

# Octave Tutorial 3: Vector and Matrix Operations

with extracts from *Introduction to Octave*, by P.J.G. Long

In this tutorial you will learn how to

- distinguish between componentwise operations on matrices and matrix operations that are not componentwise.
- perform basic operations on vectors and matrices using the operators `+` `-` `*` `^` and `.`
- perform specific operations on vectors using built-in functions.

Storing a list of numbers in one vector allows Octave to use some of its more powerful features to perform calculations. If you are familiar with C or C++, you know that if you wanted, say, to multiply each element of an array by 2, you would have to use a `for` loop to step through each element. This can also be done in Octave, but it is much better (and faster) to make use of Octave's vector operators.

Matrix operations in Octave follow the rules of linear algebra. Let's start with addition and scalar multiplication of vectors. Recall that these are componentwise operations. This means that if we add two vectors  $X$  and  $Y$  we simply add each component of  $X$  to the corresponding component of  $Y$ . Matrix addition is defined the same way. Notice that in order to add two matrices, their dimensions must be identical. Try it! Define

```
octave#:#> X= [1 2 3];
octave#:#> Y= [2 2 2];
```

Now add the two vectors by typing

```
octave#:#> X+Y
```

Scalar multiplication and division are also componentwise operations. For example, to multiply all elements of the previously defined vector  $X$  by 3, simply type

```
octave#:#> X*3
```

What happens if you try to multiply two vectors? Try typing

```
octave#:#> X*Y
```

Octave complains about this because here the single asterisk `*` denotes matrix multiplication. As you know, matrix multiplication is not a componentwise operation, instead it is defined only if the dimensions of the matrices satisfy certain conditions. In order to perform the multiplication  $X*Y$ , vector  $Y$  would have to be a 3 by 1 matrix (i.e. a 3 row column vector). This means that the command

```
octave#:#> X*Y'
```

where we used the transpose operator `'`, would successfully show the result of the matrix

multiplication  $[1\ 2\ 3] \begin{bmatrix} 2 \\ 2 \\ 2 \end{bmatrix}$ .

If we insist on wanting to do a componentwise multiplication of matrices, we need to use the operator `.*` (a dot followed by a single asterisk). Try

```
octave#:#> X.*Y
```

and check that each component of the result is the product of the corresponding components of  $X$  and  $Y$ .

The dot in front of operators such as  $*$  / and  $\wedge$  means it's is an element-by-element operation.

Of course, you can always perform operations on individual elements of a vector or matrix. For example,

```
octave#:#> X(2)/Y(3)
```

will divide the second element of vector  $X$  by the third element of  $Y$ .

Now let's move on to more sophisticated operations. What happens if you pass a vector to a built-in function, e.g. `log` which is the function that computes the natural logarithm ? Try it! Let's redefine  $X$

```
octave#:#> X= [1 2 3];
```

Now type

```
octave#:#> log(X)
```

```
ans =
```

```
0.00000 0.69315 1.09861
```

Octave will return a vector of the same size in which each entry is found by performing the specified operation on the corresponding entry of the original vector. Another example, the sine function:

```
octave#:#> sin(X)
```

```
ans =
```

```
0.84147 0.90930 0.14112
```

For a list of predefined functions that can be used in Octave, see Tutorial 1.

The ability to work with these vector functions is one of the advantages of using Octave. Now complex operations can be defined that can be done quickly and easily. For example, imagine you'd like to know how a complicated function behaves on a certain interval, e.g.  $y = \frac{x \sin x}{1 + \cos x}$  for  $x > 0$ . The simplest way would be to plot its graph over a sufficiently large positive interval of values of  $x$ . In Octave this can be done with three simple commands. Start by defining a vector  $x$ , for example

```
octave#:#> x=[0:0.1:100];
```

Then build a vector  $y$  containing the values of the function  $y = f(x)$  at values of  $x$  specified by the elements of  $x$ . This sounds complicated but in fact it's just one command

```
octave#:#> y= x.*sin(x)./(1+cos(x));
```

Note that to perform the multiplication between  $x$  and  $\sin x$  and the division between the numerator and denominator we need to use componentwise operators, so for the multiplication it is not simply  $*$  but  $.*$  and so on.

Now plot the values of  $y$  against the corresponding values of  $x$  using the `plot` command,

```
octave#:#> plot(x,y)
```

The `plot` command will open a new window showing the graph of the function over the interval  $(0, 100)$  at steps of 0.1. Easy, isn't? You can then tweak the graph as you like. If you want to plot the graph on a different interval of values of  $x$ , change the length of  $x$ ; if you want a more refine grid to plot your graph, change the increment step in the definition of  $x$ .

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*Practice Problems*

1. Given  $\mathbf{x}=[1\ 4\ 6]$  and  $\mathbf{Y}=[-1\ 3\ 10]$ , use Octave to find the elements of the vector obtained by adding  $\mathbf{X}$  to twice  $\mathbf{Y}$ .
2. Given  $X = [1,4]$  and  $A = \begin{bmatrix} 3 & 1 & 6 \\ 5 & 2 & 7 \end{bmatrix}$ , use Octave to compute the elements of the matrix  $2XA$ .
3. Given a vector  $\mathbf{X}$ , explain the output of the command  $\mathbf{X}.\wedge 2$ . Test your answer on a few vectors.
4. Given the vectors  $\mathbf{X}$  and  $\mathbf{Y}$  defined in Exercise 1, what is the command required to divide each element of  $\mathbf{X}$  by the corresponding element of  $\mathbf{Y}$ ?
5. The Octave function `sum(X)` returns the sum of the elements in vector  $\mathbf{X}$ . Use this function to compute the sum over the columns of the matrix  $A=[2\ 4\ 1; 6\ 7\ 2; 3\ 5\ 9]$ .
6. Let  $\mathbf{x} = [2\ 9\ 1\ 16]$ . Use an Octave command to compute the square of each element of  $\mathbf{x}$ . Then use the function `sqrt` to compute the square root of each element of  $\mathbf{x}$  in the most efficient way.
7. Let  $\mathbf{x} = [2\ 5\ 1\ 6]$  and  $\mathbf{y} = [4\ 1\ 3\ 5]$ . Use an Octave command to divide each element of  $\mathbf{y}$  by the corresponding element in  $\mathbf{x}$ . Perform this calculation in the most efficient way.
8. Plot the sine function  $y = \sin x$  over its period. Then plot the function  $y = \sin\left(\frac{x}{2}\right)$  on the same interval.
9. Plot the function  $y = \cos(x^2)$  over the interval  $(0, 2\pi)$ .