Oracle Client, which you can download from the Oracle site.
The usage is as follows. With this, you can develop modules while checking columns.

```
import sqlalchemyimport pandas as pd
import pandas as pdimport cx_Oracle
import osfrom sqlalchemy
import create_engine
LOCATION = r"C:\Users\Admin\Downloads\instantclient-basic-windows.x64-23.8.0.25.04\instantclient_23_8"
os.environ["PATH"] = LOCATION + ";" + os.environ["PATH"]

oracle_connection_string = 'oracle+cx_oracle://{username}:{password}@{hostname}:{port}'
DATABASE = "FREE"
SCHEMA = "rquser"
PASSWORD = "0000"
engine = create_engine(    oracle_connection_string.format(username=SCHEMA,
            password= PASSWORD,   hostname='177.175.54.97',    port='1521',    database='FREE',    ))

conn = engine.connect()
SQL = \
'''
SELECT ...
'''
df = pd.read_sql_query(SQL, conn)
```

21 R Module Development (Input)

In a development environment without BDAE(TM) , it is possible to use the ROracle package.
ROracle installation is done using Github or the Internet, but the installation on Windows is on GitHub.
Oracle Client is required, which is uploaded to the Cloud. (Installation file folder)
The usage is as follows. With this, development is performed by expecting BDAE(TM) input.

```
#  Oracle Installation Location

Sys.setenv("ORACLE_HOME"="/u01/app/oracle/product/12.2.0.1/db_1")
library(DBI)
library(ROracle)

driv <- dbDriver("Oracle")

connect.string <- paste(
  "(DESCRIPTION=",
  "(ADDRESS=(PROTOCOL = TCP)(HOST = 177.175.54.97)(PORT = 1521))",
  "(CONNECT_DATA=(SERVER = DEDICATED)",
  "(SERVICE_NAME = FREE)))", sep = "")

conn <- dbConnect(driv, username="rquser", password="0000", dbname=connect.string)
df <- dbGetQuery(conn,"SELECT * FROM FDC_TRACE WHERE ROWNUM < 10")
```

22 Python Output to Oracle Data Type(#1)

In the end, I created a utility because it was difficult to manually do the SELECT … FROM DUAL part of BDAE(TM) SQL every time.

It is the Output part, and if you use the below, it will be created, and if you make it into a View again, it will be convenient.

```
def dtype_to_dbtype(typestr):
    return {
        'int64': lambda: '1',
        'object': lambda: "CAST(''AA'' AS VARCHAR2(40))",
        'float32': lambda: '1.0',
        'float64': lambda: '1.0',
        'datetime64[ns]': lambda: 'TO_TIMESTAMP(NULL)',
        'byte': lambda: 'TO_BLOB(NULL)'
    }.get(typestr, lambda: typestr + "not defined type.")()

def space_fill_underbar(column_name):
    return '_'.join(column_name.split(' '))
```

Python Output to Oracle Data Type(#2)

Calling generate_dual_select (df) below will create a "SELECT ... FROM dual" statement.

```
def generate_dual_select (df):
    types = df.dtypes
    column_name_list = []
    column_type_list = []
    for i in range(len(types.index.tolist())):
        column_name_list.append(types.index.tolist()[i])
        column_type_list.append(str(types[types.index.tolist()[i]]))
        print("%-40s %s" %(types.index.tolist()[i], str(types[types.index.tolist()[i]])))

    sql = 'SELECT '
    last_index = len(column_name_list) - 1
    for i in range(last_index + 1):
        if i == last_index:
            sql = sql + ' ' + dtype_to_dbtype(column_type_list[i]) + ' ' + space_fill_underbar(column_name_list[i])  + '\nFROM dual'
        else:
            sql = sql + ' ' + dtype_to_dbtype(column_type_list[i]) + ' ' + space_fill_underbar(column_name_list[i]) + ',\n'

    return (sql)
```

```
sql = generate_dual_select(df)
print(sql)
```

R Output to Oracle Data Type

In the case of R, calling generate_dual_select(df) below will create a "SELECT … FROM dual" statement.

```
r_to_oracle_type <- function(r_type)
{
  switch(r_type,
        "character" = "VARCHAR2(4000)",
        "integer"   = "NUMBER(10)",
        "numeric"   = "FLOAT",
        "double"    = "FLOAT",
        "logical"   = "CHAR(1)",
        "Date"      = "DATE",
        "POSIXct"   = "TIMESTAMP",
        "factor"    = "VARCHAR2(4000)",
        "list"      = "CLOB",
        "unknown"   = "VARCHAR2(4000)",
        "VARCHAR2(4000)")  # default
}
```

```
generate_dual_select <- function(df)
{
  types <- sapply(df, function(col) class(col)[1])
  oracle_types <- sapply(types, r_to_oracle_type)


  select_parts <- mapply(function(col_name, ora_type) {
    paste0("CAST(NULL AS ", ora_type, ") AS ", col_name)
  }, names(df), oracle_types, USE.NAMES = FALSE)


  paste("SELECT", paste(select_parts, collapse = ", "), "FROM dual")
}


# 실행
query <- generate_dual_select(df)
cat(query)
```

24 | BDAE(TM) SQL

* If you do not use Dynamic SQL statements, this means that you will be dependent on the customer's schema, which means that you will have to change the code every time to fit the customer.

However, BDAE(TM) has been implemented to enable Dynamic SQL, which is a key differentiating feature. BDAE(TM) has also been implemented to enable the same level as Oracle R Enterprise (TM) .

(※ The only RDBMS that fully supports Database Dictionary is **Oracle Database(TM)**.
The core of Dynamic SQL is that even if it becomes a SubQuery of a SubQuery .., it must transparently support the Dictionary of top-level column information. Oh, I'm talking about the API level. Not SQL execution ..)

* About Parallel processing

1. Oracle Optimizer checks the input query, output query, and statistical information and decides on parallel processing.
2. Therefore, Oracle Database(TM) gives up parallel processing when it detects that an image (BLOB) or a string (CLOB) larger than 4000 bytes is included.
3. The same applies when using BDAE(TM). However, there are many ways to circumvent this and use tricks to enable parallel processing, but this can only be done by using BDAE(TM) rather than a regular SQL statement.

25 DB-based development

Before creating BDAE(TM) SQL, analysts should do the following:
Create a single module, a single function, without considering parallel processing.

