

# 16.216: ECE Application Programming

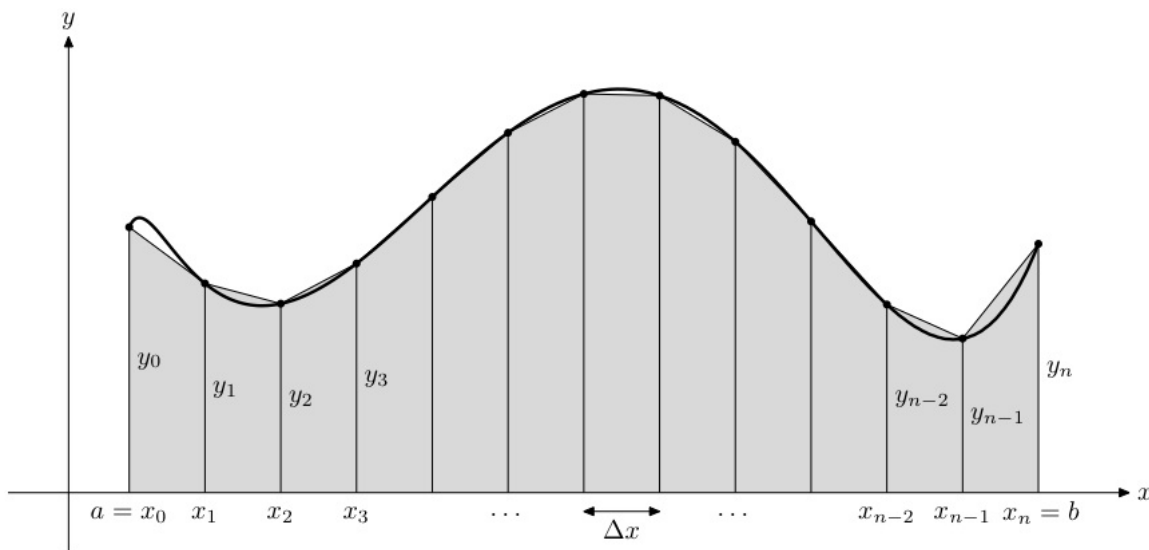
Summer 2014

## Programming Assignment #5: Integral Approximation with Functions

Due **Tuesday, 6/10/14**, 11:59:59 PM

### 1. Introduction

In this program, you will design functions that allow you to approximate the integral of a function,  $f(x)$ , using the trapezoidal rule. To find this integral—the area under the curve—we can approximate the area as a series of trapezoids, as shown below:



In the figure, the range  $[a, b]$  has been divided into  $n$  different trapezoids, each of which has the same base,  $\Delta x = (b - a)/n$ . Recall that a trapezoid with base  $b$  and sides  $h_1$  and  $h_2$  has area:

$$0.5 \times b \times (h_1 + h_2)$$

Therefore, the area of trapezoid number  $k$  ( $1 \leq k \leq n$ ) from the figure above is:

$$0.5 \times \Delta x \times (y_{k-1} + y_k) = 0.5 \times \Delta x \times (f(x_{k-1}) + f(x_k))$$

To find the total area under the curve—and therefore the approximate integral—sum the areas of all trapezoids:

$$\begin{aligned} \text{Area} &= 0.5 \times \Delta x \times (y_0 + y_1) + 0.5 \times \Delta x \times (y_1 + y_2) + \dots + 0.5 \times \Delta x \times (y_{n-1} + y_n) \\ &= 0.5 \times \Delta x \times (y_0 + y_1 + y_1 + y_2 + \dots + y_{n-1} + y_n) \\ &= 0.5 \times \Delta x \times (y_0 + 2y_1 + 2y_2 + \dots + 2y_{n-1} + y_n) \\ &= \mathbf{0.5 \times \Delta x \times \left( y_0 + 2 \sum_{k=1}^{n-1} y_k + y_n \right)} \approx \int_a^b f(x) dx \end{aligned}$$

Your integral function will use the equation shown in bold above to approximate the integral, given the endpoints of the interval  $[a, b]$  and the number of trapezoids,  $n$ .

