hw01-christinemswanson (/github/BEE4750-FA23/hw01-christinemswanson/tree/Fall23)
/ hw01.ipynb (/github/BEE4750-FA23/hw01-christinemswanson/tree/Fall23/hw01.ipynb)

BEE 4750 Homework 1: Introduction to Using Julia

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> **Due Date**
>
> Friday, 9/8/23, 9:00pm

Overview

Instructions

- Problems 1-3 consist of a series of code snippets for you to interpret and debug. For Problems 1 and 2, you will be asked to identify relevant error(s) and fix the code. For Problem 3, the code works as intended; your goal is to identify the code's purpose by following its logic.
- Problem 4 asks you to convert a verbal description of a wastewater treatment system into a Julia function, and then to use that function to explore the impact of different wastewater allocation strategies.

Load Environment

The following code loads the environment and makes sure all needed packages are installed. This should be at the start of most Julia scripts.

In [1]:

```
import Pkg
Pkg.activate(@__DIR__)
Pkg.instantiate()
```

```
  Activating project at `c:\Users\chris\OneDrive\Documents\Cornell\classwork\BEE5750\h
omeworks\hw1\hw01-christinemswanson`
```

In [2]:

```
using Plots
using GraphRecipes
using LaTeXStrings
using Statistics
```

Problems (Total: 40 Points)

Problem 1 (8 points)

You've been tasked with writing code to identify the minimum value in an array. You cannot use a predefined function. Your colleague suggested the function below, but it does not return the minimum value.

In [3]:

```
function minimum(array)
    min_value = 0
    for i in 1:length(array)
        if array[i] < min_value
            min_value = array[i]
        end
    end
    return min_value
end

array_values = [89, 90, 95, 100, 100, 78, 99, 98, 100, 95]
@show minimum(array_values);
```

```
minimum(array_values) = 0
```

Problem 1.1 (3 points)

Describe the logic error.

My colleague mistakenly assigned the minimum value as 0, where they should have assigned it as the first index position of the array. This is because we want to go through the array one-by-one to find the minimum value. Because Julia starts indexing at 1 and not 0, this means we need to change `min_value` from 0 to array[1], which means we first want to retrieve the first value in the array to perform our comparisons. The rest of the code works perfectly fine.

Problem 1.2 (3 points)

Write a fixed version of the function.

In [4]:

```
function minimum(array)
    min_value = array[1] # correct assignment of min_value
    for i in 1:length(array)
        if array[i] < min_value
            min_value = array[i]
        end
    end
    return min_value
end

array_values = [89, 90, 95, 100, 100, 78, 99, 98, 100, 95]
@show minimum(array_values);
```

```
minimum(array_values) = 78
```

Problem 1.3 (2 points)

Use your fixed function to find the minimum value of `array_values` .

In [5]:

```
print("The minimum value of the specified array is: ", minimum(array_values))
```

```
The minimum value of the specified array is: 78
```

Problem 2 (8 points)

Your team is trying to compute the average grade for your class, but the following code produces an error.

In [6]:

```
student_grades = [89, 90, 95, 100, 100, 78, 99, 98, 100, 95]
function class_average(grades)
  average_grade = mean(student_grades)
  return average_grade
end

@show average_grade;
```

```
UndefVarError: `average_grade` not defined



Stacktrace:

 [1] top-level scope

   @ show.jl:1128
```

Problem 2.1 (3 points)

Describe the logic and/or syntax error.

The first issue the class made was in defining `average_grade` . We want to take the average grade of `grades` (which is user input to the function) as opposed to the array `student_grades` itself. The next issue pertains to showing the `average_grade` . We need to call the function `class_average()` on the `student_grades` array in order to get the correct result.

Problem 2.2 (3 points)

Write a fixed version of the code.

In [7]:

```
# correct class_average function
student_grades = [89, 90, 95, 100, 100, 78, 99, 98, 100, 95]
function class_average(grades)
  average_grade = mean(grades)
  return average_grade
end
```

```
class_average (generic function with 1 method)
```

Problem 2.3 (2 points)

Use your fixed code to compute the average grade for the class.

In [8]:

```
average_grade = class_average(student_grades)
print("The average grade in the class is: ", average_grade)
```

```
The average grade in the class is: 94.4
```

Problem 3 (8 points)

You've been handed some code to analyze. The original coder was not very considerate of other potential users: the function is called `mystery_function` and there are no comments explaining the purpose of the code. It appears to take in an array and return some numbers, and you've been assured that the code works as intended.