Based on import sqlalchemy, let's first create a DataFrame with SQL and develop it.

SQL1 = “SELECT .. “ # This SQL statement is used to create the query to be analyzed.
df_data = pd.read_sql_query(SQL1, conn)

There are two cases where the function of the Class you want to create requires arguments.

1) Combination of simple Scalars

SQL2 = “SELECT 1 as ARG1, 0.5 as ARG2 FROM DUAL”

2) Referenced data (reference tables, e.g. Reference tables for similarity measurement, inference tables)

SQL2 = “SELECT … FROM TABLE …. “

df_args = pd.read_sql_query(SQL2, conn)

You can create a function for your purpose using those two, and register the module name and function name in BDAE(TM) .
(※ You can work with R using ROracle, and the process is similar.)

26 R Precautions

As mentioned earlier, R has two coding styles.

1. function() style : Input variables can be used with any name, explicit return like return df
2. In the description format, the input data name to be analyzed is data, and additional data is fixed as args.

   You only need to write df once without a return statement, and any name other than df can be used.

   However, both 1 and 2 return data.frame format and stringsAsFactor=FALSE.

   The stringsAsFactor part will of course be familiar to R analysts.
   If you create a data.frame without thinking, the Category column is saved as a Factor such as 1, 2, 3, etc.

3. The attributes of the data.frame returned like Python are generally strings, numbers, and DateTime. (converting - as.character(), as.numeric(), ..)

27 Visualization 과 Serialization/DeSerialization

Both R and Python can create charts in three different forms.

1. Image Binary File Format (PNG, JPG, ...)
2. Image, String encoded in base64
3. Interactive Java Script String using plotly

When learning AI, there are many verification data results, various visualization charts, and parameters, and you want to see them. Since the SQL statement returns only once, you can put all of these in a DataFrame, data.frame, and that's it.

In particular, in the case of Model, it must be serialized, so it must be stored as an Oracle BLOB, and when performing real-time inference during later operation, it must be deserialized and used again.

It is quite easy and possible using BDAE(TM).

28 | BDAE(TM) does not use storage space at runtime..

BDAE(TM) is executed in memory, without any separate storage space, and after analysis via Python and R engines, everything is done in memory.

There are two ways to save the return results of BDAE(TM) in a DB: one is to have the analyst create a separate session within Python or R, and the other is to use the following universal database techniques.

```
CREATE TABLE RESULT_TEMPORARY_TABLE AS SELECT ... ;
INSERT INTO RESULT_PERMANENT_TABLE SELECT ... ;
```

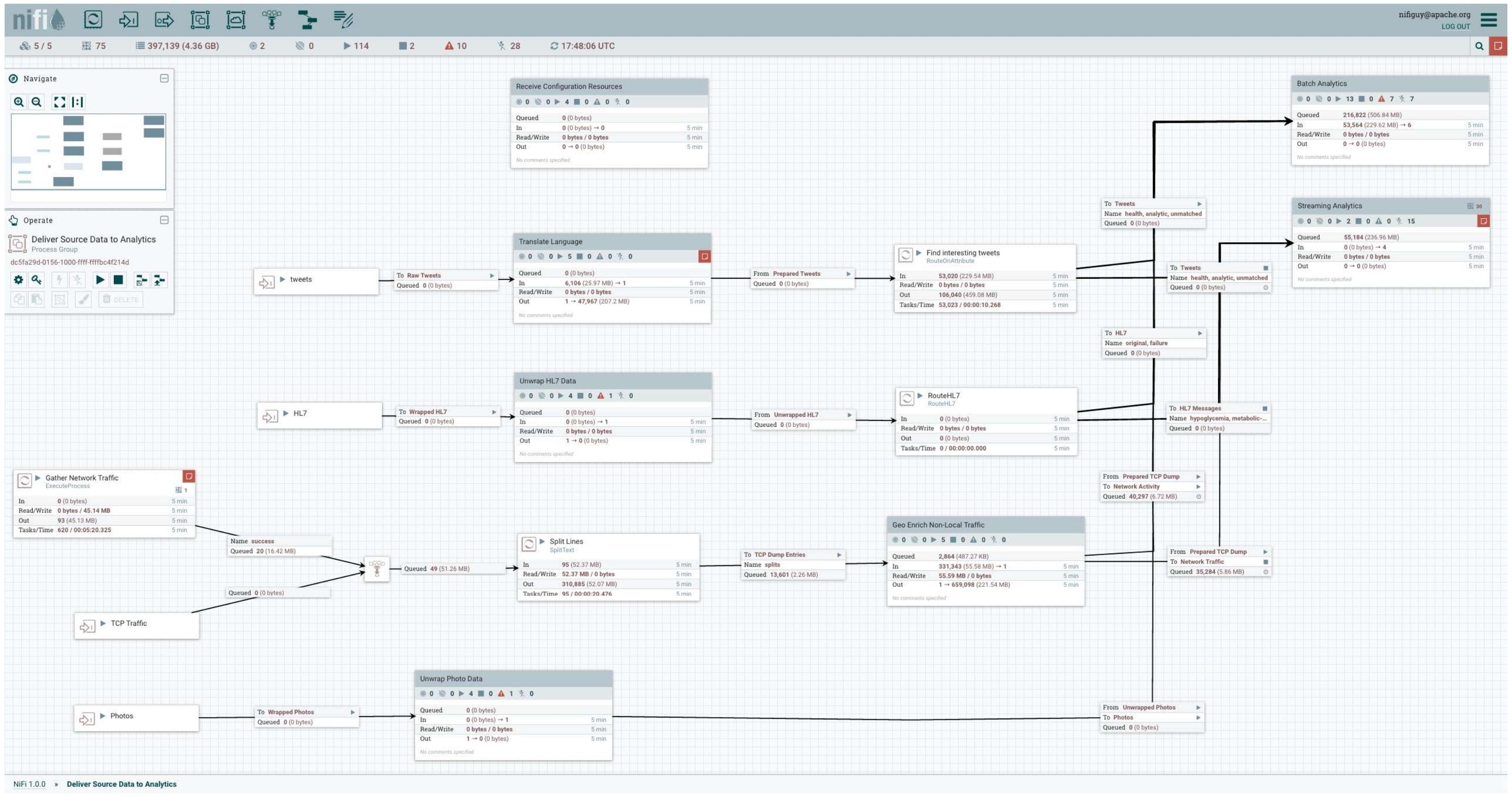
※ Problems with Oracle In-Database Programs and Solutions with BDAE(TM)

1. Since it is managed separately from the SGA, PGA area of Oracle Database(TM). if Python or R internal code excessively uses a lot of memory, it can kill the server where the Oracle Instance is located. (Out of Memory in terms of OS)

2. Because we have seen this happen in real Oracle R Enterprise(TM) operations, BDAE(TM) is designed to set the maximum available memory for a single session memory and monitor it during execution (every 10 seconds for that session).

