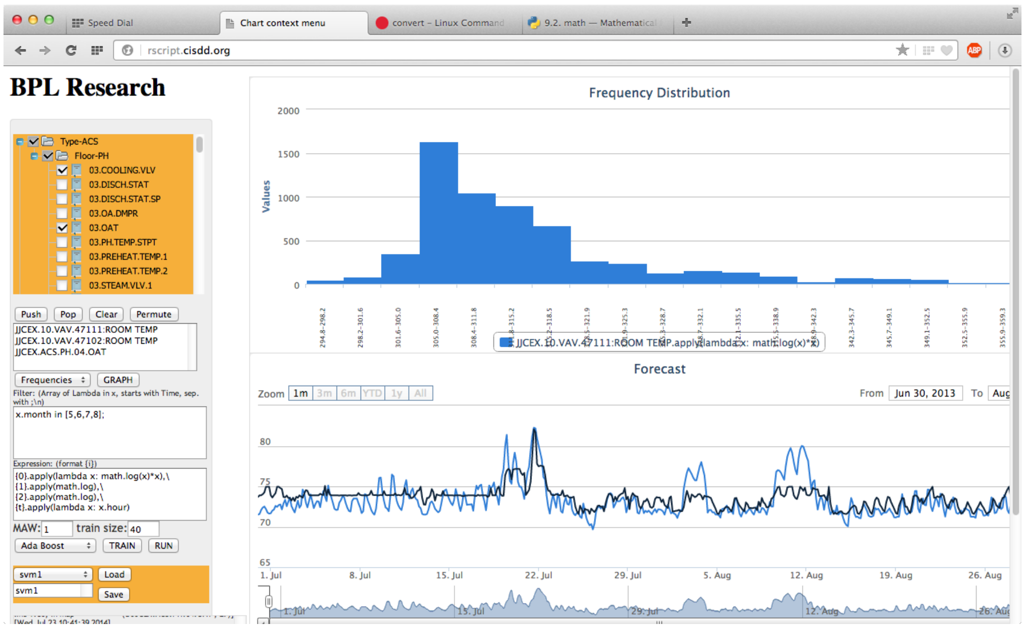
BPL Lab User Guide

Abstract

This document is meant to explain how to make use of a Web application 'rscript.cisdd.org' that offers some basic tools to perform research on a building's functioning using sensor data or other data such as weather: visualization, basic statistics and forecasting.

Questions should be addressed to the developer, Eric Dagobert, a PhD student at the CUNY Graduate School. The application makes use of Django/Python, the application data model is based on Panda objects and exposes a small set of Python functionalities to the user.



1 Data Sources and Graphing

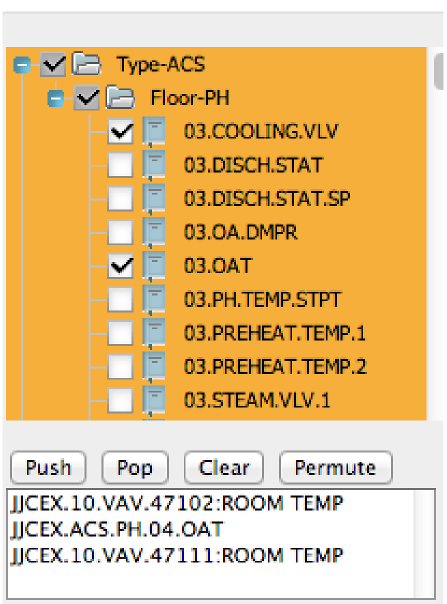
The site is provided with a collection of sensor data coming from the John Jay's building management system. As of today, it contains data from hundreds of sensors collected every fifteen minutes for over more than one year. Data is stored on a local slqlite database and updated asynchronously by a separate process. This architecture guarantees a quick and constant access time to data allowing complex computations in a reasonable amount of time.

1.1 Introduction

There are five windows that are used in the system. They are in order of going down the screen, the Selection window, the filter box window, the expression box window, and the expressions to learn from window. Not all windows need be used in any exercise. The first one for is necessary any new run as it is used to choose which of the many sensors to use in the run.

