Assignment #4 – Tree Growth and Tree Carbon

Part 1 Due Monday, May 13th 2024 at Midnight
Part 2 Due Monday, May 20th 2024 at Midnight

Assignment Overview and Outcomes

The focus of this project is on how to solve simple problems using primitive data types, variables, loops, and arithmetic operations. In this project, you will…

- Develop code to read data from the standard input and produce data to the standard output.
- Translate a given mathematical expression into equivalent syntactically correct programming statements.
- Write code that conforms to a programming style specified by the instructor.
- Select and implement the appropriate control structure(s) for this problem.

Be sure to properly document the program. Consult the Class Programming Style Guideline document (provided by the instructor) for style expectations. A well-written program is easier to debug, easier to maintain over time, and easier to extend as new requirements arise.

The United Nations (UN) has set forth 17 goals for sustainable development. Goal 15 is designed to "Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss." The effects of deforestation – both man-made and otherwise – can have a dramatic impact in a number of social, biological, and economic sectors. For example, many industries rely on trees or tree products as a fundamental component of their operations, whether it be for construction, paper, or agriculture.

Trees (and, consequently, forests) provide a number of benefits, but are a resource which takes time to replenish. In this project, we will consider the growth rate of trees.

Benefits of Trees

Trees provide a number of benefits for the environment. Trees are able to absorb dangerous gases such as carbon dioxide (CO_2) while, at the same time, producing oxygen for us to breathe. Trees also absorb and distribute water that otherwise may lead to runoff, thus reducing pollution and loss of topsoil. Some forms of trees even produce food for us to eat (think: apple trees) and provide habitat for many species. Watch the following animated video to learn more about the benefits of trees to our society. Though not Pennsylvania-specific, the concepts discussed in the video apply to Pennsylvania or any other temperate region:

Tree Video

Trees and Growth Patterns

As we plant trees strategically, we often want to know how tall a tree can be expected to grow. While there are environmental factors that impact tree growth patterns, we can approximate the height and diameter of a tree if we know certain facts, such as whether it is a fast, medium, or slow growing tree. As trees grow, their diameter and height change each year. If we know this rate of growth for both, we can compute the expected diameter and height of a tree over time.

Calculating the growth of a tree over time can help determine which trees will best thrive in a specific environment, as tall-growing trees can stifle shorter trees if planted in close proximity. Tree heights can also help researchers determine such things as the likely bird inhabitants of a forest – species often prefer to nest in trees of a specific height, for example – as well as the animal life, level of stream shade, and ground vegetation of the underlying surface. Such information can be helpful for land development and management purposes: as trees compete for vital resources such as sunlight and water, computing such things as the height or the expected gain in mass over time can inform choices of which trees to plant for a sustainable ecosystem.

Trees and CO_2 Absorption

Trees absorb carbon dioxide through photosynthesis. The amount of CO_2 absorbed can grow over time, as a tree with greater mass can absorb a greater amount of carbon. Suppose we want to measure the amount of carbon absorbed by a tree over time. To calculate the amount of carbon stored by a tree, we need to know a few facts about the tree. One thing we need to know is the *diameter (d)* of the tree measured at approximately 1.4 m (4.5 ft) above ground, which is the *diameter breast height,* in centimeters (cm). The other thing we need to know is the *height (h)* of the tree in meters (m). We can use the diameter *d* and height *h* to compute the green weight mass (wood content + moisture) of the tree in kilograms (kg), as follows:

Diameter	Green Weight (gw) Formula (kg)*
< 28 cm	0.0577 x $d^2 \times h$
>= 28 cm	0.0346 x $d^2 \times h$
*These equations account for the different between meters and centimeters for the height and diameter, as well as the volume to weight in kilograms.	

The root system weighs about 20% as much as the above-ground weight of the tree. Therefore, to determine the total green weight of the tree, multiply the above-ground weight by 120%.

Once we have the total green weight mass *gw*, we can determine the *dry weight* of the tree in kilograms (kg). On average, a tree is 72.5% dry weight and 27.5% moisture. So, multiply the total green weight by 72.5% for the dry weight.

Use the total dry weight to compute the amount of carbon stored by the tree, using this formula, which will be in kilograms (kg):

*carbon = 0.5 * dry_weight*

Then, we can calculate the amount of CO_2 stored by the tree using this equivalency: **3.67 kg of CO2 absorbed for every 1 kg of carbon stored**. Now we know the approximate amount of CO_2 stored in the tree **to date**. Let's see how much more CO2 is stored each year as the tree gets bigger, but remember the equations give you total CO2 to date, not per year!

