hw01-kespineira73 (/github/BEE4750-FA23/hw01-kespineira73/tree/14addbc1b253ca085c124bd420f41ed59aa7990c)
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hw01.ipynb (/github/BEE4750-FA23/hw01-kespineira73/tree/14addbc1b253ca085c124bd420f41ed59aa7990c/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 [17]:
```
import Pkg
Pkg.activate(@__DIR__)
Pkg.instantiate()
```

```
  Activating project at `~/Desktop/BEE 4750/hw01-kespineira73`
```

In [18]:
```
using Plots
using GraphRecipes
using LaTeXStrings
```

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 [19]:
```
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.

ANSWER

The logic error is found in the minimum value line. The minimum value is intially set to 0 when it should be set to either infintity or the first value in the array. The minimum value should not be set to 0 as it will only return 0 since no values in the array are less than 0.

Problem 1.2 (3 points)

Write a fixed version of the function.

In [20]:
```
function minimum(array)
    #Correction: instead of the minimum value being set to 0, it is set to the
    #   first value in the array.
    #This way the code compares all the values present in the array given.
    min_value = array[1]
    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 [21]:
```
array_values = [89, 90, 95, 100, 100, 78, 99, 98, 100, 95]
@show minimum(array_values);
```

```
minimum(array_values) = 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 [22]:
```
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.

ANSWER

The first error in this code is that the team did not actually run the function. They only said "show average_grade" which does not run the function and is an invalid input. They must call the function and input student_grades as the arguement. Another error is that in the function. The team references "student_grades" which is the specific input, not the general argument for the function. This specific input is not defined in the scope of the funtion and should be replaced with the argument "grades" instead of "student_grades."

Problem 2.2 (3 points)

Write a fixed version of the code.

In [23]:
```
using Statistics

student_grades = [89, 90, 95, 100, 100, 78, 99, 98, 100, 95]
function class_average(grades)
  #Correction: argument is "grades" (original argument)
  average_grade = mean(grades)
  return average_grade
end

#Correction: call function
@show class_average(student_grades);
```

```
class_average(student_grades) = 94.4
```

Problem 2.3 (2 points)

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

In [24]:
```
@show class_average(student_grades);
```

```
class_average(student_grades) = 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 [25]:
```
function mystery_function(values)
    y = []
    for v in values
        if !(v in y)
            append!(y, v)
        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` .

ANSWER

The purpose of mystery_function is to return an array with only the unique values found in the input. If the inputted array of values has repeated numbers, the function is supposed to append those numbers so there are no repeats.

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.

In [26]:
```
function mystery_function(values)
    # initialize array of unique values
    y = []
    # iterate through the inputted array
    for v in values
        # if the current value v is not in the array y, add it the array y
        if !(v in y)
            append!(y, v)
        end
    end
    # return the array y of unique values
    return y
end

# this is the initial testing variable (array with unique and repeated values)
# run the function with testing variable as argument
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 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 1kg/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 20kg/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 of wastewatertreated. Thechemicaltreatmenthasanefficiencyof e= 1 - 0.005X_2, whereX_2 isthequantityofwastewater(\text{m}^3\text{/day})treated. Forexample, if X_2 = 50 \text{m}^3\text{/day}, thene = 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)

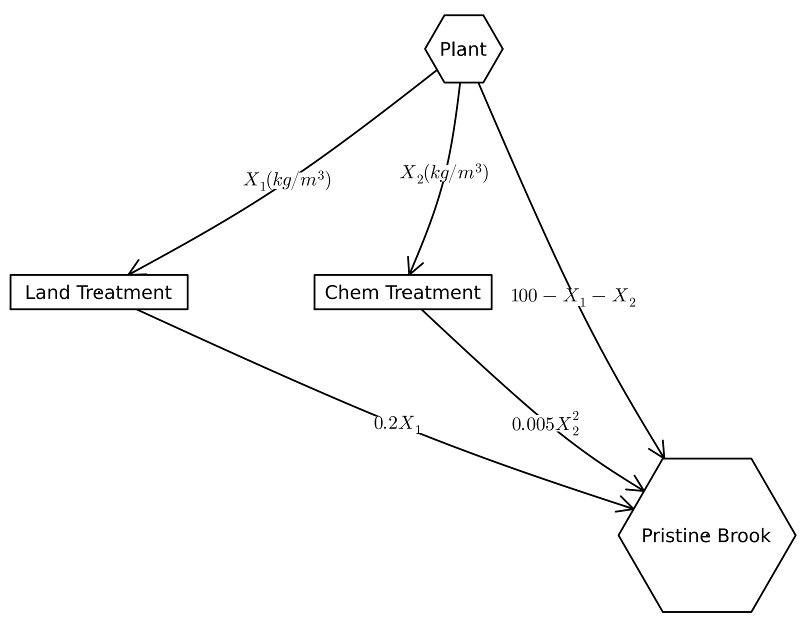
The flow of wastewater through this treatment system is shown in Figure 1. Modify the edge labels (by editing the `edge_labels` dictionary in the code producing Figure 1) to show how the wastewater allocations result in the final YUK discharge into Pristine Brook. For the `edge_label` dictionary, the 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 [27]:
```
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
# X1 and X2 refer to the wastewater
# Scaled to account for YUK at 100 kg/day being produced by the plant
edge_labels = Dict((1, 2) => L"X_1 (kg/m^3)", (1,3) => L"X_2 (kg/m^3)", (1, 4)
=> L"100 - X_1 - X_2",(2, 4)
=> L"0.2 X_1",(3, 4) => L"0.005 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, markercolor=:white,
x=xpos, y=ypos)
```



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).

ANSWER

$$X_1 = \mathrm{Flowlandtreatment}(m^3/day)$$
$$X_2 = \mathrm{Flowchemicaltreatment}(m^3/day)$$
$$C(X_1, X_2) = \frac{X_1^2}{20} + 150X_2$$

The total cost combines the costs for Method 1: Land Treatment and Method 2: Chemical Treatment. Total Cost = Method 1 Cost + Method 2 Cost. The units for this equation are [USD/day]. Note that for the Method 2 Cost portion, the equation needs to be converted to the correct units as the intial cost equation is: USD 1.50 / m^3 of wastewater treated (X2). This can be adjusted by multiplying by the amount of YUK produced per day by the plant which is 100 kg/day YUK.

$$Y(X_1, X_2) = 0.2X_1 + 0.005X_2^2 + (100 - X_1 - X_2)$$

The total YUK concentration discharged into Pristine Brook is based on the wastewater allocations to each treatment method. The constraints to X1 and X2 include that the total value of wastewater cannot exceed 100 m^3/day as this is the maximum input of wastewater from the plant per day. Additionally, the final cost should not be over $10,000, and the final YUK concentration must be below 20kg/day.

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 [28]:
```
#this function is an example of how to return two values
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 [29]:
```
#create a function that determines the final cost and YUK produced
# C = cost
# Y = Final YUK concentration
C = 0
Y = 0
function yuk_model(x₁, x₂)
   #create an equation to calculate the cost
    C = ((x₁^2)/20) + (150x₂)

    #create an equation to calculate the final YUK concentration
    Y = (0.2x₁) + (0.005(x₂^2)) + (100 - x₁ - x₂)

    return (C, Y)
end

#input amount of wastewater being distributed to each treatment method
#X1 = land disposal
#X2 = chemical treatment
X₁ = []
X₂ = []

#create a for loop that goes through possible wastewater amounts and
# returns values for the final cost and YUK concentration
C = zeros(length(X₁))
Y = zeros(length(X₁))
for i = 1:length(X₁)
    C[i], Y[i] = yuk_model(X₁[i], X₂[i])
end
```