In [9]:

```
# return only unique values from a given array
function mystery_function(values)
    y = []
    for v in values
        if !(v in y) # if current value is not in y
            append!(y, v) # append the value to y
        end
    end
    return y
end

list_of_values = [1, 2, 3, 4, 3, 4, 2, 1]
@show mystery_function(list_of_values);
```

```
mystery_function(list_of_values) = Any[1, 2, 3, 4]
```

Problem 3.1 (4 points)

Explain the purpose of `mystery_function` .

`mystery_function` takes in an array by the user. Element-by-element, the function checks whether the current element is *not* in the array, `y`, which starts off as an empty array on the first iteration. If the current element is not in the array `y`, then it gets appended to `y`. This continues until we reach the last element of the array. Essentially, this function returns unique values from an array. Thus, with the example of `list_of_values`, we only wind up with the elements of 1, 2, 3, and 4 in the final result.

Problem 3.2 (4 points)

Add comments to the code, explaining why and how it works. Refer to “Best Practices for Writing Code Comments” (https://stackoverflow.blog/2021/12/23/best-practices-for-writing-code-comments/), and remember that bad comments can be just as bad as no comments at all. You do not need to add comments to every line (in fact, this is very bad practice), but you should note the *purpose* of every “section” of code, and add comments explaining any code sequences that you don’t immediately understand.

Problem 4 (16 points)

Cheap Plastic Products, Inc. is operating a plant that produces $100\text{m}^3/\text{day}$ of wastewater that is discharged into Pristine Brook. The wastewater contains $1\text{kg}/\text{m}^3$ of YUK, a toxic substance. The US Environmental Protection Agency has imposed an effluent standard on the plant prohibiting discharge of more than $20\text{kg}/\text{day}$ of YUK into Pristine Brook.

Cheap Plastic Products has analyzed two methods for reducing its discharges of YUK. Method 1 is land disposal, which costs $X_1^2/20$ dollars per day, where X_1 is the amount of wastewater disposed of on the land (m^3/day). With this method, 20% of the YUK applied to the land will eventually drain into the stream (*i.e.*, 80% of the YUK is removed by the soil).

Method 2 is a chemical treatment procedure which costs $1.50per$\text{m}^3 $ofwastewatertreated.Thechemicaltreatmenthasanefficiencyof$e= 1 - 0.005X_2 $, where$X_2$isthequantityofwastewater($\text{m}^3\text{/day}$)treated.Forexample,if$ X_2 = 50 \text{m}^3\text{/day}$, then$e = 1 - 0.005(50) = 0.75$, so that 75% of the YUK is removed.

Cheap Plastic Products is wondering how to allocate their wastewater between these three disposal and treatment methods (land disposal, and chemical treatment, and land disposal) to meet the effluent standard while keeping costs manageable.

Problem 4.1 (3 points)

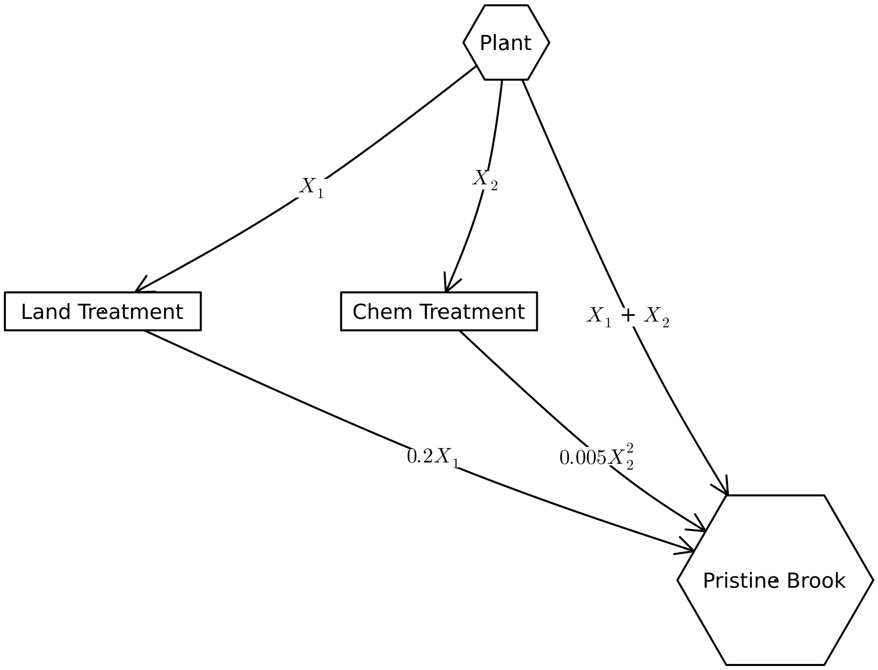
The flow of wastewater through this treatment system is shown in Figure 1. Modify the edge labels (by editing the `edge_labels` dictionary in the code producing Figure 1) to show how the wastewater allocations result in the final YUK discharge into Pristine Brook. For the `edge_label` dictionary, the tuple (i, j) corresponds to the arrow going from node i to node j. The syntax for any entry is `(i, j) => "label text"` , and the label text can include mathematical notation if the string is prefaced with an `L` , as in `L"x_1"` will produce x_1.

```
In [10]: using GraphRecipes, Plots

         A = [0 1 1 1;
             0 0 0 1;
             0 0 0 1;
             0 0 0 0]

         names = ["Plant", "Land Treatment", "Chem Treatment", "Pristine Brook"]
         # modify this dictionary to add labels
         edge_labels = Dict((1, 2) => L"$X_1$", (1,3) => L"$X_2$", (1, 4) => L"$X_1$ + $X_2$",(2
         shapes=[:hexagon, :rect, :rect, :hexagon]
         xpos = [0, -1.5, -0.25, 1]
         ypos = [1, 0, 0, -1]

         graphplot(A, names=names,edgelabel=edge_labels, markersize=0.15, markershapes=shapes, r
```



