Fall 2020: CSCI 4588/5588 Programming Assignment #1B”.

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Solution to Genetic Algorithm

Program:

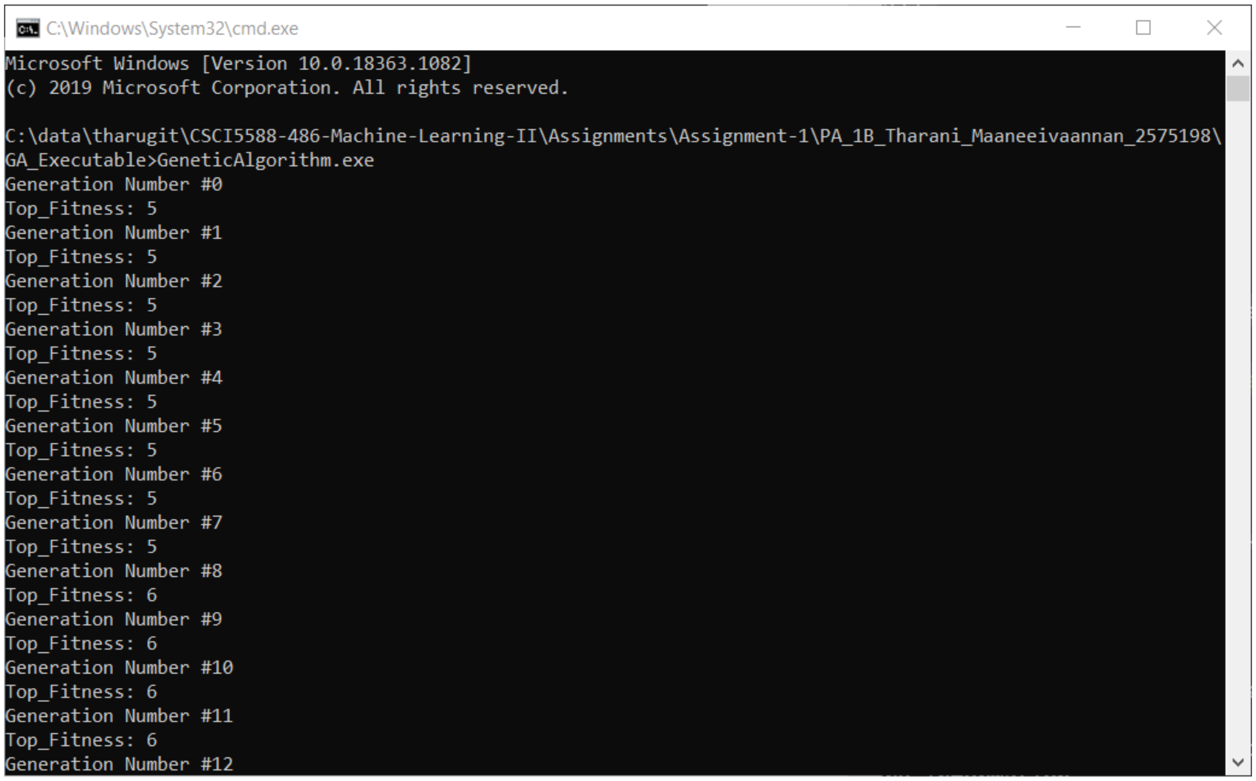
```
import os
import random
import operator
import matplotlib.pyplot as plt
from textwrap import wrap


class GeneticAlgorithm:
    def __init__(self):
        """
        1. Initialize the Population
        """
        self.newPopulationList = []

    """
    This module generates the Chromosome Orientation/structure in Random for the 
given sequence
    Input: [gene1,gene2,....,gene_N]
    Output: [(gene1, (X1, Y1)), (gene2, (X2, Y2)), ...., (gene_N, (Xn, Yn))]
    """
    def chromosomeOrientation(self,sequence):
        #Assigning the first value of binary sequence to (0,0) position initially
        currentPosition=(0,0)
        chromosome=[(sequence[0],currentPosition)]
        #Creating a dictionary to store assigned coordinates
        assignedCoordinates={currentPosition}
        for gene in sequence[1:]:
            allOptions=[]
            validOptions=[]
            # Adding the right direction option
            allOptions.append((currentPosition[0]+1,currentPosition[1]))
            # Adding the left direction option
            allOptions.append((currentPosition[0]-1,currentPosition[1]))
            # Adding the Up direction option
            allOptions.append((currentPosition[0],currentPosition[1]+1))
            # Adding the Down direction option
            allOptions.append((currentPosition[0],currentPosition[1]-1))

            # filtering valid options from allOptions
            for axis in allOptions:
                if axis not in assignedCoordinates:
                    validOptions.append(axis)
            # Select one Valid position in random and assign the gene as it's pos
ition and move forward with the orientation
            forwardPosition = random.choice(validOptions)
            chromosome.append((gene, forwardPosition))
            assignedCoordinates.add(forwardPosition)
            currentPosition = forwardPosition
        return chromosome
    """
    Given a chromosome this function calculates and returns the fitness value
    """
    def calculateFitness(self,chromosome):
        chromosome_dict={}
        fitness=0
        for indexposition,chromosomedata in enumerate(chromosome):
            chromosome_dict[chromosomedata[1]]=(indexposition,chromosomedata[0])

        for key,_ in chromosome_dict.items():
            #get the fitness value if there is a topological neighbour in right
            fitness = fitness + self.individualFitness(key,(key[0]+1,key[1]),chro
mosome_dict)
            #get the fitness value if there is a topological neighbour in left
            fitness = fitness + self.individualFitness(key,(key[0]-
1,key[1]),chromosome_dict)
            #get the fitness value if there is a topological neighbour in up
            fitness = fitness + self.individualFitness(key,(key[0],key[1]+1),chro
mosome_dict)
            #get the fitness value if there is a topological neighbour in down
