Open Source Integration Using the Base SAS® Java Object

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ABSTRACT

This paper illustrates a new technique that uses the Base SAS® Java Object to integrate SAS software and popular open source packages. The communication medium between SAS and the open source packages is a pair of freely available Java classes and data sets in standard comma-separated-value (CSV) format. Examples in this paper pass CSV data sets to support vector machine (SVM) models that are implemented with scikit-learn in Python and kernlab in R, and return the modeling results to SAS for assessment.

INTRODUCTION

The capability to run third-party packages from SAS enables statisticians and data scientists to use open source tools alongside the statistical, data mining, and machine learning methodologies that are available in SAS. This paper describes a methodology that uses the Java Object DATA step component to execute Python and R scripts from Base SAS. First introduced in 2004 with SAS 9.1.3, the Base SAS Java Object provides a mechanism for instantiating and accessing Java objects from within a DATA step. This interface serves as a gateway within SAS to call Java programs, enabling users to create hybrid solutions that bring together the capabilities of SAS and Java. Applications for various purposes such as transferring data streams, reading archived data, data visualization, and data persistence have been implemented using the Base SAS Java Object (DeVenezia 2004; Mengelbier and Skowronski 2008; Hall and Snyder 2012).

CONFIGURATION AND EXAMPLE DATA

INITIAL SETUP

To begin, you download and extract the project ZIP file, SAS_Base_OpenSrcIntegration.zip, from:

https://communities.sas.com/docs/DOC-10746

The uncompressed directory is referred to as WORK_DIR throughout the paper and is assumed to be C:\SGF2015\OpenSrcIntegration in the examples.

The project directory (WORK_DIR) contains the following:

- Training and test data sets: digitsdata_17_train.csv and digitsdata_17_test.csv
- Two Java classes: SASJavaExec.java and StreamManagerThread.java
- A Python script and an R script: digitsdata_svm.py and digitsdata_svm.R
- A SAS program: main_caller.sas

Next, you open main_caller.sas, find the WORK_DIR, PYTHON_EXEC_COMMAND, and R_EXEC_COMMAND variables located at the top of the file, and update them appropriately for your system. The WORK_DIR variable specifies the working directory of the project. The PYTHON_EXEC_COMMAND and R_EXEC_COMMAND variables should specify the location of the Python and R executables (as shown in the following example); these locations can vary depending on where these packages are installed.

```
*** WORKING DIRECTORY      (----- USER UPDATE NEEDED -----);
%let WORK_DIR = C:\SGF2015\OpenSrcIntegration;
*** SYSTEM PYTHON LOCATION (----- USER UPDATE NEEDED -----);
%let PYTHON_EXEC_COMMAND = C:\Anaconda\python.exe;
*** SYSTEM R LOCATION      (----- USER UPDATE NEEDED -----);
%let R_EXEC_COMMAND = C:\Program Files\R\R-3.1.2\bin\x64\Rscript.exe;
```

The example code was developed and tested using SAS 9.4, Anaconda Python 2.7, R 3.1.2, and Oracle Java Development Kit (JDK) 1.7.0_25 on a Windows 7 Professional workstation with 16G RAM. Having suitable installed versions of Java, Python, and R is a prerequisite to run the example code, but their installation is beyond the scope of this paper.

DATA

The example data are a subset of the MNIST database, which is a set of labeled handwritten digit images that are commonly used for experimenting with new approaches in the field of machine learning and image processing (Wikipedia 2015). The label (independent variable) is the actual digit that the image represents, which is located in the first column of the example data. The 784 predictor columns that follow contain the associated pixel intensity values. The example data include only the digits 1 and 7. The digits are equally balanced within the training and test data in the provided digitsdata_17_train.csv and digitsdata_17_test.csv files, respectively. CSV format is used for both the input data files and the output files from R and Python.

COMPILING THE PROVIDED JAVA CLASSES

The source code for the Java classes is located in WORK_DIR\src\dev; it should be compiled and placed in WORK_DIR\bin\dev directory. To compile the Java classes, change directories to the WORK_DIR directory and issue the following javac command. This operation assumes that an appropriate JDK is part of the PATH environment variable.

```
cd C:\SGF2015\OpenSrcIntegration
javac src/dev/* -d bin
```

SETTING THE JAVA CLASSPATH

The Base SAS Java virtual machine (JVM), on which the Base SAS Java Object depends, needs the location of the compiled Java classes to access the additional functionality that is implemented in SASJavaExec.java and StreamManagerThread.java Java classes. This location is contained in the CLASSPATH environment variable. There are multiple ways to provide the CLASSPATH to SAS (Snyder and Hall 2012). For this example, it is provided by adding the following line of text to the bottom of the sasv9.cfg configuration file for the local SAS installation:

```
-SET CLASSPATH "C:\SGF2015\OpenSrcIntegration\bin"
```