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?

In [30]:
```
#TRIAL 1
 #input amount of wastewater being distributed to each treatment method
 X₁ = 80
 X₂ = 20

#call the yuk_model function and run with possible values
yuk_model(X₁,X₂)

 #create a for loop that goes through possible wastewater amounts and
 # returns values for the final cost and YUK concentration
C = zeros(length(X₁))
Y = zeros(length(X₁))
 for i = 1:length(X₁)
     C[i], Y[i] = yuk_model(X₁[i], X₂[i])
 end

 @show C;
 @show Y;
```

```
C = [3320.0]
Y = [18.0]
```

In [31]:
```
#TRIAL 2
 #input amount of wastewater being distributed to each treatment method
 X₁ = 60
 X₂ = 40

#call the yuk_model function and run with possible values
yuk_model(X₁,X₂)

 #create a for loop that goes through possible wastewater amounts and
 # returns values for the final cost and YUK concentration
C = zeros(length(X₁))
Y = zeros(length(X₁))
 for i = 1:length(X₁)
     C[i], Y[i] = yuk_model(X₁[i], X₂[i])
 end

 @show C;
 @show Y;
```

```
C = [6180.0]
Y = [20.0]
```

In [32]:
```
#TRIAL 3
 #input amount of wastewater being distributed to each treatment method
 X₁ = 65
 X₂ = 20

#call the yuk_model function and run with possible values
yuk_model(X₁,X₂)

 #create a for loop that goes through possible wastewater amounts and
 # returns values for the final cost and YUK concentration
C = zeros(length(X₁))
Y = zeros(length(X₁))
 for i = 1:length(X₁)
     C[i], Y[i] = yuk_model(X₁[i], X₂[i])
 end

 @show C;
 @show Y;
```

```
C = [3211.25]
Y = [30.0]
```

ANSWER

After running multiple combinations of wastewater charge and treatment variations, it is possible to find combinations that satifies the YUK effluent standard. The YUK effluent standard states that after treatment, the plant can only produce 20 kg/day YUK. In the "yuk_model" function, the "Y" output represents the final YUK concentration disposed in the stream, and the "C" output represents the final cost for both treatment options combined.

Each trial changes the amount of wastewater being distributed to each treatment method. X1 represents Method 1, the amount of wastewater being treated/disposed through land. X2 represents Method 2, the chemical treatment method.

Based on the YUK effluent standard, Trial 2 satisfies the standard to an exact measure of producign 20 kg/day YUK. The final cost of this trial is $6,180, a relativley high cost for treatment. In this trial, 60 m3/day wastewater was distributed to Method 1, and 40 m3/day wastewater was distributed to Method 2.

Trial 3 decreases the amount of wastewater being distributed to Method 2 and increases the amount of wastewater being distributed to Method 1 and the stream directly. With this, the cost decreased to $3,211. However, it does not reach the YUK effluent standard as it has a high concentration of 30 kg/day YUK.

Trial 1 is the best option based on the three different combinations. The final YUK concentration is 18 kg/day YUK, the lowest amount YUK out of the three combinations. Additionally, the cost is considered relatively low at $3,320.

Therefore, it can be concluded that increasing the amount of wastewater being sent over to Method 1 is the best option as it decreases the cost and final YUK concentration, ideal for the company. To find an optimal solution, the company will need to experiment with different amounts of wastewater being put into each option: Method 1, Method 2, and direct stream. It is also important that the company considers the amount of time it takes for the wastewater to be treated and the amount of resources needed for each method when deciding the best solution.

BEST SOLUTION: TRIAL 1

Final Cost: $3,320

Final YUK Concentration: 18 kg/day

References

List any external references consulted, including classmates.