

A wood craftsman wants to make a tube-shaped decoration without a lid. The tube is expected to hold a liquid of not less than 200. Help the craftsman to design the tube with minimal materials using genetic algorithms.

Answer :

### 1. Problem Formulation

The number of materials required is equal to the surface of the lidless tube. So, the formula of surface area of a tube without the lid is :

$$A(r,t) = 2 * \phi * r * t + \phi * r * r$$

where the area formula is based on the combination of area formula for tube + area formula for circle;

$\phi = 22/7$  or 3.14

$r$  = radius

$t$  = height

Since the tube is expected to hold a liquid with less than 200, so the math formula for lidless tube volume :

$$V(r,t) = \phi * r * r * t \geq 200$$

To sum up, the problem formulation should minimize  $A(r,t)$  with restraint of;

$r > 0$

$t > 0$

$V(r,t) \geq 200$

### 2. Chromosomes representation

The chromosomes that will be generated are based on  $r$  and  $t$  that we defined in advance. Those 2 are positive real numbers as  $\phi$  is involved. Hence, the individual will be composed of 2 real positive numbers genes.

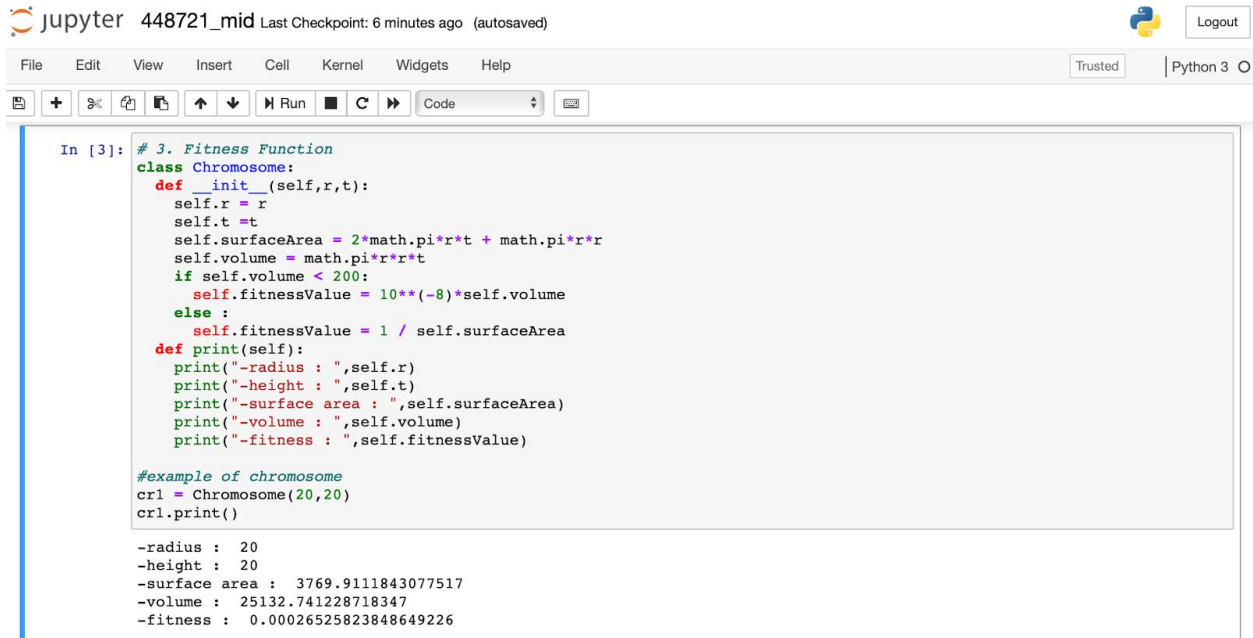
$C1 = (r, t)$

### 3. Fitness Function

The penalty method will be used so that the chromosomes can still survive in the population even if it violates the constraints. However, violating chromosomes' fitness values will be penalized for having a much lower fitness value.

$$\begin{aligned} F(A, V) &= \text{fitness function} \\ F(A, V) &= 1/A, & \text{if } V \geq 200 \\ F(A, V) &= 10^{-8} V, & \text{if } V < 200 \end{aligned}$$

A smaller surface area will make the fitness value bigger, but violating the volume limit will be excessive so that it actually decreases the fitness value.