The sasv9.cfg file is often located in a directory similar to C:\Program Files\SASHome\SASFoundation\9.4\nls\en. If necessary, you can refer to multiple directories in the CLASSPATH by concatenating them using a semicolon (;) in a Windows environment or a colon (:) in UNIX and Linux environments. The following code snippet from main_caller.sas performs a quick test to check whether the CLASSPATH variable is set correctly. When the JAVA_BIN_DIR variable points to the directory where the compiled Java classes are located, these code statements should not return an error. If there is an error in the SAS log after running this code snippet, do not proceed further without correcting the problem.

```
*** JAVA LIBRARIES/CLASS FILES LOCATION;
%let JAVA_BIN_DIR = &WORK_DIR.\bin;
*** VALIDATE JAVA CLASSPATH;
data _null_;
   length _x1 $32767;
   _x1 = sysget('CLASSPATH');
   _x2 = index(trim(_x1), "&JAVA_BIN_DIR");
   if _x2 = 0 then put "ERROR: Invalid Java Classpath.";
run;
```

PROGRAM FLOW: MAIN_CALLER.SAS

The SAS program main_caller.sas contains the primary execution flow. After you successfully complete all the preceding configuration steps, you can run this program in a SAS session. The following sections sequentially explain the work done by this program.

JAVA: SASJAVAEXEC.JAVA

The Base SAS Java Object is used to call the Java class SASJavaExec. This class provides a universal mechanism for calling Python, R, or executables in other languages from SAS. It has two methods: main and runExec.

The main method creates a new Process object; assigns STDIN, STDOUT, and STDERR streams to separate threads; and executes the commands that are passed in as arguments. The STDOUT and STDERR streams carry log and error output messages, respectively, and print them to the SAS log. When an error occurs (say, in a Python or R script), execution is halted and SASJavaExec quits the external process with an exit return code of 1. In this paper, the arguments are calls to Python and R scripts, but they can be any valid executable command and their necessary command line arguments.

Although runExec is never used in this example, it is an alternative to the main method and provides a timeout option to force an external process to quit after a certain predefined period of time in minutes. This method can be used to prevent an errant process from hanging.

PYTHON: EXECUTING DIGITSDATA_SVM.PY

In the following DATA step, the Java Object is instantiated by giving the class name (dev.SASJavaExec) and its two constructor arguments. The constructor arguments are the commands that include the location of a Python executable (C:\Anaconda\python.exe) and the Python script to be executed (digitsdata_svm.py) along with any arguments that need to be passed to that script through STDIN as additional command-line arguments. The main method in SASJavaExec then executes the concatenated string of the two constructor arguments. Additional parameters that are passed to the second constructor argument are treated as command-line arguments by the script.

In the following example code, WORK_DIR is passed in as an argument to the Python script in the python_call variable. This is necessary because the script needs access to the working directory, from which input data are read and to which output data are written.

```
*** SYSTEM PYTHON LOCATION (----- USER UPDATE NEEDED -----);
%let PYTHON_EXEC_COMMAND = C:\Anaconda\python.exe;
/*** Part I: Python ***/
data _null_;
   *** Python script takes working directory as first argument;
   python_pgm = "&WORK_DIR.\digitsdata_svm.py";
   python_arg1 = "&WORK_DIR";

   python_call = cat('"', trim(python_pgm), '" "', trim(python_arg1),'"');
   declare javaobj j("dev.SASJavaExec", "&PYTHON_EXEC_COMMAND",
                     python_call);
   j.callStaticVoidMethod("main");
run;
```

The digitsdata_svm.py script uses the pixel intensity values for each image in the training data to build an SVM model that assigns a label to the handwritten digits. The fitted model is then used to assign a predicted label to the images in the test data. The assigned labels are output to a CSV file named predict_test_python.csv in WORK_DIR.

The following example Python code from digitsdata_svm.py shows an SVM model fitting the training data and scoring the test data. Output 1 contains statements from the SAS log after successful execution of this step.

```
clf = svm.LinearSVC()
clf.fit(X, y)
pred = clf.predict(Xtest)
```

```
Executing "C:\Anaconda\python.exe C:\SGF2015\OpenSrcIntegration\digitsdata_svm.py
C:\SGF2015\OpenSrcIntegration" ...
Forking external process ...
dev.StreamManagerThread consuming STDOUT ...
dev.StreamManagerThread consuming STDERR ...
dev.StreamManagerThread consuming STDIN ...
Forked external process exit value 0.
NOTE: DATA statement used (Total process time):
      real time           4.29 seconds
      cpu time            0.00 seconds
```

Output 1. Output from SAS Log after Executing the Python Script

R: EXECUTING DIGITSDATA_SVM.R

The execution of the R script is very similar to that of the Python script. The only difference is that instead of Python executable and script names, the R executable and script names are passed as the constructor arguments. Here, R_EXEC_COMMAND points to Rscript.exe because it is the command-line alternate to the R graphical user interface (GUI).

```
*** SYSTEM R LOCATION      (----- USER UPDATE NEEDED -----);

%let R_EXEC_COMMAND= C:\Program Files\R\R-3.1.2\bin\x64\Rscript.exe;

/*** Part II: R ***/

data _null_;

   *** R program takes working directory as first argument;

   r_pgm = "&WORK_DIR.\digitsdata_svm.R";
   r_arg1 = "&WORK_DIR";


   r_call = cat('"', trim(r_pgm), '" "', trim(r_arg1), '"');
   declare javaobj j("dev.SASJavaExec", "&R_EXEC_COMMAND", R_call);

   j.callStaticVoidMethod("main");

run;
```

Much like the Python script, the R script digitsdata_svm.R uses the training data to build an SVM model, which is then used to make predictions of the digit label for the test data. The output is written to a CSV file named predict_test_R.csv in WORK_DIR.

