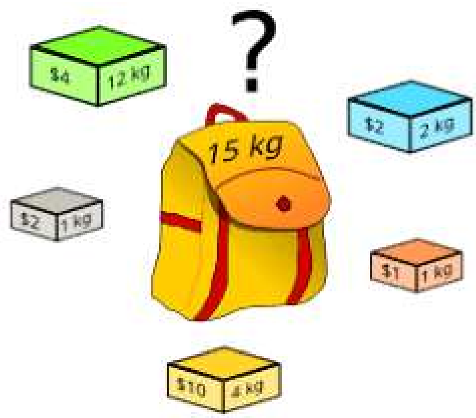
Week 10 Lab

The Kanpsack Problem

The knapsack problem is a classical optimisation problem thet has been studied for more than a century. The statement of the problem is as follows: Given a set of items, each with a weight and a value, collect a combination of items with the largest value, such that the weight of the sollection has to be limited by a given capacity.



The brute force solution to this problem works by calculating the weight and value of all possible combinations and pick the combination with the maximum value and wight <= capacity. The computational complexity of this brute force solution is exponential!! Using genetic algorithms, we can find very good solutions (near optimal) very efficiently. In this lab, we will learn how to do this.

Problem formulation

- Gene: an item represented by weight & value
- Individual ("chromosome"): a sack including a combination of items
- Population: a collection of possible sacks (i.e., collection of individuals)
- Parents: two individuals that are combined to create a new individual
- Fitness: a function that tells us how good each individual (i.e., sack) is
- Mutation: a way to introduce variation in our population by randomly changing the inclusion of one item in a sack

Steps

Our GA will proceed in the following steps:

1. Create the population
2. Determine fitness of each individual in the population
3. Select parents to form the mating pool for the next generation
4. Breed to get new children (individuals of next generation)
5. Mutate childern to introduce vaiations
6. Repeat steps 2-5 till the maximum number of generations is reached or till no better individuals can be produced

In [2]:
```
import random
import sys
import operator
import matplotlib.pyplot as plt

# an item is represented by weight & value
#This is the gene
class Item(object):
        def __init__(self,  value, weight, name =''):
                self.name = name
                self.value = value
                self.weight = weight

class Knapsack(object):

        #initialize variables and lists
        def __init__(self, itemList, capacity, populationSize,numGenerations,patience
                self.itemList = itemList
                self.capacity = capacity
                self.populationSize = populationSize
                self.verbose=verbose

                self.population = []
                self.fitness = []
                self.parents = []
                self.numGenerations = numGenerations
                self.patience=patience
                self.patienceCounter = 0
                self.bestFitness=-1000000
                self.bestfoundAt=-1
                self.bestIndividual=None
                self.listOfBestFitness=[]

                self.initialisePopulation()
                print("finished intitialisation")

        # Step number 1: create the individuals in the initial population
        def initialisePopulation(self):
                for i in range(self.populationSize):
                        individual = []
                        for k in range(0, len(self.itemList)):
                                k = random.randint(0, 1)
                                individual.append(k)
                        self.population.append(individual)


        #Step 2: calculate fittness
        def evaluation(self,generationNumber):
    # loop through individuals and calculate fitness
```

```
              for i in range(len(self.population)):
                      ft = self.calcFitness(self.population[i])
                      self.fitness.append((ft, self.population[i]))

              # sort the fitness list by fitness
              self.fitness.sort(key=operator.itemgetter(0), reverse=True)
              if self.fitness[0][0]> self.bestFitness:
                      self.bestFitness = self.fitness[0][0]
                      self.bestIndividual = self.fitness[0][1]
                      self.bestfoundAt = generationNumber
                      self.patienceCounter = 0

      #Step 2 continued - calculate the fitness of a given individual (sack)
      def calcFitness(self, sack):
              #print(sack)
              sum_w = 0 # sum of weights of items in the sack
              sum_v = 0 # sum of values of items in the sack

              # calculate sum of weights and values
              for i in range(len(sack)):
                      sum_w += sack[i]* self.itemList[i].weight
                      sum_v += sack[i]* self.itemList[i].value

              if sum_w > self.capacity: # --> not valid solution so retun fitness of
                      return -1
              else:  #fitness = sum of item values in the sack
                      return sum_v

# Step 3 select parents to form the mating pool
      def selectParents(self):
              numElites =  self.populationSize//4
              numParents = numElites*2
              self.parents = [x[1] for x in self.fitness[:numElites]]
              otherParentsIndecies = random.sample(range(numElites,numParents),numPa
              for i in otherParentsIndecies:
                      self.parents.append(self.fitness[i][1])

      # Step 4 breeding via crossover of two parents to produce two children
      def crossover(self, sack1, sack2):
              threshold = random.randint(0, len(sack1))
              tmp1 = sack1[threshold:]
              tmp2 = sack2[threshold:]
              sack1 = sack1[:threshold]
              sack2 = sack2[:threshold]
              sack1.extend(tmp2)
              sack2.extend(tmp1)

              return sack1, sack2

      #Step 5 mutate child
      def mutation(self, sack):
              for i in range(len(sack)):
                      k = random.uniform(0, 1)
                      if k > 0.8:
                              if sack[i] == 1:
                                      sack[i] = 0
                              else:
                                      sack[i] = 1
              return sack
```

```
        # run all the steps of the GA algorithms for a given numGenerations
        def run(self):

                for g in range(self.numGenerations):
                        self.evaluation(g)
                        self.selectParents()
                        newPopulation = []

                        for i in range(self.populationSize):
                                [parent1Indx ,parent2Indx]= random.sample(range(0,len(
                                child1, child2 = self.crossover(self.parents[parent1Ir
                                newPopulation.append(child1)
                                newPopulation.append(child2)

                        # mutate the new children
                        for i in range(len(newPopulation)):
                                newPopulation[i] = self.mutation(newPopulation[i])
                        self.patienceCounter += 1
                        self.listOfBestFitness.append(self.bestFitness)
                        if self.patienceCounter == self.patience:
                                print ("Stopped after {} generations" .format(g))
                                break

                        else:
                                if g%10==0 and self.verbose:
                                        print("Generation {} Best fitness so far {} ;

                                self.population = newPopulation
                                self.fitness = []
                                self.parents = []
                print("Best individual is {} ; fitness value is {} ; found at generati
```