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```
In [3]: # 3. Fitness Function
class Chromosome:
    def __init__(self,r,t):
        self.r = r
        self.t = t
        self.surfaceArea = 2*math.pi*r*t + math.pi*r*r
        self.volume = math.pi*r*r*t
        if self.volume < 200:
            self.fitnessValue = 10**(-8)*self.volume
        else :
            self.fitnessValue = 1 / self.surfaceArea
    def print(self):
        print("-radius : ",self.r)
        print("-height : ",self.t)
        print("-surface area : ",self.surfaceArea)
        print("-volume : ",self.volume)
        print("-fitness : ",self.fitnessValue)

#example of chromosome
crl = Chromosome(20,20)
crl.print()

-radius : 20
-height : 20
-surface area : 3769.9111843077517
-volume : 25132.741228718347
-fitness : 0.00026525823848649226
```

#### 4. Generate Initial Population

INPUT: number of chromosomes, radius of upper bound, height of upper limit

OUTPUT: chromosome population

**Chromosome 0 :**

```
-radius : 9.20423251938926
-height : 8.32753234254347
-surface area : 747.7461259891968
-volume : 2216.365409340458
-fitness : 0.0013373522981173528
```

**Chromosome 1 :**

```
-radius : 9.653101188131737
-height : 9.48345030463475
-surface area : 867.9333735657469
-volume : 2776.1949686511493
-fitness : 0.0011521621710335681
```

**Chromosome 2 :**

```
-radius : 10.145530389022685
-height : 1.9103470270497018
-surface area : 445.1471998133061
-volume : 617.7484318889058
-fitness : 0.0022464479174965
```

**Chromosome 3 :**

```
-radius : 8.48134257586777
-height : 13.320122890537473
-surface area : 935.8120359851042
```

```
-volume : 3010.1442998142606
-fitness : 0.001068590658750533
Chromosome 4 :
-radius : 8.964934291140148
-height : 7.012185704955071
-surface area : 647.4747532341789
-volume : 1770.5064091659813
-fitness : 0.001544461764732809
Chromosome 5 :
-radius : 11.038187989156427
-height : 8.42403135658231
-surface area : 967.0251881125517
-volume : 3224.5225600897356
-fitness : 0.00103409922749976
```

## **5. Parental Selection Method by using Baker's SUS**

### **6. Matting Pool Size : 10**

INPUT : population, number of parents to select (default 10)

OUTPUT : selected parents

