ECE1401

Homework 7
Due April 26, 2024

Objective

Your task is to write two functions that can calculate the derivative and integral of an unknown function. Unknown functions typically arise because the function values come from data collected from a signal. In such cases, since you don't have a mathematical equation describing the function, you can't use the techniques you learned in Calc 1 and 2 to do the derivative or the integral. Therefore, you have to fall back on the definitions of a derivative and an integral.

To calculate the derivative, let's revisit the definition of the derivative:

$$\frac{df(t)}{dt} = \lim_{\Delta t \to 0} \frac{f(t+\Delta t) - f(t)}{\Delta t}$$

Let's assume that you set dt to a very small value, so that you can eliminate the limit. Therefore,

$$\frac{df(t)}{dt} \approx \frac{f(t+\Delta t) - f(t)}{\Delta t} = \frac{f(t) - f(t-\Delta t)}{\Delta t}$$

The second form of the derivative equation shows that your code can calculate the derivative by comparing the current value of the function (or signal) with the last value from the previous time point and dividing by Δt.

The integral term is the area under the function curve. From calculus, you should remember that you can approximate the integral by summing up all the signal points and multiplying by Δt. That means as you go through time, you can keep a running sum of the total signal values which represents the integral up to that point.

Writing the code

Here is the template for the function that you will need to complete:

```
function [df,intf] = dfint(f,dt)
    df=zeros(1,length(f));
    intf=zeros(1,length(f));
    % iterate over the f array and for each time value,
    % 1. calculate the derivative value by taking the current value
    %    of f, subtracting the previous value and dividing by dt
    % 2. Calculate the integral by keeping a running sum of the f
    %    values and multiplying by dt
end
```

The function takes in two arguments corresponding to an `f` array containing the signal data points and a `dt` value. If we assume that the data points are due to sampling a signal, the `dt` value is corresponds to the sampling period. The result of the derivative calculation will be put into the `df` array and the result of the integral calculation will be put into the `intf` array. Both arrays should have the same number of values as the `f` array.

You can rewrite the derivative equation in array terms as follows:

$$\frac{df_i(t)}{dt} = \frac{f(t_i) - f(t_{i-1})}{\Delta t}$$

where $f(t_i)$ is the i'th term in the `f` array and $\frac{df_i(t)}{dt}$ is the i'th term in the `df` array. You can assume that $f(t_0)$=0. Thus, `df(1)` will be equal to `(f(1)-0)/dt`, `df(2)` will be equal to `(f(2)-f(1))/dt`, `intf(3)` will be equal to `(f(3)-f(2))/dt`, and so on.

Likewise, the integral can be written as:

$$\int_0^{t_i} f\, dt = \Delta t \sum_{n=0}^{i} f(t_n)$$

where $\int_0^{t_i} f\, dt$ is the i'th term in the `intf` array. In other words, `intf(1)` will be equal to `f(1)*dt`, `intf(2)` will be equal to `(f(1)+f(2))*dt`, `intf(3)` will be equal to `(f(1)+f(2)+f(3))*dt`, and so on.

Here is an example of what you should get with $f = t^2$ and $dt = 0.001$

```
>> dt = 0.001;
>> t = [0:10000]*dt;
>> f = t.^2;
>> [df,intf] = dfint(f,dt);
```

I have uploaded to HuskyCT a "`dfint.mat`" file that contains the expected `df` and `intf` values. Make sure you download this to your MATLAB default directory. You can verify your results as follows:

```
>> load('dfint.mat');
>> sum(abs(df-dfexpected)<0.000001)==10001

ans =

  logical

  1
>> sum(abs(intf-intfexpected)<0.000001)==10001

ans =

  logical

  1
```

Depending on how you do the calculations, you may get some rounding errors that may cause your `df` and `intf` arrays to not exactly equal the expected values from the `dfint.mat` file. The code above will check that your answer is within 0.000001 of the expected values. If not, you will get 0 as an answer, and you will need to fix your code.