            fitness = fitness + self.individualFitness(key,(key[0],key[1]-
1),chromosome_dict)
        return fitness
    """
    This function returns the individual fitness at a selected axis by comparing
    the topological neighbours
    """
    def individualFitness(self,baseAxis,neighbourAxis,chromosome_dict):
        #if the neighbouraxis is part of the chromosome orientation
        if neighbourAxis in chromosome_dict:
            baseGene=chromosome_dict[baseAxis]
            # print(baseGene)
            neighbourGene=chromosome_dict[neighbourAxis]
            # print(neighbourGene)
            # checking the topological neighbours in ascending order and eliminat
ing the covalent bonded neighbours
            if (baseGene[0]<neighbourGene[0]) and (abs(baseGene[0]-
neighbourGene[0])>1):
```

```
                if baseGene[1]=='h' and neighbourGene[1]=='h':
                    return 1
        return 0

    def rouletteWheelSelection(self,population):
        max=0
        current=0
        for i in population:
            max+=i[1]
        selection=random.randint(0,max)
        for i in population:
            current+=i[1]
            if current>selection:
                return i[0]

    def crossover(self,selectedChromosomes,crossoverPosition):
        chromosome1 = selectedChromosomes[0]
        chromosome2 = selectedChromosomes[1]
        # print(chromosome1,chromosome2,crossoverPosition)
        partOfChromosome1=chromosome1[:crossoverPosition+1]
        partOfChromosome2=chromosome2[crossoverPosition+1:]
        partOfChromosome1Axes={i[1] for i in partOfChromosome1}

        #Detecting Previous Direction
        prevDir = None

        Ax = [0,0,0]
        Ay = [0,0,0]

        if chromosome1[crossoverPosition][1][1]==chromosome1[crossoverPosition-
1][1][1]:
            if (chromosome1[crossoverPosition-
1][1][0] - chromosome1[crossoverPosition][1][0]) == 1:
                prevDir = 'RIGHT'
            else:
                prevDir = 'LEFT'
        else:
            if (chromosome1[crossoverPosition-
1][1][1] - chromosome1[crossoverPosition][1][1]) == 1:
                prevDir = 'UP'
            else:
                prevDir = 'DOWN'

        if prevDir == 'RIGHT':
            Ax = [-1,0,0]
            Ay = [0,1,-1]

        elif prevDir == 'LEFT':
            Ax = [1,0,0]
            Ay = [0,1,-1]

        elif prevDir == 'UP':
            Ax = [1,-1,0]
            Ay = [0,0,-1]
        elif prevDir == 'DOWN':
            Ax = [1,-1,0]
            Ay = [0,0,1]

        # performing three crossovers based on the direction of the first chromosome
        for itr in range(3):
            crossoverList = partOfChromosome2
            crossover_Xdir = chromosome1[crossoverPosition][1][0]+Ax[itr] - chromosome2[crossoverPosition+1][1][0]
            crossover_Ydir = chromosome1[crossoverPosition][1][1]+Ay[itr] - chromosome2[crossoverPosition+1][1][1]

            crossoverList[0] = (crossoverList[0][0],(chromosome1[crossoverPosition][1][0]+Ax[itr],chromosome1[crossoverPosition][1][1]+Ay[itr]))