```
Selected Parent 0 :
-radius : 9.653101188131737
-height : 9.48345030463475
-surface area : 867.9333735657469
-volume : 2776.1949686511493
-fitness : 0.0011521621710335681
Selected Parent 1 :
-radius : 9.20423251938926
-height : 8.32753234254347
-surface area : 747.7461259891968
-volume : 2216.365409340458
-fitness : 0.0013373522981173528
Selected Parent 2 :
-radius : 9.20423251938926
-height : 8.32753234254347
-surface area : 747.7461259891968
-volume : 2216.365409340458
-fitness : 0.0013373522981173528
Selected Parent 3 :
-radius : 9.20423251938926
-height : 8.32753234254347
-surface area : 747.7461259891968
-volume : 2216.365409340458
-fitness : 0.0013373522981173528
```

**Selected Parent 4 :**

-radius : 9.20423251938926  
-height : 8.32753234254347  
-surface area : 747.7461259891968  
-volume : 2216.365409340458  
-fitness : 0.0013373522981173528

**Selected Parent 5 :**

-radius : 9.20423251938926  
-height : 8.32753234254347  
-surface area : 747.7461259891968  
-volume : 2216.365409340458  
-fitness : 0.0013373522981173528

**Selected Parent 6 :**

-radius : 9.20423251938926  
-height : 8.32753234254347  
-surface area : 747.7461259891968  
-volume : 2216.365409340458  
-fitness : 0.0013373522981173528

**Selected Parent 7 :**

-radius : 9.20423251938926  
-height : 8.32753234254347  
-surface area : 747.7461259891968  
-volume : 2216.365409340458  
-fitness : 0.0013373522981173528

**Selected Parent 8 :**

-radius : 9.20423251938926  
-height : 8.32753234254347  
-surface area : 747.7461259891968  
-volume : 2216.365409340458  
-fitness : 0.0013373522981173528

**Selected Parent 9 :**

-radius : 4.182391545333953  
-height : 8.256814309525463  
-surface area : 271.93267791753607  
-volume : 453.74491009514145  
-fitness : 0.0036773807681298653

## **5. Do Crossover with $P_c = 0.8$**

selectParents

- INPUT : parents ,  $P_c$
- OUTPUT : selected parents based on  $P_c$

Crossover - Whole arithmetic crossover will be employed

- INPUT : 2 Chromosomes for parents, alpha
- OUTPUT : 2 Chromosomes for offspring

**Selected Parent from Crossover 0 :**

-radius : 9.653101188131737  
-height : 9.48345030463475  
-surface area : 867.9333735657469  
-volume : 2776.1949686511493  
-fitness : 0.0011521621710335681

**Selected Parent from Crossover 1 :**

-radius : 9.20423251938926  
-height : 8.32753234254347  
-surface area : 747.7461259891968  
-volume : 2216.365409340458  
-fitness : 0.0013373522981173528

**Selected Parent from Crossover 2 :**

-radius : 9.20423251938926  
-height : 8.32753234254347  
-surface area : 747.7461259891968  
-volume : 2216.365409340458  
-fitness : 0.0013373522981173528

**Selected Parent from Crossover 3 :**

-radius : 9.20423251938926  
-height : 8.32753234254347  
-surface area : 747.7461259891968  
-volume : 2216.365409340458  
-fitness : 0.0013373522981173528

**Selected Parent from Crossover 4 :**

-radius : 9.20423251938926  
-height : 8.32753234254347  
-surface area : 747.7461259891968  
-volume : 2216.365409340458  
-fitness : 0.0013373522981173528

**The offspring after crossover, with Offspring size = selected parent size \* (selected parent size - 1)**

**Offspring from Crossover 0 :**

-radius : 9.428666853760499  
-height : 8.90549132358911  
-surface area : 806.8664892464574  
-volume : 2487.1864293069957  
-fitness : 0.0012393624141385676

**Offspring from Crossover 1 :**

-radius : 9.428666853760499  
-height : 8.90549132358911  
-surface area : 806.8664892464574  
-volume : 2487.1864293069957  
-fitness : 0.0012393624141385676

**Offspring from Crossover 2 :**

-radius : 9.428666853760499  
-height : 8.90549132358911  
-surface area : 806.8664892464574  
-volume : 2487.1864293069957  
-fitness : 0.0012393624141385676

**Offspring from Crossover 3 :**

-radius : 9.428666853760499  
-height : 8.90549132358911  
-surface area : 806.8664892464574  
-volume : 2487.1864293069957  
-fitness : 0.0012393624141385676

**Offspring from Crossover 4 :**

-radius : 9.428666853760499  
-height : 8.90549132358911  
-surface area : 806.8664892464574  
-volume : 2487.1864293069957  
-fitness : 0.0012393624141385676

**Offspring from Crossover 5 :**

-radius : 9.428666853760499  
-height : 8.90549132358911  
-surface area : 806.8664892464574  
-volume : 2487.1864293069957  
-fitness : 0.0012393624141385676

**Offspring from Crossover 6 :**

-radius : 9.428666853760499  
-height : 8.90549132358911  
-surface area : 806.8664892464574  
-volume : 2487.1864293069957  
-fitness : 0.0012393624141385676

**Offspring from Crossover 7 :**

-radius : 9.428666853760499  
