

# Wrapnumpy3 User Manual

- Package wrapnumpy3
- Module name wrapnumpy3
- class names Matrix and Utilities
- File wrapnumpy3.py

## Purpose

### Basic Matrix algebra using numpy in Python 3

The objective of this matrix algebra module is to provide an easy access to the power of **numpy** for elementary matrix operations of linear algebra, including the solution of linear equations and matrix inversion. Wrapnumpy3 wraps the all powerful numpy module, using Python 3.2 for easy access that facilitates the choice and use of numpy module.

## Usage

Install the module with the standard command

```
sudo setup.py install
```

After the installation check that the module is functioning as expected:

```
cd wrapnp3-tst
./testwrap3.py
This works, if no failures reported...
```

Unit test program **testwrap3.py** checks that the module **wrapnumpy3** is installed and functions correctly.

In the following we are providing examples. Preferably, the examples should be entered by hand in the Python Shell of the "Idle" IDE, executed and verified. They can also be entered into a Python Shell that opens up on the terminal after Python is invoked in CLI.

At this stage all examples are solved by Python 3.2. They are likely to work in Python 3.x with  $x \geq 1$ , though that has not been verified. A Linux platform is assumed, but the examples should run under other OS's as Python was and remains a programming environment that runs on most OS's.

## Basic Introduction to Matrix Algebra.

### Matrices from Simultaneous Equations

For wrapnumpy3 we postulate that all entries in matrices are floating point numbers, or integers, which will be automatically converted to floats. Actually, that is the case for many kinds of applications.

Commonly matrices are used to represent simultaneous linear equations. Consider an example:

```
c11*x1 + c12*x2 + c13*x3 = rhs1
c21*x1 + c22.x2 + c23*x3 = rhs2
c31*x2 + c32.x2 + c33*x3 = rhs3
```

In matrix form this can be written in three matrices:

```
[cmat] * [x] = [rhs]
```

where square brackets indicate matrices. **cmat** has 9 terms arranged in 3 columns of rows, each row with 3 entries. We say that it is a 3 by 3 matrix. **[x]** has 3 terms and is usually written as a column and we say that it is a 3 by 1 matrix with entries  $x_1$ ,  $x_2$  and  $x_3$ . The  $(3 \times 1)$  matrix  $x$  are the unknowns, whilst terms of the  $(3 \times 1)$  **[rhs]** matrix are the given data. Most frequently we will want to determine the unknowns **[x]**. That is the most basic operation of matrix algebra.

Consider a numerical example:

```
5 *x1 + 6 *x2 + 7 *x3 = 18
10*x1 + 12*x2 + 3 *x3 = 25
20*x1 + 17*x2 + 19*x3 = 56
```

All the numbers are floats, though in the example their values are whole numbers, so it is permissible to enter them as floats. A  $(3 \times 3)$  matrix of is created in one statement:

```
>>> from wrapnumpy3 import wrapnumpy3 as _m
>>> Matrix = _m.Matrix
>>> uts = _m.Utilities()
>>> cmat = uts.enterdata(3, 3, [[5, 6, 7], [10, 12, 3], [20, 17, 19]])
Echo check of enterdata
A matrix of dimensions (m x n), where m, n, LineLen = 3 3 5
 5.00000E+00  6.00000E+00  7.00000E+00
1.00000E+01  1.20000E+01  3.00000E+00
2.00000E+01  1.70000E+01  1.90000E+01
```

Similarly we enter right hand sides,  $(3 \times 1)$  matrix, rhs

```
>>> >>> rhs = uts.enterdata(3, 1, [[18], [25], [56]])
Echo check of enterdata
A matrix of dimensions (m x n), where m, n, LineLen = 3 1 5
 1.80000E+01
 2.50000E+01
 5.60000E+01
```

The data to enterdata procedure starts with the two dimensions of the matrix followed by data entries in a list of lists.

Each inner list is a row of the matrix. The automatic echo check can be disabled by specifying the last argument as False, which by default is True, so we have the verification of data in a printed format in "Echo check".

The rows and columns are numbered with a number sequence starting with zero in the usual Python manner.

