CGN 3421, Homework 2, Fall 2018
Due Date: November 1, 2018

1. **Problem 1.** Write a Python function MultAll that takes 2 arrays of floats, A and B,of length M and N as inputs and returns an array AB that consists of a sorted array of all the products of $a \in A$ and $b \in B$.

   For example, if A = [2, 4, 6] and B = [3,7], then AB should be a sorted version of

   [2*3, 2*7, 4*3, 4*7, 6*3, 6*7]

   which is

   [6, 12, 14, 18, 28, 42].

   You will need to use the built-in Python function sorted() that sorts an array of numbers into ascending order. For example, after the function call AB = sorted([5, 2, 3, 1, 4]), the value of AB will be [1, 2, 3, 4, 5].

   Submit the function MultAll.

2. **Problem 2.** In programming, a *flag* is often used to refer to a variable that can have two values: True or False, which are often represented as 1 and 0. Write a Python function SecDeriv that takes a one-dimensional array f and a flag Forward as an input and:

   (a) If Forward is True, returns the estimated first and second derivatives, fp and fdp, of f using the *Forward Approximation* twice:

   $$\frac{df}{dt} = \frac{f\left(x + dx\right) - f\left(x\right)}{dx}.$$

   (b) If Forward is False, returns the estimated first and second derivatives, fp and fdp, of f using the *Backward Approximation* twice:

   $$\frac{df}{dt} = \frac{f\left(x\right) - f\left(x - dx\right)}{dx}.$$

   Test SecDeriv by discretizing $f\left(t\right) = sin\left(t\right)$ to a one-dimensional array f with 4 samples uniformly spaced in the interval $\left[0, \frac{\pi}{2}\right]$ and calling SecDeriv twice: once with f and True and once with f and False and comparing the result with hand calculation.

   Submit the function SecDeriv.

3. **Problem 3.**

Write a Python function, DispDeriv, that takes a one-dimensional array f and estimates of fp and fdp of the first and second derivatives of f produced by SecDeriv. The function should create a figure with one column of three subplots, one each for f, fp and fdp. The horizontal axis of every plot should be time and the vertical axis should be f, fp and fdp.

Call DispDeriv with Test SecDeriv by discretizing $f(t) = sin(t)\,cos(2t)$ to a one-dimensional array f with 180 samples uniformly spaced in the interval $[0, 4\pi]$ and calling SecDeriv twice: once with f and True and once with f and False.

Submit the function DispDeriv

4. **Problem 4.** Write a Python function, DispIm, that displays a two-dimensional array A as an image. Use the commands:

    ```
    from scipy import misc
    ```

    and

    ```
    A = misc.imread('PaulGaderCube.png')
    ```

    to read and display the image in the file PaulGaderCube.png.

    Submit the function DispIm.

5. **Problem 5.** This problem uses *polar coordinates* which you should have studied in Calculus. Write a Python function, PlotPolar, that takes three floating point arguments, a,b, c, and one integer argument n. PlotPolar should use plt.scatter from matplotlib.pyplot to plot the points (r, θ) where θ is obtained by selecting n uniformly spaced samples from the interval $[0, 2\pi]$ and $r = a + bcos(c\theta)$. Test your function by taking n = 3 and comparing the result to a hand calculation. Use PlotPolar to

    (a) Plot $r = 2 + 2cos(\theta)$.

    (b) Plot $r = 2 - 2cos(\theta)$.

    (c) Plot $r = 2 + 2cos(2\theta)$.

    (d) Plot the following on the same axis:

    i. $r = 2 + 2cos(2\theta)$ in Red,

    ii. $r = 2 + 2cos(3\theta)$ in Green,

    iii. $r = 2 + 2cos(4\theta)$ in Blue,

    iv. $r = 2 + 2cos(5\theta)$ in Magenta.