            for j in range(len(crossoverList)-1):
                crossoverList[j+1] = (chromosome2[crossoverPosition+j+2][0],(chromosome2[crossoverPosition+j+2][1][0]+ crossover_Xdir ,chromosome2[crossoverPosition+j+2][1][1]+ crossover_Ydir))

            crossover_Axes = {a[1] for a in crossoverList}

            if not self.collision(partOfChromosome1Axes,crossover_Axes):
                return partOfChromosome1 + crossoverList

            elif itr == 2:
                return None

    def collision(self,axes1,axes2):
        for axis in axes2:
            if axis in axes1:
                return True
        return False

    def mutate(self,chromosome):
        # print(chromosome)
        # Selecting the random index by omitting 1st and last positions.
        # This index will be used for mutation
        randomIndexInChromosome = random.randint(1,len(chromosome)-2)
        # print(randomIndexInChromosome)

        selectedGeneAxis = chromosome[randomIndexInChromosome][1]

        # First Part will remain constant
        firstPart = chromosome[:randomIndexInChromosome+1]
        possibleCollisionAxes = {i[1] for i in firstPart}

        #Second part will be rotated and joined
        secondPart = chromosome[randomIndexInChromosome+1:]

        #90 Degree Rotation
        rotated=[(value,(axis[1]+selectedGeneAxis[0]-
selectedGeneAxis[1],selectedGeneAxis[0]+selectedGeneAxis[1]-
axis[0])) for value,axis in secondPart]
        rotatedAxes={i[1] for i in rotated}
        if (not(self.collision(possibleCollisionAxes,rotatedAxes))):
            # print("90 Rotated")
            return firstPart+rotated

        #180 Degree Rotation
        rotated=[(value,(2*selectedGeneAxis[0]-axis[0],2*selectedGeneAxis[1]-
axis[1])) for value,axis in secondPart]
        rotatedAxes={i[1] for i in rotated}
        if (not(self.collision(possibleCollisionAxes,rotatedAxes))):
            # print("180 rotated")
            return firstPart+rotated

        #270 Degree Rotation
        rotated=[(value,(selectedGeneAxis[0]+selectedGeneAxis[1]-
axis[1],axis[0]+selectedGeneAxis[1]-
selectedGeneAxis[0])) for value,axis in secondPart]
        rotatedAxes={i[1] for i in rotated}
        if (not(self.collision(possibleCollisionAxes,rotatedAxes))):
            # print("270 Rotated")
            return firstPart+rotated

        # If all rotations failed
        return None

    def plotFigure(self,chromosome,filename,sequence,bestfitness,maxFitness):
        x = [x[1][0] for x in chromosome]
        y = [y[1][1] for y in chromosome]
        x0 = [x[1][0] for x in chromosome if x[0]=='h' ]
        x1 = [x[1][0] for x in chromosome if x[0]=='p' ]
        y0 = [y[1][1] for y in chromosome if y[0]=='h' ]
        y1 = [y[1][1] for y in chromosome if y[0]=='p' ]
        plt.figure(figsize=(10,8))
        plt.title("\n".join(wrap("Sequence: '%s', Best Fitness: %d, Max_Fitness:
%d"%(sequence,bestfitness,maxFitness))))
        plt.plot(x,y,linewidth=3.0)
        hmarker = dict(color='0',marker='o',markersize=10,linewidth=0,label='h')