The following example code from digitsdata_svm.R shows the SVM model fitting the training data and scoring the test data. Output 2 shows statements from the SAS log after successful execution of this step.

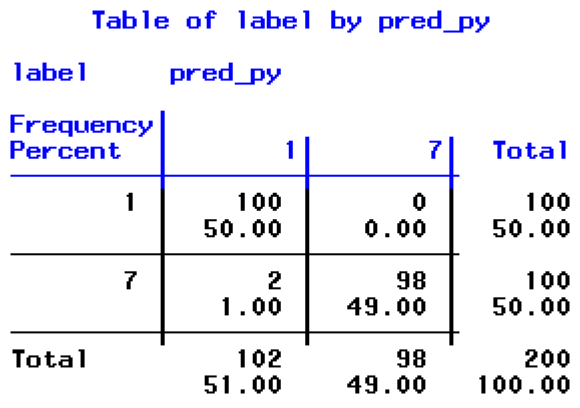
```
svmmodel = ksvm(label~., data=train, type='C-svc', scaled=c(FALSE))
pred = predict(svmmodel, test[, -1])
```

```
Executing "C:\Program Files\R\R-3.1.2\bin\x64\Rscript.exe
C:\SGF2015\OpenSrcIntegration\digitsdata_svm.R C:\SGF2015\OpenSrcIntegration" ...

Forking external process ...

dev.StreamManagerThread consuming STDOUT ...

dev.StreamManagerThread consuming STDERR ...

dev.StreamManagerThread consuming STDIN ...

STDERR> Loading required package: methods

STDOUT> Using automatic sigma estimation (sigest) for RBF or laplace kernel

Forked external process exit value 0.

NOTE: DATA statement used (Total process time):

      real time           1.98 seconds

      cpu time            0.00 seconds
```

Output 2. Output from SAS Log after Executing the R Script

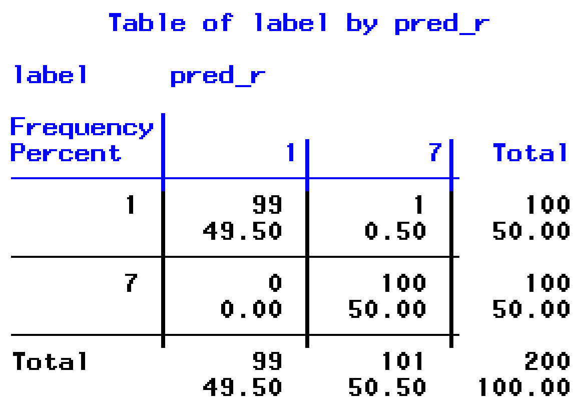
ASSESSING RESULTS IN SAS

The last step is to bring all the test data predictions together by using PROC IMPORT in Base SAS to convert CSV files that were produced by Python and R scripts into SAS data sets. Figures 1 and 2 are produced by using PROC FREQ, which prints confusion matrices that compare the actual and predicted label assignments.



```
      Table of label by pred_py

label      pred_py

Frequency|
Percent  |       1|       7|  Total
---------+--------+--------+
       1 |     100|       0|    100
         |   50.00|    0.00|  50.00
---------+--------+--------+
       7 |       2|      98|    100
         |    1.00|   49.00|  50.00
---------+--------+--------+
Total          102       98     200
             51.00    49.00  100.00
```

Figure 1. Actual (label) versus Predicted (pred_py) Using SVM in Python



```
        Table of label by pred_r

label       pred_r

Frequency|
Percent  |       1|       7|  Total
---------+--------+--------+
       1 |     99 |      1 |    100
         |  49.50 |   0.50 |  50.00
---------+--------+--------+
       7 |      0 |    100 |    100
         |   0.00 |  50.00 |  50.00
---------+--------+--------+
Total          99      101      200
            49.50    50.50   100.00
```

Figure 2. Actual (label) versus Predicted (pred_r) Using SVM in R

The misclassification rate, which is defined as the proportion of misclassified predictions out of the total is 2/200 (1%) for the SVM model in Python and 1/200 (0.5%) for the SVM model in R. (The goal of this paper is not to build the best or most comparable models between Python and R, but to show how these packages can easily be integrated with SAS.)

SUMMARY

This paper gives an example of how data can be manipulated, modeled, scored, and assessed using SAS, Python, R, and the Base SAS Java Object. However, the presented integration scheme is not limited to the Python and R scripts. The functionality in Base SAS to run Java programs by using the Base SAS Java Object is a flexible and powerful integration tool that enables users to mix and match techniques from many different types of third-party software.

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