29 BDAE(TM) and Apache NIFI(TM) Integration

Using Apache NIFI(TM) and BDAE(TM) together allows you to configure batch jobs with a more stable workflow. In particular, it is effective and can be organized neatly when it is SQL-based rather than file-based.



Utilizing BDAE$^{(TM)}$

1

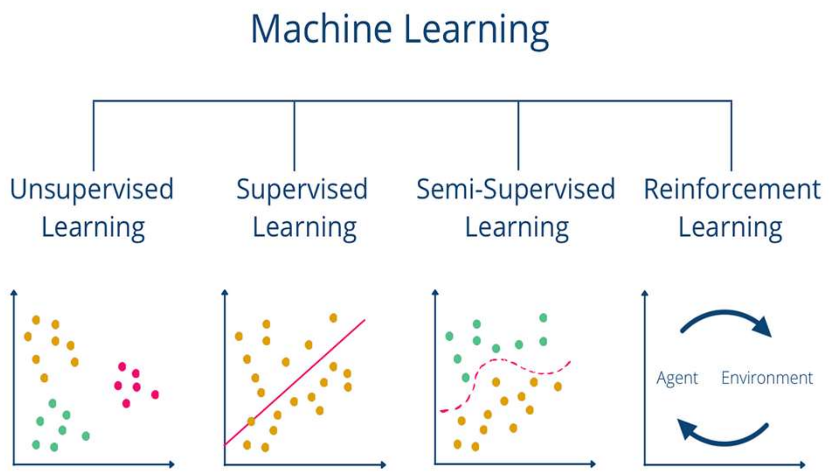
1. Various AI tasks performed with Python and R (#1)

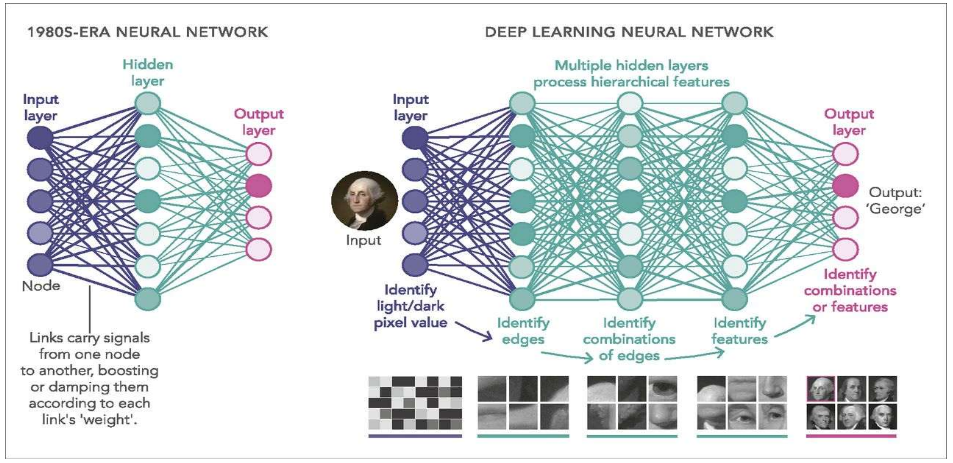
The initial development goal of BDAE(TM) was to find a way to easily apply the latest algorithms to existing solutions in manufacturing systems, such as SPC, FDC, and YMS.

In particular, there is a doubt about whether it is advisable to perform defect analysis, SPC, descriptive statistics, ANOVA, etc. through pattern recognition in backends such as JAVA, or to purchase separate expensive analysis products.

In actual high-tech fields, raw data is commonly in Oracle Database(TM), and R or Python scripts are run on a separate application server.

However, BDAE(TM) solves problems such as algorithm source management, parallel processing, and best performance on a separate server without massive data movement.

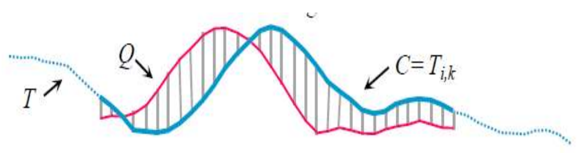


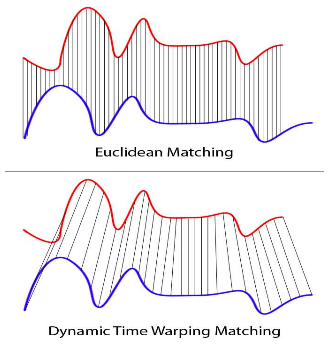

1980S-ERA NEURAL NETWORK
Input layer
Hidden layer
Output layer
Node
Links carry signals from one node to another, boosting or damping them according to each link's 'weight'.
DEEP LEARNING NEURAL NETWORK
Input layer
Multiple hidden layers process hierarchical features
Output layer
Input
Output: 'George'
Identify light/dark pixel value
Identify edges
Identify combinations of edges
Identify features
Identify combinations or features

2 | Various AI tasks performed with Python and R (#2)

If you perform real-time analysis quickly and receive the results as a universal SQL query result like the one below, the application has a very simple structure.