        plt.plot(x0,y0,**hmarker)
        pmarker = dict(color='0',marker='o',markersize=10,fillstyle='none',linewi
dth=0,label='p')
        plt.plot(x1,y1,**pmarker)
        plt.grid(True)
        # plt.show()
        plt.legend(loc="best")
        plt.savefig('figure-%s'%(str(filename)))
        plt.close()

    def GA_Main(self,proteinList,sIdx):
        sequence=proteinList[0]
        maxFitness=proteinList[1]
        # print(sequence)
        # print(fitness)
        chromosomeList = []
        populationList = []
        elitePopulation = []
        crossoverPopulation = []
        randomPopulation = []
        topFitnessList = []

        generation = 0
        # binarySequence=self.getBinarySequence(sequence)

        while (len(chromosomeList)<300):
            try:
                chromosomeList.append(self.chromosomeOrientation(list(sequence)))
            # When there is situation of collision while forming chromosome rando
mly, Indexerror occurs
            # I catch the exception and drop that structure
            except IndexError:
                # print("No Valid Options to select")
                continue
        """
        2. Compute Fitness of Population for all Chromosome Ci
        """
        for chromosome in chromosomeList:
            populationList.append((chromosome, self.calculateFitness(chromosome))
)
        # print(self.populationList[0],len(self.populationList))
        """
        3. Sort the Population in descending order based on their fitness
        """
        populationListSorted = sorted(populationList,key=operator.itemgetter(1),r
everse=True)
        # print(*populationListSorted,sep='\n')
        #currentGenerationPopulation =
        """
        4. Examine: C1/Progress or Max_gen, Exit Condition
        """
        while generation < 80000:
            print("Generation Number #%d"%(generation))
            if generation > 0:
                currentGenerationPopulationSorted = sorted(self.newPopulationList
,key=operator.itemgetter(1),reverse=True)
                self.newPopulationList = []
            else:
                currentGenerationPopulationSorted = populationListSorted

            topFitness = currentGenerationPopulationSorted[0][1]
            topFitnessList.append(topFitness)
            print("Top_Fitness: %d"%(topFitness))
            """
            Breaking conditions defined below
            """
            # break if the program reached 80000 generations
            if generation>80000:
                break
            # break the program if the maximum fitness is attained
            if topFitness == maxFitness:
                self.plotFigure(currentGenerationPopulationSorted[0][0],sIdx,sequ
ence,topFitness,maxFitness)
                break
            # break the program if there is no progress in the fitness value afte
r 100 iterations,
            # if the last 30 top fitness is same exit the program
            if len(topFitnessList)>100:
                if len(set(topFitnessList[-30:]))==1:
                    print("No Progress - So Breaking")