It is possible to refer to each element of a matrix in the Pythonic way as **rhs[i][j]** or in a matrix customary way as **rhs[i, j]** . **It's your choice!**

## Solution of equations

We are now ready to get the solution as matrix solution:

```
>>> solution = cmat ** rhs
>>> solution.neatprint()
A matrix of dimensions (m x n), where m, n, LineLen = 3 1 5
```

```
1.00000E+00
1.00000E+00
1.00000E+00
```

The solution is obtained in the first line of the code above. Each matrix, "knows" various matrix methods, including the `neatprint()` method that prints out the matrix in a neat format.

The simplicity of solution is not really a coincidence-we chose the rhs matrix to give a simple answer :)

As you may have noticed, there are many ways of printing a matrix. The user can choose which command is appropriate. Many commands can be classified as high and low. This is best shown with an example. Consider a matrix operation:

```
>>> cmat = amat * bmat
```

This is a high level command. It is easy to see that `cmat` is the product of `amat` and `bmat`. In matrix algebra we would say that `amat` is post-multiplied by `bmat`. If you look into the program, you would find that the above high level command calls a low level command:

```
cmat = amat.matmult(bmat)
```

You will agree that this is not as clear as the high level command, but we could use it directly and would get exactly the same answer. So we recommend that whenever there is a choice of a high level command, use it, rather than its lower level equivalent.

Some commands are only available in low level, as there is no equivalent in algebra of scalar numbers. For instance, for a transpose of a matrix there is only a low level command, viz:

```
bmat = amat.mattranspose()
```

We could use some contrived symbol to designate the transposition, but that is not very useful, as an artificial symbol would not help us to remember the command.

In the following, when there are several commands that give the same result, we will occasionally mention which are the high and which are the low level. We will now describe most commands of `wrapnmpy3` module.

## Commands

### Make a matrix:

Command:

```
amat = Matrix(m, n)
```

creates a (m×n) matrix with **m** rows, each row **n** entries long. All entries are filled with zeros. The dimensions **m** and **n** are stored within the matrix `amat` as `amat.m` (no of rows) and `amat.n` (length of rows). This instantiation creates a `Matrix` object, named `amat`. As a consequence object `amat` has access to all `Matrix` methods and other attributes - matrix dimensions and entries.

We already discussed another way of creating a matrix and at the same time fill it with entries:

```
amat = uts.enterdata(m, n, [list of lists of entries])
```

## Output

The module provides several methods of outputting a matrix. Output can be obtained simply by using the print command:

```
>>> print(amat)
```

Let us look at an example:

```
>>> amat = Matrix(2, 3)
>>> print(amat)
[0.0, 0.0, 0.0]
[0.0, 0.0, 0.0]
```

This looks OK when all the terms are about the same size, but let us look at an example when some entries are much longer than others:

```
>>> amat = uts.enterdata(2, 3, [[7, 2/3, 15], [4, 5, 6]], False)
>>> print(amat)
[7, 0.6666666666666666, 15]
[4, 5, 6]
```

Now that does not look so good, does it? Let us call a low level command to help with a neater formatting. The command has an appropriate name, **neatprint**:

```
>>> amat.neatprint()
A matrix of dimensions (m x n), where m, n, LineLen = 2 3 5
  7.00000E+00  6.66667E-01  1.50000E+01
  4.00000E+00  5.00000E+00  6.00000E+00
```

I think you will agree that this is neater than `print(amat)`.

A special print function that is handy for gui development is **printline**. Printline simulates appending text to a `plainText` widget of PyQt:

```
line = string          printline(line)
```

## Matrix Addition

```
cmat = amat + bmat
```

The above is the high level version. The same result can be had with the following low level matrix addition command:

```
cmat = amat.matadd(bmat)
```

## Matrix Subtraction

```
cmat = amat - bmat
```

with its low level equivalent:

```
cmat = amat.matsub(bmat)
```

## Matrix Multiplication

```
cmat = amat * bmat
```

with its low level equivalent:

```
cmat = amat.matmult(bmat)
```

A reminder: `amat * bmat` is in general not the same as `bmat * amat`.