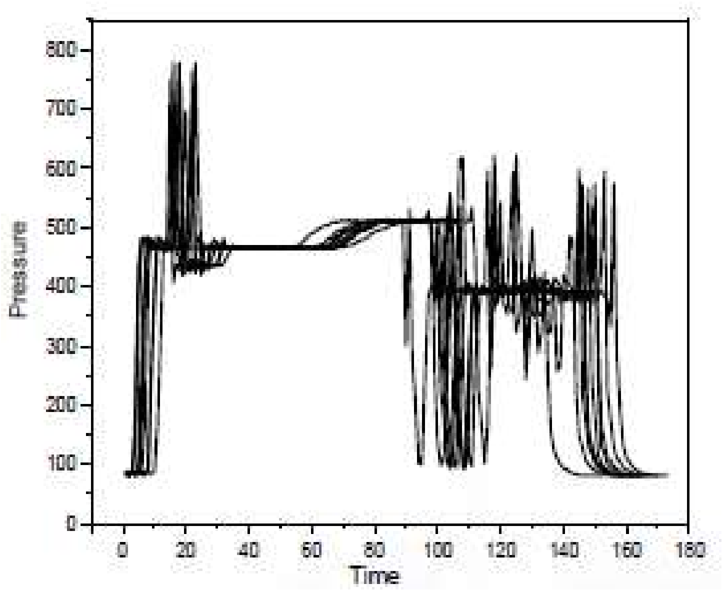
※ The second argument of BDAE(TM) is used as
Query Data for comparison,
Model Data for inference,
or Argument for functions used in Python, R.





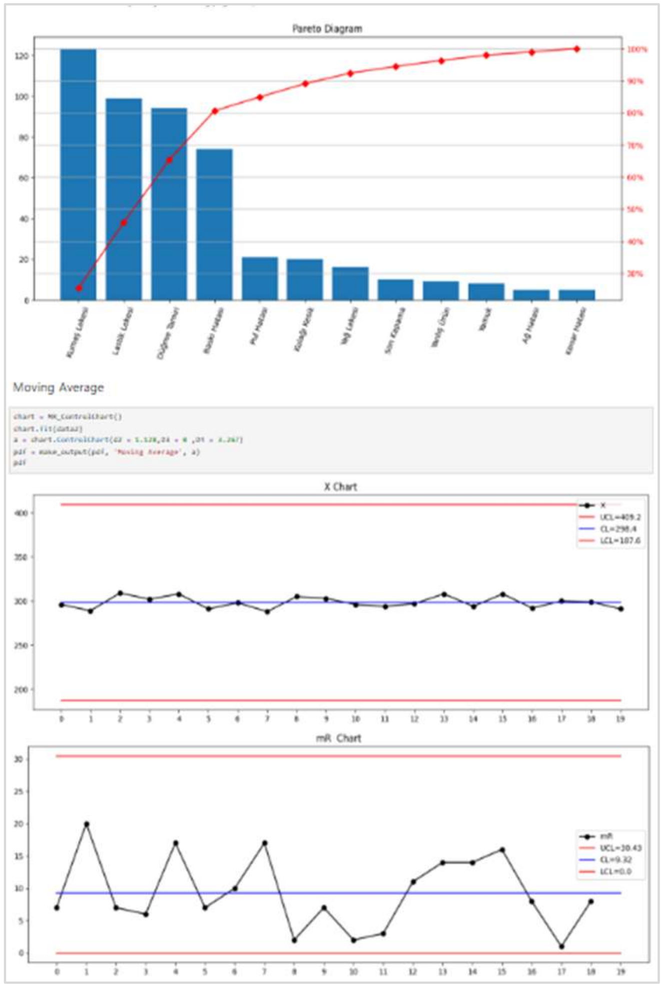
```
SQL> SELECT * /*+ parallel(20) */
  2  FROM TABLE (apGroupEvalParallel (
  3                    cursor (
  4                         SELECT *
  5                         FROM TRACE_DATA
  6                         WHERE EQP_ID = 'EPS001'
  7                            AND LOT_ID = 'LOT001'
  8                            AND ETC = '.....'
  9                       ),
 10                   cursor(SELECT * FROM GOLDEN_EQUIPMENT ...),
 11                   'SELECT  CAST("A" AS VARCHAR2(40)) PARAMETER_ID,
                          1.0 SIMILARITY FROM DUAL',
 11                   'EQP_ID, LOT_ID, ....',
 12                   'DefectUtil:FastDTW');


 PARAMETER_ID     SIMILARITY
--------------------  -------------
 RF_POWER_1          2.23
 O2_PUMP_1            0.5
 Ch1_TEMP_1           2.1
 .........           ......
 .........           ......
```