In [3]:

```
# function to test knapsack optimisation using a given sets of parameters
def optimiseKnapsack(numAvailableItems, capacity, maxWeightPerItem, maxValuePerItem, p
  itemList = []
  for i in range(numAvailableItems):
    itemList.append(Item(random.randint(1, maxWeightPerItem), random.randint(1, maxVal

  print("Available Items:")
  print("weights " + str([x.weight for x in itemList]))
  print("values " + str([x.value for x in itemList]))

  k = Knapsack(itemList, capacity, populationSize,numGenerations,patience = 500,verbos
  k.run()
  plt.plot(k.listOfBestFitness)
  plt.xlabel("Generation")
  plt.ylabel("Best Fitness")
  plt.title("Best Fitness over Generations")
  plt.show()
```

Test the GA algorithm on knapsack problems with different parameters

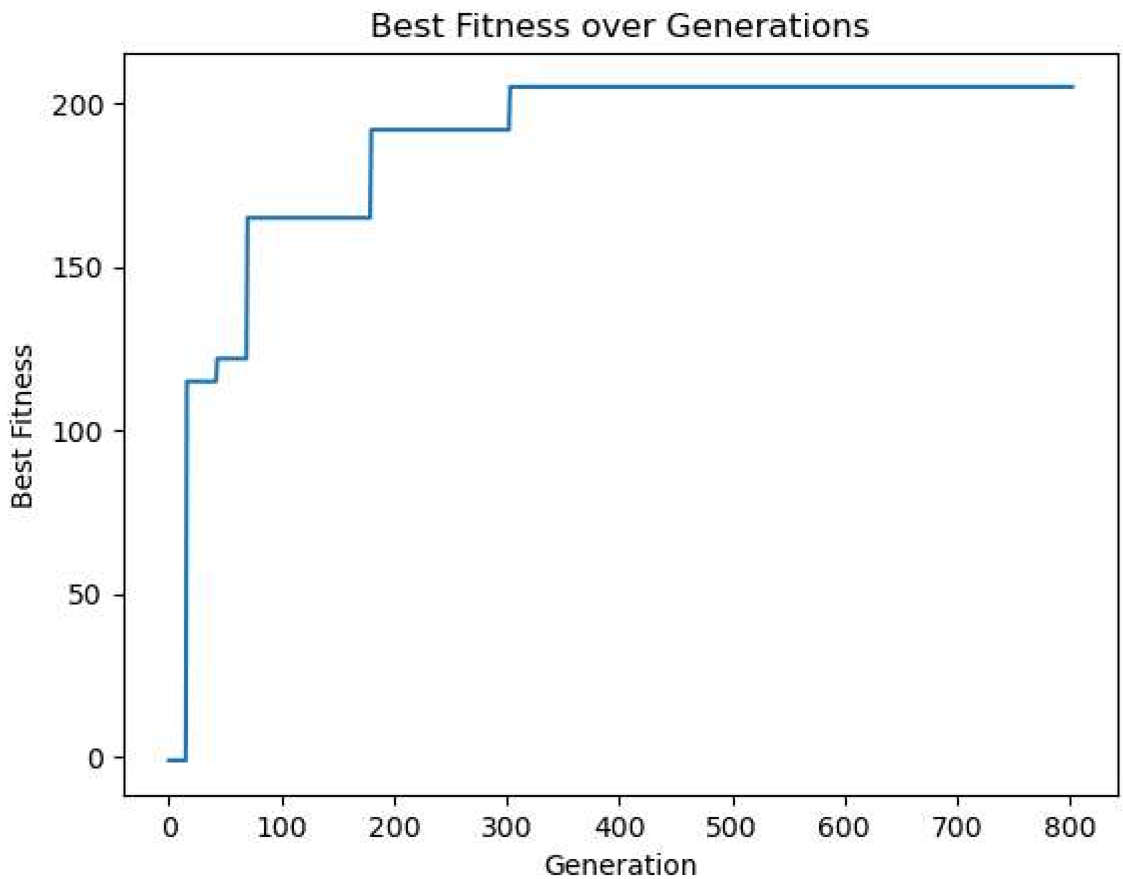
Valid solution have fitness>0 such that fitness increases with object value. Invalid solutions have a fitnees < 0.

In [4]:
```
#parameters related to the knapsack problem itself regardless of the algorithm used fo
numAvailableItems=50
capacity=50
maxWeightPerItem=20
maxValuePerItem=10


#parameters related to the GA algorithm
populationSize=500
numGenerations= 1000
patience = 500 # determines condition for early stopping if no better individuals are

optimiseKnapsack(numAvailableItems, capacity, maxWeightPerItem, maxValuePerItem, popul
```

```
Available Items:
weights [8, 5, 4, 4, 2, 8, 8, 1, 9, 10, 9, 9, 1, 4, 5, 3, 5, 1, 10, 6, 3, 3, 10, 3, 1