1.2 choosing the sensors for the run

The sensors that the system has data for are presented in a a tree-like fashion, ordered by type, location and name:



1.3 The Selection Window

The Selection Window will contain reference data that will be used during the analysis session. Users first choose what they want to include in the graphs and/or the calculations. A mouse click on a plus sign on the left expands the type of sensor to location, which is expanded to a mouse click on any of these expands the list to sensor name at the lowest level. To get these choice or choices into the selection window one clicks on the "PUSH" button below the window. By clicking in the box next to the sensor name, floor, or sensor category, users choose one or several sensors, entire floors, or an entire categories. Once chosen, one must transfer their selections into the Selection Window, the first open window, by pressing the "Push" button below the window. These steps can be done multiple times,allowing the hoosing of additional items.

Besides the "Push" button there are three others. To modify the order sequence of the listed sensors in the window, the button 'Permute' (see its use below) will swap the selected item with the first item in the list. 'Clear' will clear all items and 'Pop' will remove the selected item.

If one just wants to graph the selected items against time, the "GRAPH" button below can be pressed. (The default is a time series (one of the choices to the left of the "GRAPH"botton; the other choices are described below.) The following windows allow more other often complicated calculations to be done on the chosen items, such as only choosing some time periods, doing computations on the sensor values, and restricting the sensor values to be graphed or included in calculations.

Raw Data

Below the selection box are two buttons : 'Filtered' and 'Unfiltered'. The purpose of these is to display all of part of raw data without any transformation except filtering: the filter box can be applied or not. By default the entire selection is drawn. But choosing particular sensors is possible by selecting the ones to be drawn with Mouse Right Click, CTRL+Click and SHIFT+Click. This feature is very useful to compare data before and after transformation.

1.4 The request box

Another way to select sensors is to use a formula . The request box contains a 'select' request to add a set of sensors instead of a manual selection.

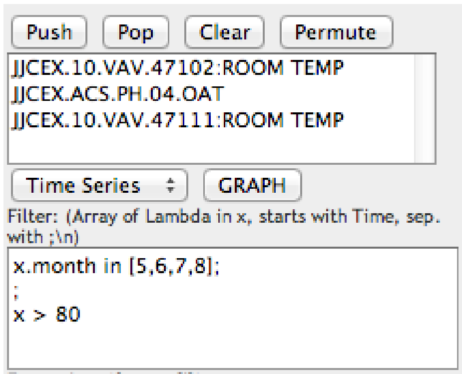
```
select(type = 'VAV", subtype = ['RM STPT DIAL','ROOM TEMP'],
floor = 6,
nexp = '47*',
pattern ='({i} - {i+1})',
cond='cmax(x,4)',
maxn = 20)
```

all parameters are optional.

- **type** and **subtype** are by default VAV and dial temp/room temp but can be anything
- **nexp** is a regular expression to filter out room numbers
- **pattern** is the type of operation, or expression, applied on a sensor 'i' . For instance i - i+1 computes the difference between sensor i and sensor i+1. Can be any arithmetic operation.
- **cond** : is a condition to be applied on the expression. Can be any function
- **maxn** :is the max number of sensors to be displayed

1.5 The filter box

Right under the selection stack we have the filter box. The purpose of this box is to keep only those parts of the sensor or time line that the user wants to be kept. For example one can choose to only keep month 6 (June) or sensor values greater than a value any expression composed of sensor values. For the purposes of filtering the rows (items) in the Selection Box are implicitly indexed (0,1,2 etc.). The index references are used during the filtering and the formatting phases. The user writes expressions in the form of Python lambda functions in 'x' to filter out input data. The filters are separated by ';' followed by a return. Each line matches with the corresponding sensor from the Selection Stack, starting with the time axis. That is the first line is used to filter the time axis, then line two for the first sensor listed on the stack, followed by sensor 2 , etc.



In this example we want data for which the observation month is either 5,6,7 or 8. There is no constraint on sensor 1, and sensor 2 must have values greater than 80.