Pattern Matching Algorithms

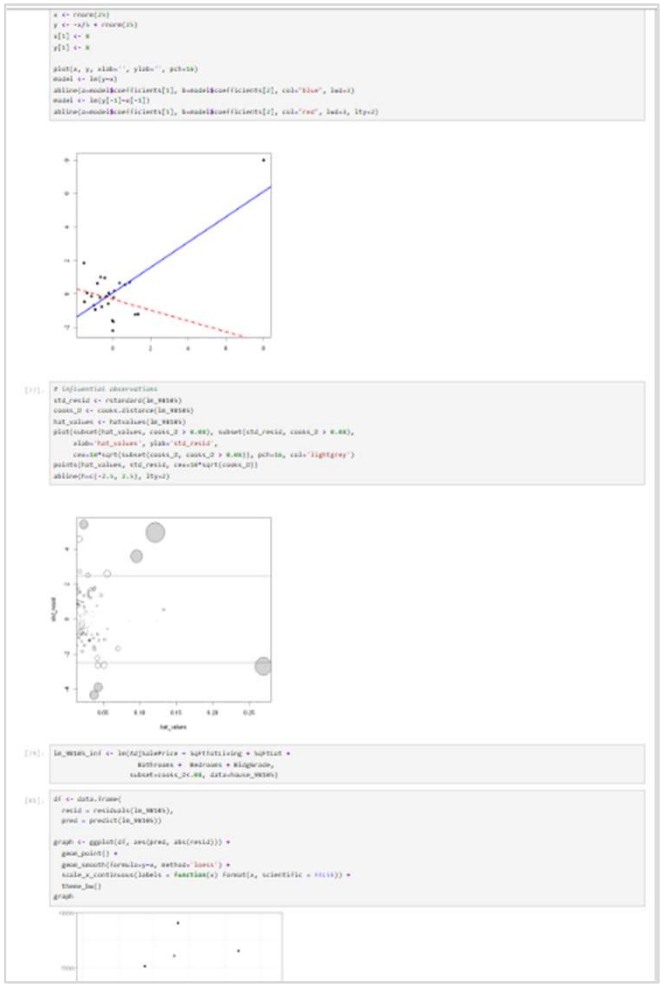


3 Batch and integrate analytics tasks

If you wrap the SQL statement above in Python or R and create a class, you can integrate various analysis tasks and perform them at once, but parallel processing is possible, and the results can also be received at once.



```
chart = MR_ControlChart()
chart.fit(data2)
a = chart.ControlChart(d2 = 1.128,D3 = 0 ,D4 = 3.267)
pdf = make_output(pdf, 'Moving Average', a)
pdf
```



```
x <- rnorm(25)
y <- -x/5 + rnorm(25)
x[1] <- 8
y[1] <- 8

plot(x, y, xlab='', ylab='', pch=16)
model <- lm(y~x)
abline(a=model$coefficients[1], b=model$coefficients[2], col="blue", lwd=3)
model <- lm(y[-1]~x[-1])
abline(a=model$coefficients[1], b=model$coefficients[2], col="red", lwd=3, lty=2)
```

```
# influential observations
std_resid <- rstandard(lm_98105)
cooks_D <- cooks.distance(lm_98105)
hat_values <- hatvalues(lm_98105)
plot(subset(hat_values, cooks_D > 0.08), subset(std_resid, cooks_D > 0.08),
     xlab='hat_values', ylab='std_resid',
     cex=10*sqrt(subset(cooks_D, cooks_D > 0.08)), pch=16, col='lightgrey')
points(hat_values, std_resid, cex=10*sqrt(cooks_D))
abline(h=c(-2.5, 2.5), lty=2)
```

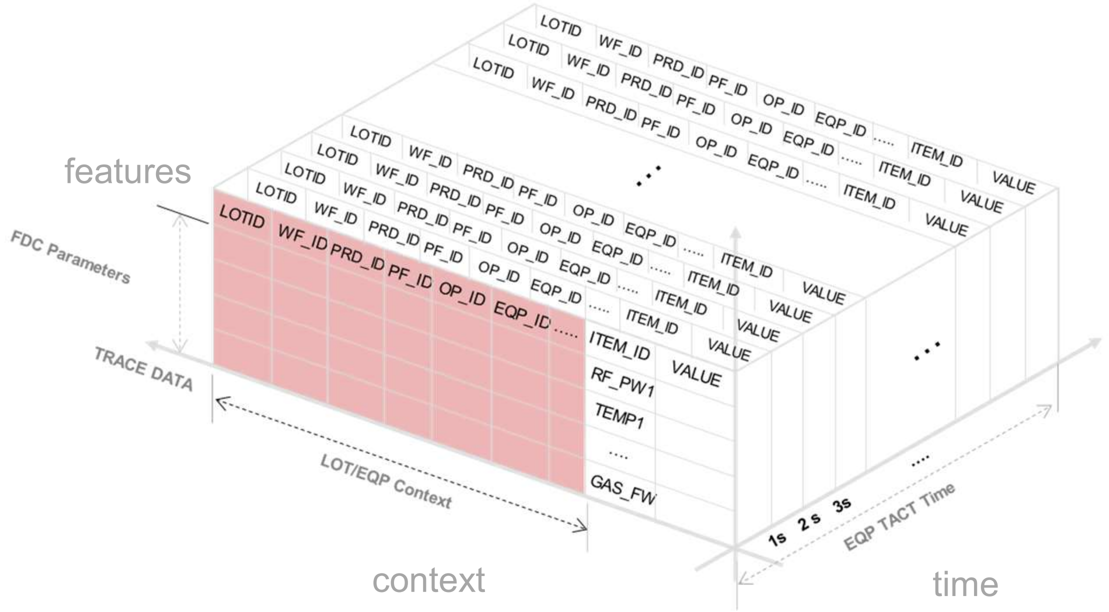
```
lm_98105_inf <- lm(AdjSalePrice ~ SqFtTotLiving + SqFtLot +
                     Bathrooms +  Bedrooms + BldgGrade,
                   subset=cooks_D<.08, data=house_98105)
```

```
df <- data.frame(
  resid = residuals(lm_98105),
  pred = predict(lm_98105))

graph <- ggplot(df, aes(pred, abs(resid))) +
  geom_point() +
  geom_smooth(formula=y~x, method='loess') +
  scale_x_continuous(labels = function(x) format(x, scientific = FALSE)) +
  theme_bw()
graph
```

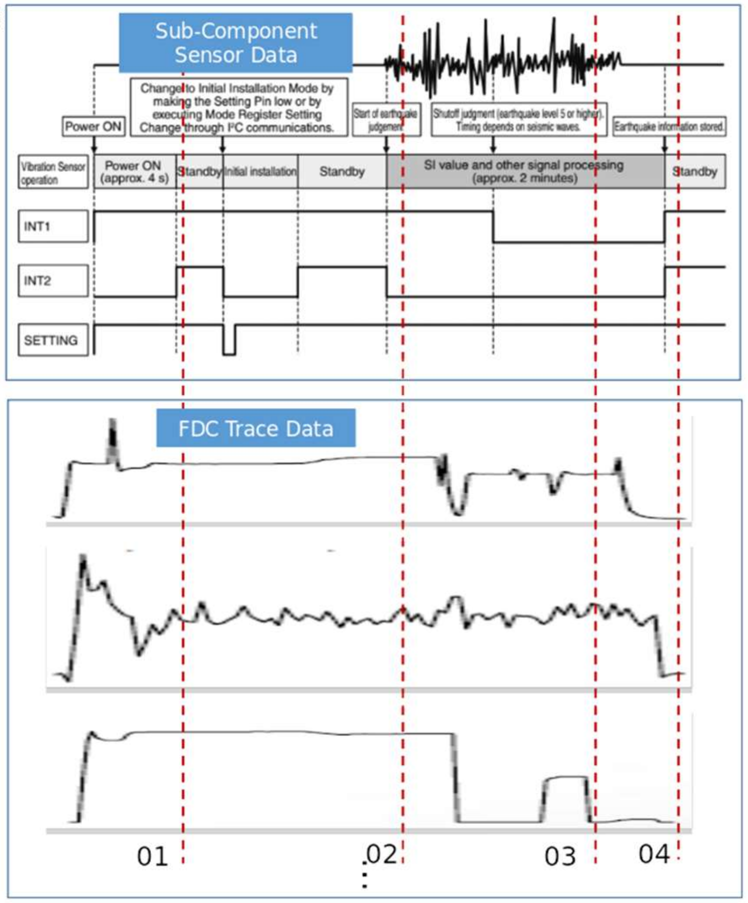
4 Parallel distributed processing (#1)

When grouping large tables and applying the same algorithm at once to receive results, using parallel processing in Python or R can result in excessive reusability, performance, and memory usage.