                    self.plotFigure(currentGenerationPopulationSorted[0][0],sIdx,
sequence,topFitness,maxFitness)
                    break

            """
            5. Taken 5% of Elite and form a New Population
            """
            elitePopulation = currentGenerationPopulationSorted[:15]
            self.newPopulationList = self.newPopulationList + elitePopulation
            # print("After Elite : %d"%(len(self.newPopulationList)))
            """
            6. 80% crossover chromosomes and fill the New Population
            """
            beforeCrossoverPopulation = currentGenerationPopulationSorted[15:255]
            crossoverResultList = []
            while (len(crossoverResultList)<240):
                try:
                    selectedChromosomes=[]
                    for _ in range(2):
                        selectedChromosomes.append(self.rouletteWheelSelection(be
foreCrossoverPopulation))
                    crossoverResult=self.crossover(selectedChromosomes,random.ran
dint(2,len(selectedChromosomes[0])-2))
                    if not (crossoverResult==None):
                        crossoverResultList.append(crossoverResult)
                except:
                    # print(e)
                    continue

            for xover in crossoverResultList:
                crossoverPopulation.append((xover,self.calculateFitness(xover)))
            # print(crossoverPopulation)
            crossoverPopulationSorted = sorted(crossoverPopulation,key=operator.i
temgetter(1),reverse=True)
            # print(self.crossoverPopulation)
            self.newPopulationList = self.newPopulationList + crossoverPopulation
Sorted
            # print("After Crossover : %d"%(len(self.newPopulationList)))
            """
            7. Fillup Pop2 randomly
            """
            randomPopulation = []
            forRandomPopulation = crossoverPopulationSorted + currentGenerationPo
pulationSorted[255:]
```

```
            for _ in range(30):
                selectedIndex = random.randint(0,len(forRandomPopulation)-1)
                randomPopulation.append(forRandomPopulation[selectedIndex])
            self.newPopulationList = self.newPopulationList + randomPopulation
            # print("After Random : %d"%(len(self.newPopulationList)))
            """
            8. Mutate the 5% of the Non elite chromosome in the
            population1 and fill it in Pop2
            """
            mutationPopulation = []
            while len(mutationPopulation)<15:
                selectedChromosomeIndex = random.randint(15,len(currentGeneration
PopulationSorted)-1)
                selectedChromosometoMutate = currentGenerationPopulationSorted[se
lectedChromosomeIndex]
                # print(selectedPopulationForMutation[selectedChromosomeIndex])
                mutationResult = self.mutate(selectedChromosometoMutate[0])
                    # print(mutationResult)
                if not (mutationResult == None):
                    mutationPopulation.append((mutationResult,self.calculateFitne
