

COMPARISON OF PROGRAMMING LANGUAGES FOR THE NUMERICAL ANALYSIS CLASSROOM

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On the next page are two algorithms each in MATLAB/OCTAVE (left column) and PYTHON (right column). To download these examples, go to bueler.github.io/M661F18 and follow the links.

A bit of background is useful. MATLAB (“matrix laboratory”; see mathworks.com) was created in the late 1970s by Cleve Moler for teaching numerical linear algebra without directly using FORTRAN calls. It has since become a powerful programming language and engineering tool. A large fraction of upper-division and graduate students at UAF, at least in technical majors, are already familiar with it. It is available in many labs and graduate student offices at UAF. It works well, looks good, and I like it. Note the “student (unbundled)” version at www.mathworks.com/academia/student.version.html, for \$49, works fine for the numerical mathematics classes I teach.

MATLAB is recommended if you have no existing preference, but I prefer free and open source software. Among the free alternatives to MATLAB are three which work very well for my courses:

1. OCTAVE is a MATLAB clone. Download it at www.gnu.org/software/octave. The “.m” examples on the next page, and throughout this course, work in an identical way in MATLAB and in OCTAVE. I will mostly use OCTAVE myself during the course, but I’ll also make sure examples work the same way in MATLAB.
2. The general-purpose language PYTHON (python.org) works very well if you use the SCIPY (scipy.org) and MATPLOTLIB (matplotlib.org) libraries. Then it has all of MATLAB functionality and more. Using it with the IPYTHON interactive shell (ipython.org) gives the most MATLAB-like experience.
3. The Julia language (julialang.org) is a modern redesign of MATLAB, but it is not a compatible clone like OCTAVE. It easy to learn. Equivalent codes run much faster than in MATLAB or OCTAVE.

Here are some brief “how-to” comments for the MATLAB/OCTAVE examples: Program `gaussint.m` is a *script*. A script is run by starting MATLAB/OCTAVE, usually in the directory containing the script you want to run. Then type the name of the script at the prompt, without the `.m`:

```
>> gaussint
```

Typing `help gaussint` at the MATLAB/OCTAVE prompt shows the block of comments as documentation. The second code `bis.m` is a *function* which needs inputs. At the prompt enter

```
>> f = @(x) cos(x) - x
>> bis(0,1,f)
```

for example. We have given `bis.m` three arguments; the last is a function.

For the PYTHON codes: You can do `python gaussint.py` directly from a shell. Alternatively, from the PYTHON or IPYTHON prompt, type `import gaussint`. For the function `bis.py`, first do `from bis import bis`. Then run the example as shown in the docstring. (In IPYTHON you can type `bis?` to print the docstring.)

gaussint.m

```
% plot the integrand and approximate
% the integral
%   / 1
%   |   exp(-x^2/pi) dx
%   / 0
% by left-hand, right-hand, and
% trapezoid rules

N = 1000;
dx = (1 - 0) / N;
x = linspace(0,1,N+1);
y = exp(- x.^2 / pi);

plot(x,y)
axis([0 1 0 1]), grid

format long
lhand = dx * sum(y(1:end-1))
rhand = dx * sum(y(2:end))
trap  = (dx/2) * sum(y(1:end-1)+y(2:end))
exact = (pi/2) * erf(1/sqrt(pi))
```

gaussint.py

```
#!/usr/bin/env python

# plot the integrand and approximate
# the integral
#   / 1
#   |   exp(-x^2/pi) dx
#   / 0
# by left-hand, right-hand, and
# trapezoid rules

from pylab import plot,axis,linspace,sum, \
                    pi,sqrt,exp,show,grid
from scipy.special import erf

N = 1000
dx = (1.0 - 0.0) / N
x = linspace(0.0,1.0,N+1)
y = exp(- x**2 / pi)

plot(x,y)
axis([0.0,1.0,0.0,1.0]); grid(True)

lhand = dx * sum(y[:-1])
print "lhand = %.15f" % lhand
rhand = dx * sum(y[1:])
print "rhand = %.15f" % rhand
trap  = (dx/2) * sum(y[:-1]+y[1:])
print "trap = %.15f" % trap
exact = (pi/2) * erf(1/sqrt(pi))
print "exact = %.15f" % exact
show()
```

bis.m

```
function c = bis(a,b,f)
% BIS Apply the bisection method to solve
%   f(x) = 0
% with initial bracket [a,b]. Example:
%   >> f = @(x) cos(x) - x      % define fcn
%   >> r = bis(0,1,f)           % find root
%   >> f(r)                     % confirm

if (feval(f,a)) * (feval(f,b)) > 0
    error('not a bracket!'), end
for k = 1:100
    c = (a+b)/2;
    r = feval(f,c);
    if abs(r) < 1e-12
        return % we are done
    elseif feval(f,a) * r >= 0.0
        a = c;
    else
        b = c;
    end
end
error('no convergence')
```

bis.py

```
def bis(a,b,f):
    """ BIS Apply the bisection method to solve
        f(x) = 0
        with initial bracket [a,b]. Example:

        from bis import bis
        def f(x):
            from math import cos
            return cos(x) - x
        r = bis(0.0,1.0,f)
        print([r,f(r)])

        """

    if f(a) * f(b) > 0.0:
        print("not a bracket!")
        return
    for k in range(100):
        c = (a+b)/2
        r = f(c)
        if abs(r) < 1e-12:
            return c # we are done
        elif f(a) * r >= 0.0:
            a = c
        else:
            b = c
    print("no convergence")
    return
```