This parallel processing part is left to Oracle In-Database, and the role of BDAE(TM) is to make Python and R modules have a simple form that does not consider parallel processing, and the above problems are solved.



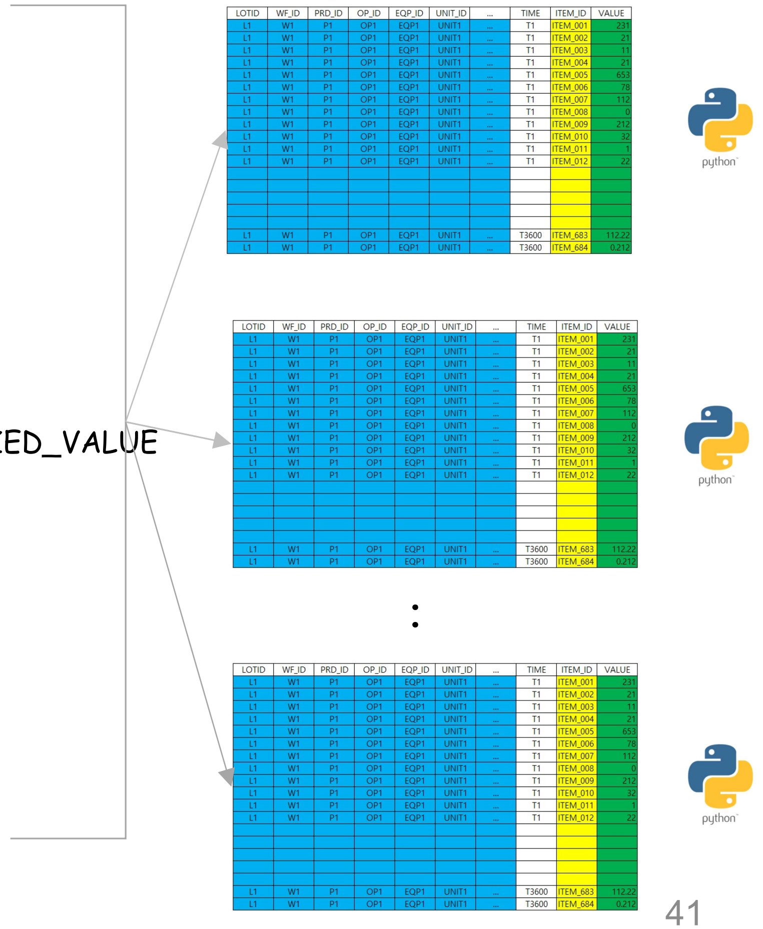
Trace Data per 1 LOT/1 EQP



4 Parallel distributed processing (#2)

The following query is an example of parallel distributed processing of a large table in units of group columns in red. The Oracle Hint (/*+ parallel(20) */) section divides it into 20 and parallelizes it, and the Python module then takes the form of a simple module that does not consider parallel processing. BDAE$^{(TM)}$ makes this possible.

```
SELECT /*+ parallel(20) */*
     FROM table(apGroupEvalParallel(
         CURSOR(
             WITH TARGET_TBLE AS
             (
                    SELECT * FROM FDC_TRACE
                    WHERE 1=1
                      AND EQP_ID='EQP-200'
                      AND UNIT_ID='UNIT-02'
             )
            SELECT EQP_ID, UNIT_ID, LOT_ID, WAFER_ID, RECIPE, PARAM_ID,
               (VALUE - (AVG(VALUE) OVER (PARTITION BY PARAM_ID)))
              / (STDDEV(VALUE) OVER (PARTITION BY PARAM_ID)) AS  NORMALIZED_VALUE
                                FROM TARGET_TBLE
         ) ,
         NULL,
          'SELECT CAST(''A'' AS VARCHAR2(40)) EQP_ID,
                 CAST(''A'' AS VARCHAR2(40)) UNIT_ID,
                 CAST(''A'' AS VARCHAR2(40)) LOT_ID,
                 CAST(''A'' AS VARCHAR2(40)) WAFER_ID,
                 CAST(''A'' AS VARCHAR2(40)) RECIPE,
                 CAST(''A'' AS VARCHAR2(40)) RESULT
                 FROM DUAL',
          'EQP_ID,UNIT_ID,LOT_ID,WAFER_ID,RECIPE,PARAM_ID',
         'Standardization:normalize'));
```



LOTID	WF_ID	PRD_ID	OP_ID	EQP_ID	UNIT_ID	...	TIME	ITEM_ID	VALUE
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_001	231
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_002	21
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_003	11
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_004	21
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_005	653
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_006	78
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_007	112
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_008	0
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_009	212
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_010	32
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_011	1
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_012	22
L1	W1	P1	OP1	EQP1	UNIT1	...	T3600	ITEM_683	112.22
L1	W1	P1	OP1	EQP1	UNIT1	...	T3600	ITEM_684	0.212

LOTID	WF_ID	PRD_ID	OP_ID	EQP_ID	UNIT_ID	...	TIME	ITEM_ID	VALUE
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_001	231
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_002	21
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_003	11
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_004	21
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_005	653
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_006	78
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_007	112
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_008	0
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_009	212
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_010	32
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_011	1
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_012	22
L1	W1	P1	OP1	EQP1	UNIT1	...	T3600	ITEM_683	112.22
L1	W1	P1	OP1	EQP1	UNIT1	...	T3600	ITEM_684	0.212

LOTID	WF_ID	PRD_ID	OP_ID	EQP_ID	UNIT_ID	...	TIME	ITEM_ID	VALUE
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_001	231
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_002	21
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_003	11
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_004	21
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_005	653
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_006	78
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_007	112
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_008	0
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_009	212
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_010	32
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_011	1
L1	W1	P1	OP1	EQP1	UNIT1	...	T1	ITEM_012	22
L1	W1	P1	OP1	EQP1	UNIT1	...	T3600	ITEM_683	112.22
L1	W1	P1	OP1	EQP1	UNIT1	...	T3600	ITEM_684	0.212

5 PreProcessing

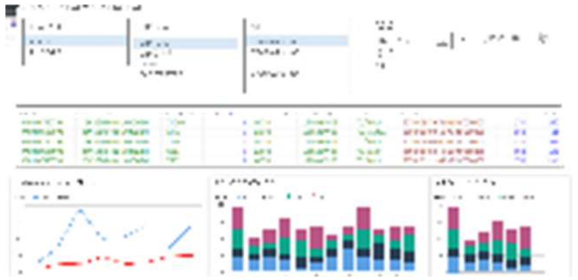
If Python or R performs preprocessing of a large portion of input data, memory and performance issues arise. BDAE(TM) can accept and preprocess complex SQL statements such as the following, and this is because Oracle Database(TM) has the most advanced SQL engine.