ss(mutationResult)))

            self.newPopulationList = self.newPopulationList + mutationPopulation
            # print("After Mutation : %d"%(len(self.newPopulationList)))
            """
            9.Increase Generation and Goto Step2
            """
            # self.newPopulationList = elitePopulation + randomPopulation
            # print(currentGenerationPopulation[:30],sep='\n')
            # print(len(self.newPopulationList))
            elitePopulation = []
            crossoverPopulation = []
            randomPopulation = []
            generation += 1



def main():
    with open("Input.txt") as f:
        content = f.readlines()
    seqValues = []
    fitnessValues = []
    contents = [x.strip() for x in content]
    for line in contents:
        if len(line)>0:
```

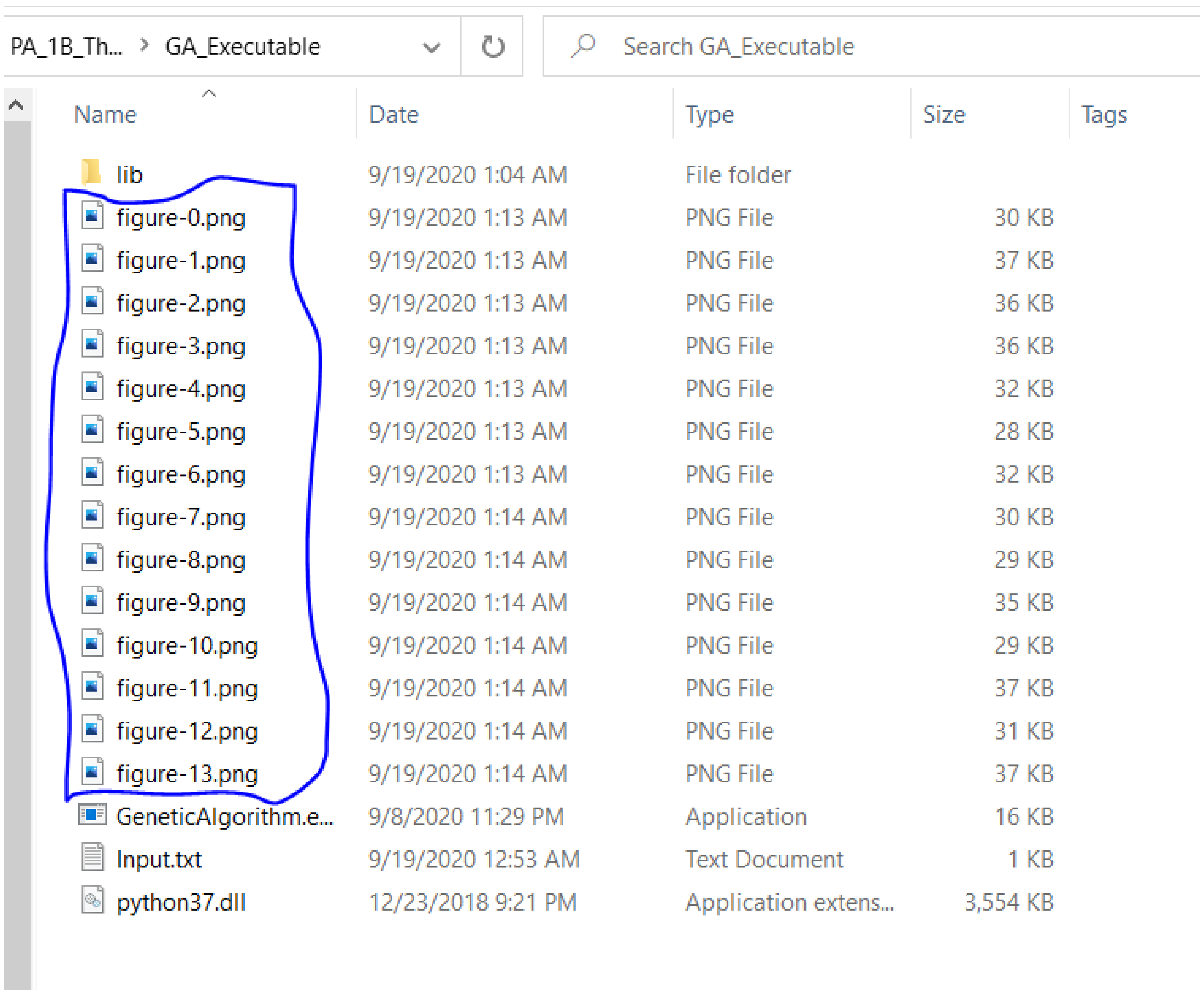
```python
            if "Comment" in line:
                continue
            if "Seq" in line:
                seqValues.append(line.replace("Seq = ",""))
            if "Fitness =" in line:
                fitnessValues.append(abs(int(line.replace("Fitness = ",""))))
    proteinList = list(zip(seqValues,fitnessValues))
    for idx,value in enumerate(proteinList):
        GeneticAlgorithm().GA_Main(value,idx)

if __name__ == '__main__':
    main()
```

Output:



C:\Windows\System32\cmd.exe

```
Microsoft Windows [Version 10.0.18363.1082]
(c) 2019 Microsoft Corporation. All rights reserved.

C:\data\tharugit\CSCI5588-486-Machine-Learning-II\Assignments\Assignment-1\PA_1B_Tharani_Maaneeivaannan_2575198\
GA_Executable>GeneticAlgorithm.exe
Generation Number #0
Top_Fitness: 5
Generation Number #1
Top_Fitness: 5
Generation Number #2
Top_Fitness: 5
Generation Number #3
Top_Fitness: 5
Generation Number #4
Top_Fitness: 5
Generation Number #5
Top_Fitness: 5
Generation Number #6
Top_Fitness: 5
Generation Number #7
Top_Fitness: 5
Generation Number #8
Top_Fitness: 6
Generation Number #9
Top_Fitness: 6
Generation Number #10
Top_Fitness: 6
Generation Number #11
Top_Fitness: 6
Generation Number #12
```



PA_1B_Th... > GA_Executable

Search GA_Executable

Name	Date	Type	Size	Tags
lib	9/19/2020 1:04 AM	File folder		
figure-0.png	9/19/2020 1:13 AM	PNG File	30 KB	
figure-1.png	9/19/2020 1:13 AM	PNG File	37 KB	
figure-2.png	9/19/2020 1:13 AM	PNG File	36 KB	
figure-3.png	9/19/2020 1:13 AM	PNG File	36 KB	
figure-4.png	9/19/2020 1:13 AM	PNG File	32 KB	
figure-5.png	9/19/2020 1:13 AM	PNG File	28 KB	
figure-6.png	9/19/2020 1:13 AM	PNG File	32 KB	
figure-7.png	9/19/2020 1:14 AM	PNG File	30 KB	
figure-8.png	9/19/2020 1:14 AM	PNG File	29 KB	
figure-9.png	9/19/2020 1:14 AM	PNG File	35 KB	
figure-10.png	9/19/2020 1:14 AM	PNG File	29 KB	
figure-11.png	9/19/2020 1:14 AM	PNG File	37 KB	
figure-12.png	9/19/2020 1:14 AM	PNG File	31 KB	
figure-13.png	9/19/2020 1:14 AM	PNG File	37 KB	
GeneticAlgorithm.e...	9/8/2020 11:29 PM	Application	16 KB	
Input.txt	9/19/2020 12:53 AM	Text Document	1 KB	
python37.dll	12/23/2018 9:21 PM	Application extens...	3,554 KB	

Protein sequence figures will be generated in the same folder