What about multiplication of a matrix by a scalar? In high level there is no change in syntax:

```
cmat = scalar * amat
```

The low level version is:

```
cmat = amat.scalarmult(scalar)
```

Low level syntax in this case is not as clear, is it? Please notice that matrix multiplication by a scalar scales the matrix in-situ, so that in the both formulae above the **amat** matrix is scaled by the scalar factor.

So what happens if we now want to multiply two scalars? Well, there is no confusion - scalar multiplication will be performed correctly, because `wrapnumpy3` passes the operation to *standard* Python. On the other hand, if the two matrices are incompatible for multiplication, an exception will be raised.

## Solution of Simultaneous Equations

We already saw an example of solution of linear simultaneous equations in the introduction:

```
solution = amat ** rhs
```

Its low level equivalent is:

```
solution = amat.solve(rhs)
```

This is probably the most frequently used facility of the `wrapnumpy3` module. It can be used to determine the inverse on account of the following matrix equation:

```
solution = amat ** I
```

where **amat** is a **(nxn)** matrix, and **I** is a **(nxn)** unit matrix. It is trivial to prove that the **solution** of this system of equations is the inverse of **amat**.

## Inversion of a Matrix

```
inverse = ~ amat
```

Take care, `~` is a tilde. The low level equivalent is:

```
inverse = amat.matinvert()
```

**amat** is a square matrix and **amat** is its inverse. Caution - not all matrices are invertible and even if they are invertible, they can be badly conditioned and our methods may be inadequate and yield inaccurate results.

A small example:

```
>>> amat = uts.enterdata(3, 3, [[3, 2, 1], [1, 4, 1], [1, 2, 6]])
Echo check of enterdata
A matrix of dimensions (m x n), where m, n, LineLen = 3 3 5
  3.00000E+00  2.00000E+00  1.00000E+00
  1.00000E+00  4.00000E+00  1.00000E+00
  1.00000E+00  2.00000E+00  6.00000E+00
```

Further:

```
>>> cmat = ~ amat
>>> dmat = cmat * amat
>>> dmat.neatprint()
A matrix of dimensions (m x n), where m, n, LineLen = 3 3 5
  1.00000E+00  -1.11022E-16  -2.77556E-17
  0.00000E+00  1.00000E+00  2.77556E-17
  0.00000E+00  0.00000E+00  1.00000E+00
```

The calculated inverse of **amat** is **cmat** and their product must be a unit matrix. It is nearly a unit matrix, **2.77556E-17** and other small numbers, are the effect of roundoff errors.

## Transpose of a Matrix

```
transpose = amat.mattranspose()
```

where **transpose** is the **amat** transposed.

## Convenience Methods

These are methods that are probably not essential, such as a method for creation of a unit matrix of a given size.

## Convert a Matrix to a Unit Matrix

```
amat.matunit()
```

An example:

```
>>> bmat = Matrix(3, 3)
>>> bmat.matunit()
>>> bmat.neatprint()
A matrix of dimensions (m x n), where m, n, LineLen = 3 3 5
  1.00000E+00  0.00000E+00  0.00000E+00
  0.00000E+00  1.00000E+00  0.00000E+00
  0.00000E+00  0.00000E+00  1.00000E+00
```

## Matrix Equality

The equality of two floats is debatable. Equality of two matrices of floats is even more debatable, on account of the round off errors that often render the equality meaningless, or rather the inequality meaningless. To assure the equality we need to measure every term in each matrix. If the terms are results of calculation, the matrices will appear unequal, even if theoretically they should be equal. So perhaps the equality check should not be included in a matrix algebra package. For what it is worth, wrapnumpy3 has an equality checking facility which returns **True** if all terms are equal, otherwise it returns **False**.

A numerical example:

```
>>> uts.enterdata(3, 3, [[3, 2, 1], [1, 4, 1], [1, 2, 6]], False)
[[3, 2, 1], [1, 4, 1], [1, 2, 6]]
>>> bmat = amat.matcopy()
>>> print(bmat == amat)
True
```

I think that the current version of numpy is 1.6.1. So why 3 in the name of wrapnumpy3? It is one writer's indication that the program is for Python 3. Enjoy!

Algis Kabaila, 2011-09-12, one day after the 10-th anniversary of an event that changed the world we live in.