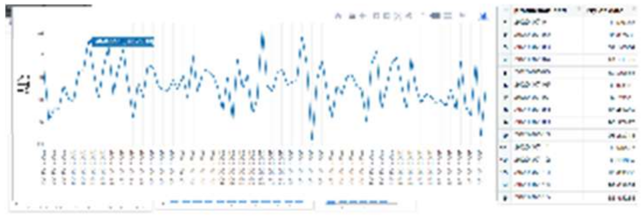
```
SELECT  eqp_id, recipe_id, …, time, parameter_name, sma, ema
FROM    (
            SELECT eqp_id, recipe_id, time, …, parameter_name, parameter_value
            FROM   trace_data
            WHERE 1=1
                  AND time between … and …
                  AND step_seq = ' …'
                  …
            ) a
MODEL
    PARTITION BY (a.parameter_name, 2 / (1 + count(*) over (partition by a.parameter_name))
                  smoothing_constant )
    DIMENSION BY (row_number() over (partition by a.parameter_name order by a.time) rn)
    MEASURES (a.time, a.parameter_value, sma, 0 ema)
    (
        ema[1] = a.parameter_value[1],
        ema[rn > 1] order by rn = ( cv(smoothing_constant) * (parameter_value[cv()] - ema[cv() -1]) ) + ema[cv() -
1]
    )
ORDER BY eqp_id, a.recipe_id, …, a.time, a.parameter_name;
```

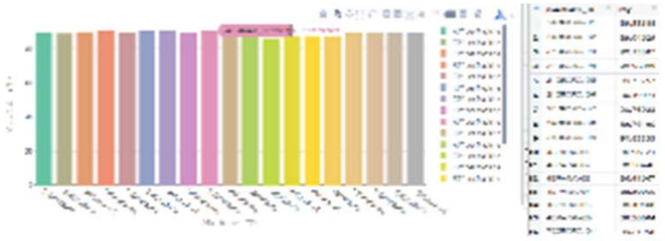
6 Smart Factory (#1)

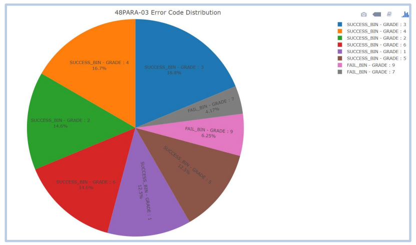
Based on existing solutions such as statistical quality analysis, anomaly detection, SPC, etc., you can easily embed flexible functions into existing solutions as SQL statements without additional cost by using various packages provided by Python and R in BDAE(TM).

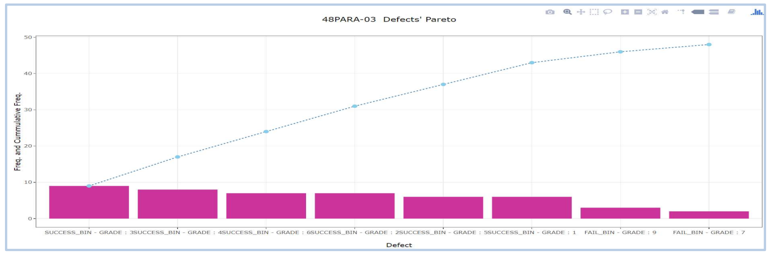
※ BDAE(TM) is implemented as a SQL statement and runs in memory, so it can be added to any solution.