Problem 4.2 (4 points)

Formulate a mathematical model for the treatment cost and the amount of YUK that will be discharged into Pristine Brook based on the wastewater allocations. This is best done with some equations and supporting text explaining the derivation. Make sure you include, as additional equations in the model, any needed constraints on relevant values. You can find some basics on writing mathematical equations using the LaTeX typesetting syntax here (https://viveks.me/environmental-systems-analysis/tutorials/latex-notebook.qmd), and a cheatsheet with LaTeX commands can be found on the course website's Resources page (https://viveks.me/environmental-systems-analysis/resources/markdown.qmd).

Model:

$cost = X_1^2/20$ + $1.5\ X_2$

$y = 100$ - X_1 - X_2 + $0.2X_1$ + $0.005X_2^2$ (discharge rate)

The cost is simply the sum of the cost variables as specified per treatment. I derived the discharge equation by including the constraint that X_1 and X_2 have to sum to 100, as well as including the YUK concentration that gets to the Pristine Brook as shown from my diagram above ($0.2X_1$ and $0.005X_2^2$). We use 0.2 times X_1 because that is what drains to the stream after the land treatment, and the chemical treatment amount after is $0.005X_2^2$ because we subtract the efficiency times X_2 from X_2.

Problem 4.3 (4 points)

Implement this systems model as a Julia function which computes the resulting YUK concentration and cost for a particular treatment plan. You can return multiple values from a function with a tuple (https://docs.julialang.org/en/v1/manual/functions/#Tuples-1), as in:

In [11]:

```julia
function multiple_return_values(x, y)
    return (x+y, x*y)
end

a, b = multiple_return_values(2, 5)
@show a;
@show b;
```

```
a = 7
b = 10
```

In [12]:

```julia
# compute [YUK] and cost for treatment plans (total)
function yuk_and_cost_per_treatment(x1, x2) # function takes 2 wastewater discharge val
    cost = x1^2/20 + 1.5*x2
    discharge = 100 - x1 - x2 + 0.2*x1 + 0.005*x2^2 # discharge rate

    return (discharge, cost)
end
```

```
yuk_and_cost_per_treatment (generic function with 1 method)
```

In [13]:

```julia
yuk_and_cost_per_treatment(80, 20)
```

```
(18.0, 350.0)
```

Make sure you comment your code appropriately to make it clear what is going on and why.

Problem 4.4 (5 points)

Use your function to experiment with some different combinations of wastewater discharge and treatment. Can you find one that satisfies the YUK effluent standard? What was the cost? You don’t have to find an “optimal” solution to this problem, but what do you think would be needed to find a better solution?

Yes, one solution that satisfies the YUK effluent standard is a wastewater discharge value of 80 (that is, specifying x1 = 80 in the function call). This is because I got a discharge value less than 20 in my output (I got a discharge value of 18.0 when 80 was specified as the first argument to the function). The associated cost for this trial was $350. To find a better solution, I think we might want to implement a more structured approach as opposed to trial-and-error, which is what I implemented in the previous code block. Perhaps we could implement some optimization algorithm to minimize YUK discharge into Pristine Brook in order to get an "optimal" solution.

References

List any external references consulted, including classmates.

I collaborated with Akshara on problem 4, particularly in terms of the problem formulation stages. I also went over some questions on problem 4 with Gabby to clarify my ideas on formulating the model.