

BME 301 Numerical Methods in Biomedical Engineering HOMEWORK 1

DUE Friday January 27, 2023, 11:59 pm

Standard late policy applies (see Syllabus for details)

This homework shows effects of errors caused because computer representations of numbers have finite precision. It uses an example from numerical differentiation, which is covered after the midterm.

In numerical differentiation, the approximate first derivative of a continuous function f can be calculated from values at two points using the formula

$$f'(x) \approx \hat{f}'(x) = \frac{f(x+h) - f(x)}{h}$$

where $'$ means the derivative and h (the distance separating the two points) is a small number. The absolute difference (AD) between $f'(x)$ and $\hat{f}'(x)$ is

$$AD = \left| f'(x) - \frac{f(x+h) - f(x)}{h} \right|$$

- [2 points] Setting $x = 0.5$, and using the `sin` function for f , write down an expression for the AD . [f' is the exact derivative of f , and you know that well.]
- [3 points] Now write a MATLAB function that can compute the AD for any value of x or h .
- [3 points] Using a suitable graph, show the output of your function with x fixed at 0.5, and with values of h ranging from 10^{-1} to 10^{-16} .
- [3 points] An expression for an upper limit on the AD can be found using a Taylor series (we will cover these soon in the course). This is

$$EA = \frac{h^2 |f''(c)|}{2}$$

Where $''$ is the exact *second derivative* of f . Calculate and plot the expression EA on top of the expression for AD at $x = 0.5$, using the same range of h values.

- [2 points] Is there a portion of the graph where the EA agrees with or is larger than the AD ? Over what range does this happen?
- [2 points] Is there a portion of the graph where the EA is smaller than the AD ? Over what range does this happen?
- [5 points] Why would EA and AD agree in some places and not in others? If there is an h value where a switch between agreeing and not agreeing happens, is that number important?

The EA and the AD *should* be the same. This can be found by using the Taylor Theorem with $n=1$.

$$f(x+h) \approx f(x) + hf'(x)(x-h) + \frac{h^2 f''(c)}{2}$$

If we rearrange this equation, we find that

$$AD = \text{abs} \left(f'(x) - \frac{f(x+h) - f(x)}{h} \right) \approx \text{abs} \left(\frac{hf''(c)}{2} \right) \approx \text{abs} \left(\frac{hf''(x)}{2} \right) = EA$$

Remember that c is some number near x and $x+h$. We can guess at EA using $c=x$.

However, calculation of AD involves this term

$$\frac{f(x+h) - f(x)}{h}$$

Numerical Methods In Biomedical Engineering Solution Manual

Ying-Ying Zheng



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