## 2. Deliverables

Submit your source file directly to Dr. Geiger ([Michael.Geiger@uml.edu](mailto:Michael.Geiger@uml.edu)) as an e-mail attachment. Ensure your source file name is ***prog5\_integral.c***. You should submit only the .c file. Failure to meet this specification will reduce your grade, as described in the program grading guidelines.

## 3. Specifications

**Program structure:** Your program should follow the general outline below:

1. Prompt for and read the following values:

- The low and high points of the interval  $[a, b]$ , over which  $f(x)$  is to be integrated.
- The number of trapezoids,  $n$ , to be used in that integration.

If an input error occurs, print an error message and repeat the prompt for that input. Input errors are as follows:

- `scanf()` cannot read the input values (for example, if the user types "A 3" for the interval endpoints).
    - In this case, you must clear the rest of the line before retrying `scanf()`.
    - See Lectures 10-11: PE2 for a reminder of how to check that the input is properly formatted and how to clear the rest of the line if it is not.
  - The "low" interval endpoint is greater than or equal to the "high" endpoint.
  - The number of trapezoids is less than 1.
2. Once the user has entered error-free input values, call the `integrate()` function (described below), which will use the trapezoidal method to approximate the integral of  $f(x)$  over the interval  $[a, b]$  using  $n$  trapezoids.
3. After printing the results, ask the user if he or she wants to repeat the program, and then read a single character that serves as the response to that question. If the user enters:
- 'Y' or 'y' → Return to Step 1.
  - 'N' or 'n' → End the program.
  - Any other character → Print an error message and repeat the question.

See Section 4 for test cases that demonstrate the proper format for input and output.

**Functions:** Your program should contain the functions with the prototypes shown below, as well as any other functions you choose to add:

- `double f(double x);`

The function being integrated, which should calculate the value:

$$f(x) = \sin(x) + \frac{x^2}{10}$$

Note that you should include the math library `<math.h>` in order to use the `sin()` function; this function takes a single argument and returns the sine of that value.

- `double integrate(double a, double b, int n);`

This function should use the trapezoidal method to approximate the integral of  $f(x)$  over the interval  $[a, b]$  using  $n$  trapezoids, as described above. The return value of the function is the result of the approximation. Note that the function should not print any values to the screen—the output should be handled in the main function.

## 4. Test Cases

Your output should match these test cases exactly for the given input values. I will use these test cases in grading of your lab, but will also generate additional cases that will not be publicly available. Note that these test cases do not cover all possible program outcomes. You should create your own tests to help debug your code and ensure proper operation for all possible inputs.

```
C:\Windows\system32\cmd.exe

Enter endpoints of interval to be integrated (low hi): -2.1 1.5
Enter number of trapezoids to be used: 15
Using 15 trapezoids, integral between -2.100000 and 1.500000 is -0.148162
Evaluate another interval (Y/N)? Y

Enter endpoints of interval to be integrated (low hi): -2.1 1.5
Enter number of trapezoids to be used: 45
Using 45 trapezoids, integral between -2.100000 and 1.500000 is -0.153692
Evaluate another interval (Y/N)? Y

Enter endpoints of interval to be integrated (low hi): A 3
Error: Improperly formatted input

Enter endpoints of interval to be integrated (low hi): 5 4
Error: low must be < hi

Enter endpoints of interval to be integrated (low hi): 0 0.1
Enter number of trapezoids to be used: Q
Error: Improperly formatted input
Enter number of trapezoids to be used: 0
Error: numT must be >= 1
Enter number of trapezoids to be used: 10
Using 10 trapezoids, integral between 0.000000 and 0.100000 is 0.005029
Evaluate another interval (Y/N)? Q
Error: must enter Y or N
Evaluate another interval (Y/N)? N
```