1.5.1 The time axis filter

More on filtering of the time. Time can make use of built-in Python functions which the following members are defined:

```
x.year, x.month, x.day, x.hour, x.minute
```

Year is four digits, month is numeric, day is numeric 1 (sunday) through 7, hour is a 24 hour clock

Also:

```
x.weekday(), x.replace()
```

One can even do comparisons with a datetime object:

```
x >= datetime(2013,2,1)
```

The complete documentation is available at :

https://docs.python.org/2/library/datetime.html#datetime-objects

1.5.2 lambda x

Almost all the sensors are represented as float 64 values, thus filters will apply to Python floats. Boolean expression and math functions are allowed, so it is possible to build complex queries, but sub function definitions are not authorized. Math functions must be prefixed by 'math.' . Example :

```
math.log(x) > 2 and math.sin(x) == math.pi;
```

More on Python expressions:

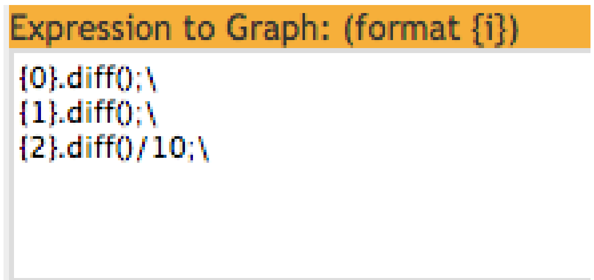
https://docs.python.org/2/reference/expressions.html

More on Python math module:

https://docs.python.org/2/library/math.html

1.6 The expression boxes

There is two expression boxes: one for graphing of data, and the other for learning. The first, under the filter text field is used for graphing. It allows additional to the chosen sensors expressions to be part of the graph output. It is in fact like a Python string format expression, but it is destined to be evaluated by the Python interpreter within the context of the analysis: Every input is represented by a format field within brackets: {0},{1}, etc.



Behind these templates are Pandas objects, more precisely Pandas columns. One has to see the output as a table where every column represents a particular sensor (plus the time). What is evaluated prior to graph is in fact a formatted expression. Basic arithmetics and special functions are allowed, as well as basic boolean expressions (for which we will prefer using the filter box because the syntax is much lighter).

- Reordering the output is then permitted :

  ```
  {1};{0};{2}
  ```

  will display sensor 2, sensor 1 then sensor 3. This will be useful during the forecast/training phase. Note : counting must starts at 0 and increments by 1.

- Basic arithmetic:

  ```
  {1} - {0}; abs({1} - {0}); {1} - {0}/{1}*200
  ```

- Basic Pandas built-ins (only those that returns a set) :

```
{0}.diff(); {0}.pct_change();{0}.cumsum()
```

- Special 'apply' function that allows math or lambda expressions:

```
{0}.apply(math.sin); {0}.apply(lambda x : x if x <= 0 else math.log
```

- Special field '{t}' to access time axis: {t} represents a datetime object

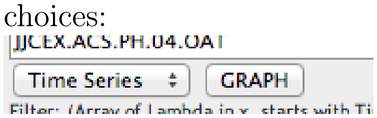
```
{t}.hour%4
{t}.weekday()
```

The complete Pandas documentation on basic functions and expressions is available here:

`http://pandas.pydata.org/pandas-docs/stable/basics.html#function-application`

1.7 Graph Types

Several graph types can be created. The following menu gives the possible choices:



Data will be filtered out according to the filter box and several graphs will be created following the template defined in the format box.

- Time Series: Y's are the data, X is the time.
- Moving Std: That will compute, for every data, the MA plus +/- 2 standard deviations computed on a rolling period of 20 ticks (20 *

15 minutes). It shows trend and values which are outside the STD envelope are likely to be 'abnormal'.

- XY : X axis is the first entry corresponding to the forma, Y's are the next ones. By default X is going to be the element on top of the stack. But it is possible to graph more complex expressions; for instance {2}-{1},{0} in the format box will display (sensor 2 - sensor 1) in X and (sensor 0) in Y. XY values are sorted and unique.
- Correl: Shows a rolling windows (20 elements) of cross correlations between the first set of values compared to the others.
- Frequencies: Show an histogram of the value distribution, only for the first element (for readability reasons)

All this types are compatible with filters and formats detailed above. Note:In the latest version we added the possibility to display raw/input data, filtered or unfiltered, along computed expressions and machine learning statuses.