-height : 8.90549132358911  
-surface area : 806.8664892464574  
-volume : 2487.1864293069957  
-fitness : 0.0012393624141385676

**Offspring from Crossover 8 :**

-radius : 9.428666853760499  
-height : 8.90549132358911  
-surface area : 806.8664892464574  
-volume : 2487.1864293069957  
-fitness : 0.0012393624141385676

**Offspring from Crossover 9 :**

-radius : 9.428666853760499  
-height : 8.90549132358911

-surface area : 806.8664892464574  
-volume : 2487.1864293069957  
-fitness : 0.0012393624141385676

**Offspring from Crossover 10 :**

-radius : 9.428666853760499  
-height : 8.90549132358911  
-surface area : 806.8664892464574  
-volume : 2487.1864293069957  
-fitness : 0.0012393624141385676

**Offspring from Crossover 11 :**

-radius : 9.428666853760499  
-height : 8.90549132358911  
-surface area : 806.8664892464574  
-volume : 2487.1864293069957  
-fitness : 0.0012393624141385676

**Offspring from Crossover 12 :**

-radius : 9.20423251938926  
-height : 8.32753234254347  
-surface area : 747.7461259891968  
-volume : 2216.365409340458  
-fitness : 0.0013373522981173528

**Offspring from Crossover 13 :**

-radius : 9.20423251938926  
-height : 8.32753234254347  
-surface area : 747.7461259891968  
-volume : 2216.365409340458  
-fitness : 0.0013373522981173528

**Offspring from Crossover 14 :**

-radius : 9.20423251938926  
-height : 8.32753234254347  
-surface area : 747.7461259891968  
-volume : 2216.365409340458  
-fitness : 0.0013373522981173528

**Offspring from Crossover 15 :**

-radius : 9.20423251938926  
-height : 8.32753234254347  
-surface area : 747.7461259891968  
-volume : 2216.365409340458  
-fitness : 0.0013373522981173528

**Offspring from Crossover 16 :**

-radius : 9.20423251938926  
-height : 8.32753234254347  
-surface area : 747.7461259891968  
-volume : 2216.365409340458  
-fitness : 0.0013373522981173528

**Offspring from Crossover 17 :**

-radius : 9.20423251938926  
-height : 8.32753234254347  
-surface area : 747.7461259891968  
-volume : 2216.365409340458  
-fitness : 0.0013373522981173528

**Offspring from Crossover 18 :**

-radius : 9.20423251938926  
-height : 8.32753234254347  
-surface area : 747.7461259891968  
-volume : 2216.365409340458  
-fitness : 0.0013373522981173528

**Offspring from Crossover 19 :**

-radius : 9.20423251938926  
-height : 8.32753234254347  
-surface area : 747.7461259891968  
-volume : 2216.365409340458  
-fitness : 0.0013373522981173528

**8. Do mutation with  $P_m = 0.1$**

Uniform mutation

- INPUT : chromosome
- OUTPUT : mutated chromosome

**--Offspring 16 is mutated**

Before mutation  $r = 9.20423251938926$  ,  $t = 8.32753234254347$

After mutation  $r = 9.20423251938926$  ,  $t = 0.17976281726188842$

**9. Do survivor selection / update generation : Generational Model**

Combine initial population with offspring, then filter the best

*populationSize*

chromosomes.

- INPUT : population, *populationSize*
- OUTPUT : a population of best
- *populationSize*
- chromosomes

**Next generation's chromosomes**

**Chromosome 0**

-radius : 9.20423251938926  
-height : 0.17976281726188842  
-surface area : 276.5451455598025



-volume : 47.843715722291655  
-fitness : 0.4784371572229166

**Chromosome 1**

-radius : 2.9996286674094246  
-height : 8.32753234254347  
-surface area : 185.2181920458737  
-volume : 235.39714529301855  
-fitness : 0.005399037691461356

**Chromosome 2**

-radius : 5.135344339138556  
-height : 8.32753234254347  
-surface area : 351.5481563317164  
-volume : 689.9304928921284  
-fitness : 0.0028445605018517367

**Chromosome 3**

-radius : 10.145530389022685  
-height : 1.9103470270497018  
-surface area : 445.1471998133061  
-volume : 617.7484318889058  
-fitness : 0.0022464479174965

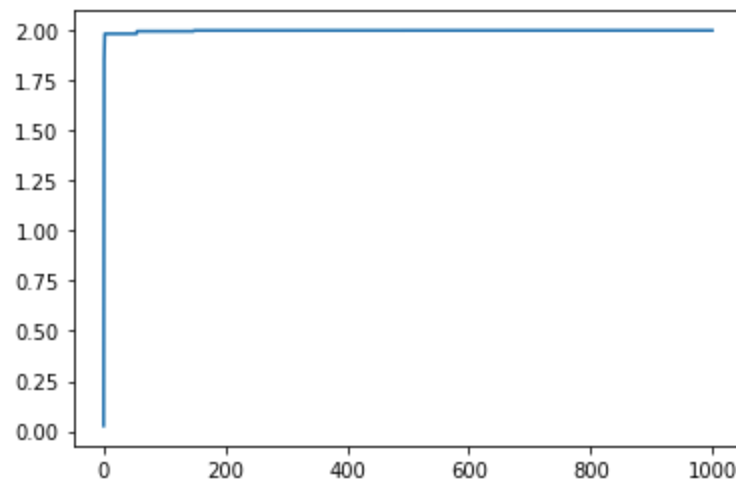
**Chromosome 4**

-radius : 9.20423251938926  
-height : 6.10236262853447  
-surface area : 619.0603368772863  
-volume : 1624.138446876901  
-fitness : 0.0016153514293037736

**Chromosome 5**

-radius : 8.964934291140148  
-height : 7.012185704955071  
-surface area : 647.4747532341789  
-volume : 1770.5064091659813  
-fitness : 0.001544461764732809

## 10. Number of Generations



**Chromosome with best fitness value after 1000 iterations:**

-radius : 2.5449274178771297  
-height : 9.825934157203386  
-surface area : 177.4661626924485  
-volume : 199.92841528313048  
-fitness : 1.9992841528313048

THE CODE : [https://github.com/dhifaaans/ga\\_midtest/blob/master/448721\\_mid.ipynb](https://github.com/dhifaaans/ga_midtest/blob/master/448721_mid.ipynb)