1 Numpy

Numpy is the library that supports linear algebra operations. The two most important data structures are the n-dimensional array and the matrix. The matrix always has 2 dimensions. It is the matrix you should be using for most of your code in this course, so let’s look at some matrix operations in the Python interpreter.

First, let’s make a row vector, storing it as a matrix:

```python
>>> import numpy as np
>>> a = np.matrix([[1,3]])
>>> a
matrix([[ 1,  3]])
```

To make a column vector, we take the transpose.

```python
>>> b = a.T
>>> b
matrix([[ 1],
        [ 3]])
```

But b is not a copy of a, merely another way to view the same data. We see this by changing a value of a and then looking the the contents of b (they have been affected, too). To access an element we use two indices (always use 2 indices for a matrix, even if it has only one row or only one column!). The row index is first and the column index is second.

```python
>>> a[0,0] = 4
>>> a
matrix([[ 4,  3]])
>>> b
matrix([[ 4],
        [ 3]])
```

To decouple b from a, we make a copy of a:

```python
>>> b = a.copy().T
>>> b
matrix([[ 4],
        [ 3]])
>>> a[0,1] = 2
>>> a
matrix([[ 4,  2]])
>>> b
```
matrix([[4],
        [3]])

To see the shape of a, we use the shape field. This is very helpful for debugging. Instead of printing the contents of a, you can print the shape. It is a tuple: the first element is the number of rows, the second is the number of columns.

```python
>>> print a.shape
(1, 2)
```

Now let's look at slicing. First make a $3 \times 3$ matrix.

```python
>>> A = np.matrix([ [1, 2, 3], [4, 5, 6], [7, 8, 9] ])
>>> A
matrix([[1, 2, 3],
        [4, 5, 6],
        [7, 8, 9]])
```

Now we take the third column and then the second row.

```python
>>> a2 = A[:, 2]
>>> print a2
[[3]
 [6]
[9]]
>>> ab = A[1, :]
...]
>>> ab
matrix([[4, 5, 6]])
```

And we try to change an entry in the row vector ab using only one index. It fails:

```python
>>> ab[1] = 10
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
IndexError: index 1 is out of bounds for axis 0 with size 1
```

So, like good little programmers, we use two indices and it works. Also we see that we are changing the data in A. So, the slices are just views on the same data.

```python
>>> ab[0, 1] = 10
>>> a2
matrix([[3],
        [6],
        [9]])
>>> a2[1, 0] = 3.0
>>> a2
matrix([[3],
        [3],
        [9]])
>>> A
matrix([[ 1, 2, 3],
        [ 4, 10, 3],
        [ 7, 8, 9]])
```

The take-home message:

- Matrices are always 2D and you should use two indices to slice them or index into them
- Slicing and transposing a matrix does not also copy the matrix.