Computing for Scientists - Lab 3

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1   Introduction

Computing the derivatives of functions are a critical step in most optimization problems. In this exercise, we will look at the sine wave or sinusoid, which desribes a smooth, repetitive oscillation. Its most basic form, as a function of time, is as follows:

$$f(t) = A * sin(\omega t + \phi) \tag{1}$$

In the equation above, A is referred to as the amplitude, ω is the angular frequency, and ϕ is the phase. In this program, you will implement an animation that draws the tangent line on the sine wave using the derivative for each point in the input domain (the number of elements in the domain vector is specified later in the assignment). You will approximate the derivative and draw the tangent line at each point as an animation.

One method to approximate derivatives for arbitrary functions is called *finite differences*. The basic idea is to look at a point $(x, f(x))$ and its neighbor to the right (called forward difference) $(x + h, f(x + h))$ or neighbor to the left $(x - h, f(x - h))$ (called backward difference), and approximate the slope using differences as follows:

$$\frac{d[f(x)]}{dx} = \frac{\Delta f(x)}{\Delta x} = \frac{f(x + h) - f(x)}{(x + h) - x} \tag{2}$$

You are to compute the derivative (forward) at each point in the domain using a for loop, and draw the tangent line, as in Figure 1, as an animation for all points (except last) on the time domain. The animation should be smooth, as you progress from left to right, the tangent should be horizontal on peaks and troughs because the derivative (or the slope) is zero.

Your program has to follow exact specifications as follows:

- The program has to prompt the user for A, ω and ϕ.

- The domain of the sine function will consist of 500 equally spaced elements between 0 and 4π.

- You have to use a `for` loop and iterate through `1:end-1`. elements of the domain.
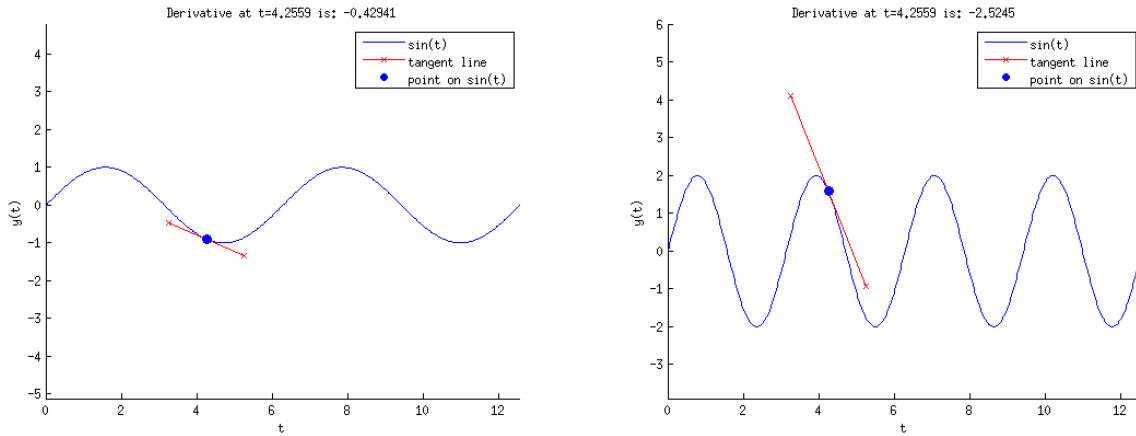
Figure 1: Sample visualization of derivative at a point on the sine wave. On the left: $A = 1$, $\omega = 1$, $\phi = 0$, on the right: $A = 2$, $\omega = 2$, $\phi = 0$.

- You have to implement forward differences to compute derivative value at each point .

- You will compute the tangent line using the slope and draw it with the `plot` command as two points, solid red, and x markers. The length of the tangent line is 2 seconds (from current $t - 1$ to $t + 1$).

- You will plot a blue solid dot at the point at which you are currently computing the derivative for using the `scatter` command.

- Your program will label the x-axis as t and y-axis $y(t)$.

- Your program will make a legend, exactly like the one given in the example figure above.

Figure title   The title of the figures in the examples above contain numbers. The `title` command takes a "string" argument, which can be thought of as a row vector of characters. For example `disp(['AB', 'CD'])` will display `ABCD`. The MATLAB function `num2str` converts a number to string. Take the following code as an example:

```
t = 3.433;
dt = 1.034;
figure_title = ['The derivative at t=', num2str(t), ' is: ', num2str(dt)];
title(figure_title);
```

The above code will set the current figure title to: "The derivative at t=3.433 is: 1.034". Use the code above as a guide to set your figure title as shown in the example Figure 1 above. This has to be done for every frame.

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2   Grading Rubric

Program Correctness (90 points)

Prompts user for sine wave parameters
Domain vector correct
Sine wave correct
For loop correct
Figure cleared every iteration
Forward finite difference correct
Tangent points correctly computed
Plot of tangent correct
Legend correct

Style and documentation (10 points)

Prolog (name & purpose)
In-code comments
Whitespaces

3   Hints

Start Early!!. Do not forget to `hold on;` when you have multiple plots per frame in an animation. You must be famililar with the `linspace` command in MATLAB. You also have to think about what your for loop iterates over. **I strongly recommend you loop over indices**, e.g.: `for x = 1:numel(domain)-1`. You have to get the slope before you can compute the tangent line. When computing the tangent line points, think about the general equation of a line i.e., $y = ax + b$. There are several options to do this, I would recommend the input domain of the tangent line to be $-1, 1$, then add the current point on the sine wave. In other words, think about the point at which you're computing the derivative, as the origin of your tangent line.

Finite Difference   In Equation 2, h is determined by the difference in consecutive elements of the domain. For example, if $x_1 = 1.00$ and $x_2 = 1.01$ then $x-(x+h)$ will be $x_2-x_1 = 0.01$. You do not have to specify a value for h directly, since you are doing something like $\frac{y(t+1)-y(t)}{x(t+1)-x(t)}$.

Due dates

1. Code: due Sunday, March 18th, before midnight.