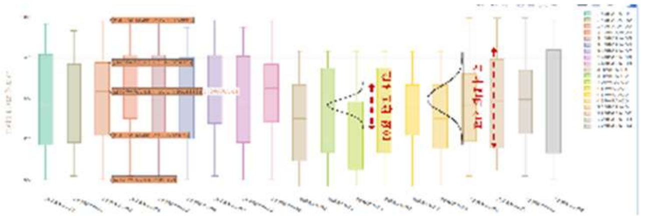


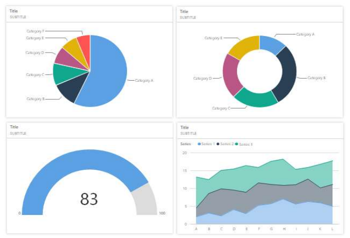


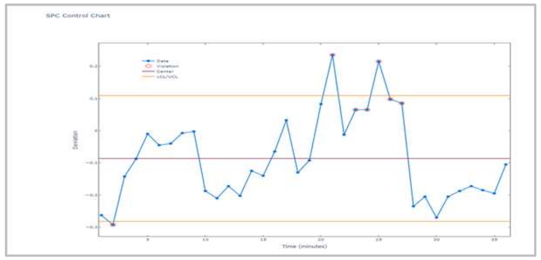








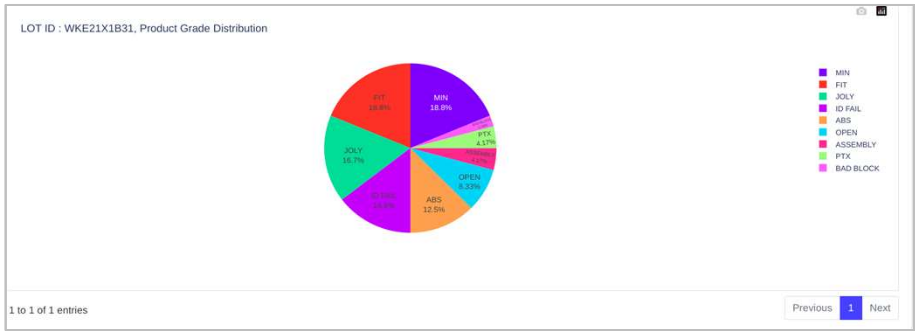




6 Smart Factory (#2)

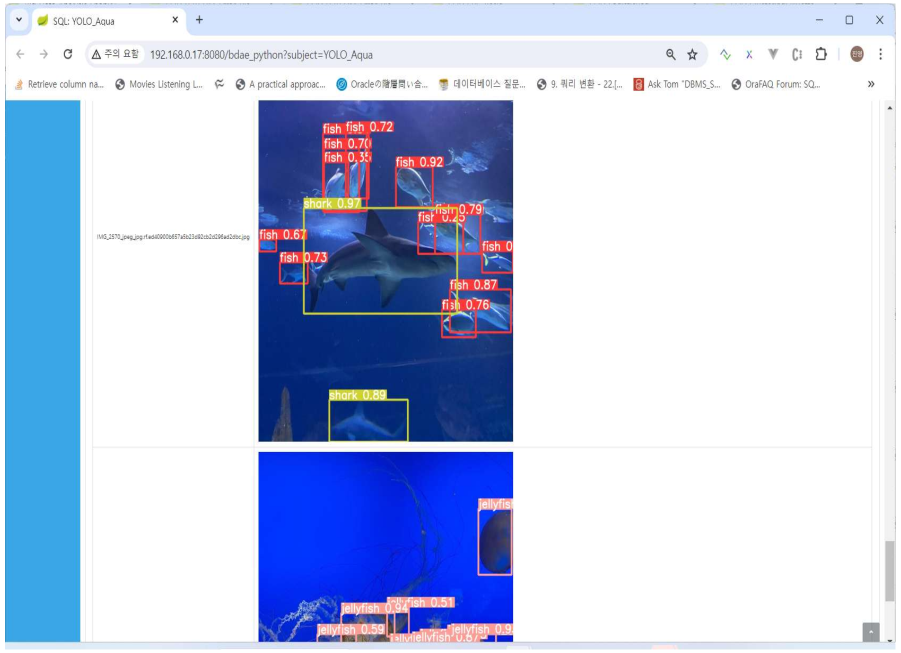
This level of functionality can be implemented in about 5 lines.
The plotly package exists for both Python and R and makes charts interactive.

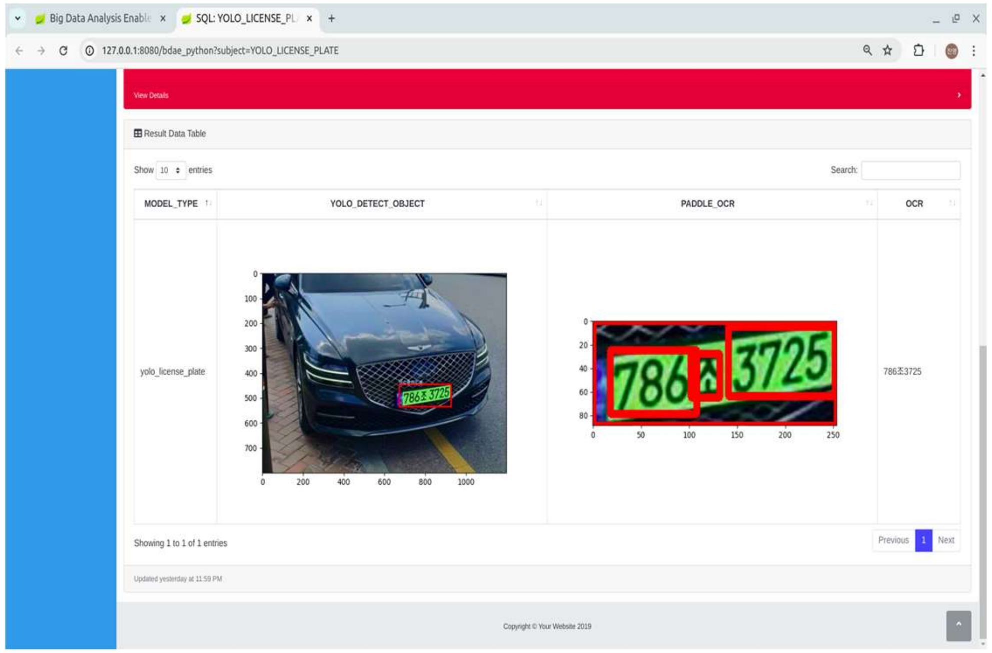
```
WITH LOT_SUM_ONE AS (
  SELECT LOT_ID,
    CASE WHEN PROD_GRADE = 9 THEN 'BAD BLOCK'
          WHEN PROD_GRADE = 8 THEN 'ASSEMBLY'
          WHEN PROD_GRADE = 7 THEN 'PTX'
          WHEN PROD_GRADE = 6 THEN 'ID FAIL'
          WHEN PROD_GRADE = 5 THEN 'OPEN'
          WHEN PROD_GRADE = 4 THEN 'ABS'
          WHEN PROD_GRADE = 3 THEN 'JOLY'
          WHEN PROD_GRADE = 2 THEN 'FIT'
          WHEN PROD_GRADE = 1 THEN 'MIN'
          ELSE
            'N/A'
      END PROD_GRADE_DESC
    , COUNT(PROD_GRADE) CNT FROM table (
      productExplodeEvalCLob(cursor(
        SELECT *
        FROM LOT_SUM
        WHERE LOT_ID = 'WKE21X1B31'
            AND MACHINE_ID = '48PARA-03' ...DURABLE_ID = 'Z718')))
        GROUP BY LOT_ID, PROD_GRADE
)
SELECT *
  FROM table(apTableEval(
   cursor(
     SELECT * FROM LOT_SUM_ONE
   ),
   NULL,
   'XML',
   'LOTSUM_ERR_PIE:display'))
```



7 Deep Learning Inference

In places where BDAE(TM) is not installed for learning cost- or GPU-dependent algorithms, you can learn the model and use it for inference in real time using BDAE(TM) .
(This is because the model may be different for each facility and product, and BDAE(TM) supports DeSerialization.)




SQL: YOLO_LICENSE_PLATE
127.0.0.1:8080/bdae_python?subject=YOLO_LICENSE_PLATE

Result Data Table

MODEL_TYPE	YOLO_DETECT_OBJECT	PADDLE_OCR	OCR
yolo_license_plate			786조3725

Showing 1 to 1 of 1 entries

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