Program to Write

In this project, you will create a program that will ultimately compute the CO_2 absorbed by a tree over some number of years. Your program inputs are as follows:

- Whether the tree species is a fast, medium, or slow growing species.
- The diameter (d) in centimeters (a floating-point value greater than 0 cm).
- The growth in diameter in centimeters (fast: 1.3 to 5.1 cm, medium: 0.5 to 2.5 cm, slow: < 0.5 cm).
- The height (h) in meters (a floating-point value greater than 0 m).
- The growth in height in meters (fast: .60 to 1.50 m, medium: .30 to .90 m, slow: < .30 m).
- The number of years to grow the tree (an integer value greater than equal to 0).

You need to validate all inputs according to the rules above, as well as making sure you are able to read the right type of value, such as a positive floating-point and integer numbers.

Then, using the mass and age, **approximate the height of the tree in meters using the formula for tree growth**. If the height is 30.48cm (.3048m) or above, use the diameter (in centimeters) and approximate height (in meters) to calculate the green weight mass and carbon to compute the amount of CO_2 absorbed by the tree each year. **If the height is less than 30.48cm (.3048m), then print a message that the tree is too small to absorb much CO_2 yet.**

Output the current dry weight mass, carbon, and CO_2 absorbed at the present age. Then, output the amount of CO2 absorbed in a year for each year the user wants to simulate (be careful because the equation provides the total year-to-date CO2 absorbed, not CO2 absorbed in one year!). Lastly, output the total diameter and height the tree would grow over some future number of years, as well as the amount of CO_2 absorbed over those years.

Requirements:

- You cannot have a function of more than 15 lines of code, including main! However, this does not include variable declarations, comments, or curly braces.
- You cannot have any global variables (those declared outside of any function)!

Part 1 Program Design: First, you will begin by going through Polya's problem-solving steps. Use the template provided to help with this.

Understanding the Problem. (5 pts)

- Do you understand everything in the problem? List anything you do not fully understand.
- What are the functional requirements of the program, i.e. what does it need to do?
- What assumptions are you making?
- What are the inputs, outputs, etc.?

Devise a Plan. (15 pts)

- What are the decisions that need to be made in this program?
- What are the sequence of steps you need to complete?
- How are you going to calculate the approximate total tree dry weight mass, carbon stored, and CO_2 absorbed to date, as well as per year? Think about units with all your variables!
- What happens when the tree is too small to absorb any CO_2?
- How are you going to handle bad input?

Based on your answers above, **provide the algorithm as pseudocode or provide a flowchart** of the specific steps that are needed to create this program, including the error checking. Be very explicit!!!

Looking Back. (5 pts)
Create a test plan with the test cases (bad, good, and edge cases).

- What are the good, bad, and edge cases for ALL input in the program?
- What do you hope to be the expected results?

Part 2 Program: After your design, you will write the computer program to simulate the drainage of a water catchment system over time, and you will revisit your testing table to make sure the program works correctly.

Carry out the plan. (60 pts)
Write the program that simulates the tree growth and CO_2 absorption over a certain number of years. Your program must be properly decomposed with functions. To make sure your functions are only doing one task, **you must not have a function over 15 lines!**

(15 pts) Remember, you will be graded on having the proper spacing, comments/function descriptions, and good variable/function names, as well as good, clear prompts and output messages.

Tree Growth and CO_2 Absorption Example:

```
Enter the species (1-slow, 2-medium, 3-fast): 2
Enter the diameter in centimeters: 30
Enter the diameter growth rate in cm: 1.5
Enter the height in meters: 1.6
Enter the height growth rate in m: .4
Number of years to simulate growth: 4
To Date:
The current dry weight is: 43.3469kg
The total carbon stored is: 21.6734kg
The total CO2 absorbed is: 79.5415kg

The total CO2 absorbed this year is: 30.0766kg
The total CO2 absorbed this year is: 34.7497kg
The total CO2 absorbed this year is: 39.7211kg
The total CO2 absorbed this year is: 44.9907kg

Over an additional 4 years,
The diameter will grow: 6cm
The height will grow: 1.6m
The total extra CO2 absorbed will be: 149.538kg
```