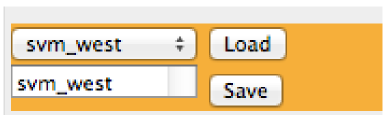
2 Persistence

The lab allows some basic persistence, it is possible to save/load a context under a given name. The context consists in :

- sensor list
- graph type

- filter box and expression boxes
- MAW and training size
- Machine type and learned set (if it exists)

To create a new context, simply type a name in the field :



The new name is then added to the menu and can be loaded.

Training a new set will automatically save it, and if a name is not provided then it will be saved under generic name 'tmp'.

Context are stored on the server so every user can see them and thus share their own sets.

Deleting a set is not possible for now and must be manually done by the developers.

3 Machine Learning

BPL Research offers some machine learning features: from a given set of data a machine can be trained and forecasts a specific output.

Machine input and output are defined the same way as graphs: Filters are applied to the selected stack and an expression is eventually computed.

From there, 'Learn' button will start training. The reference output is the first value defined in the Expression Box (by default it is the top sensor on the stack) at T + 1 tick.

Inputs are the other values at T. Learning results are shown as a graph comparing training values to forecast.

Training parameters are :

- MAW : moving average period (in ticks). A training/forecast can be performed on moving average data instead of raw data. A MAW of 1 means no moving average.
- Train size: size of training set as a percentage of the input set. The training set is uniformely sampled from the data set.
- Machine type: as of today : SVM with Poly kernel, Gaussian multinomial, Logistic Regression and SVM Laplace kernel.

Machine learning is entirely based on the Python Sci Kit libraries, and adding new models can be done easily. More information on SciKit :

`http://scikit-learn.org/stable/index.html`

So far, we have noticed that the best regressor seems to be SVM.

After training ('Learn' button), the trained set is saved as part of the selected configuration and it's then possible to run it against a different set of parameters, by modifying the sensor stack or the expression box. Beware of the fact that the number of input must be the same.

4 Advanced Features: Python plugins

Users can upload their own python code and run it through the Expression box. A sandbox environment is under development as of today. But simple functions can yet be written. Any python file can be uploaded and dynamically imported with buttons 'Choose File' and 'Upload'. As the sandbox is not created yet, one must be very careful using this feature because it can lead to a server crash. The plugin python code is uploaded in the expression box running context and therefore the data model is accessible to new functions. Here the data model is based on Pandas. Plugins are exported in the application boxes through the namespace 'P'.

4.1 Apply method

In this application, selected datas are taken from a local DB and turned into Pandas data frames, on which the Filter and Expression are applied. The simplest way to add python code is through the Pandas 'apply' method that calls a function on every row/column of a Pandas table. We have seen in 1.5 how to run lambda functions on the data, now we can extend this to regular python functions. For example an expression such as:

```
pdata.apply(f, axis=1)
```

will call the function 'f' on the entire data frame, f taking a row in argument:

```
def f (row):
```

```
        return row[1] + row[2] etc.
```

Here, every index of the argument represents a data in the order of the selection.

4.2 Generic call

Furthermore, a generic data frame can be displayed if it respects the format of the application. It is then possible to dig directly into the database and construct whatever data frame to be displayed. The constraint is such code must return a Pandas data frame with a datetime index. Then the dataset can be graphed with all the existing options or used as a learning set. Functions used by the application to retrieve sensor data and training features can be reused as well.

```
def run():
    rng = pandas.date_range('1/1/2011', periods=72, freq='H')
    return pandas.Series(numpy.random.randn(len(rng)), index=rng)
```

Calling 'P.run()' will graph a random data set.

5 Notes on code

The entire application is based on Python, the front end being HTML and JavaScript, and the framework is based on Django.

Source is available from CVS : :pserver:eric@rscript.cisdd.org:/home/eric/cvsrepo