0, 4, 5, 9, 10, 6, 7, 8, 5, 1, 2, 10, 1, 9, 7, 4, 9, 1, 9, 2, 1, 5, 1, 2, 2, 5]
values [14, 2, 1, 8, 5, 19, 13, 8, 5, 19, 2, 16, 7, 17, 16, 18, 2, 19, 2, 8, 7, 16, 1
2, 5, 4, 19, 20, 20, 14, 4, 19, 7, 4, 20, 19, 17, 14, 11, 8, 3, 16, 16, 6, 18, 5, 11,
16, 6, 9, 10]
finished intitialisation
Stopped after 802 generations
Best individual is [0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 1, 0, 1, 1, 0,
0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 0, 0, 0, 0, 1, 0, 1, 1, 1, 1, 1, 0, 0] ;
fitness value is 205 ; found at generation 303
```



Lab Tasks

1. Make a slight change the parameters of the knapsack problem one at a time and run the GA to find a solution. Notice the effect on the diffulty of finding a solution.
2. Is our GA algorithm still able to find a valid solution for difficult problems.
3. What parameters have the most impact?

In [ ]:
```
#to do : change the parameters of the knapsack problem one at a time and run the GA tc
#
```

1. Can changing the parameters of the GA algorithms enable finding a valid solution?

In [ ]:
```
#to do :

# change the parameters of the GA algorithm
# test again to see if we can get a valid solution
```

1. Use the original parameters given and set capacity = 35. Can you find any valid solution? Can we change the fitness function to help find any better solutions?? Discuss with your tutor if you are not sure.