Selection Techniques

Credits:

Soft Computing Applications, Dr. Debasis Samanta, IIT Kharagpur

Soft Computing Fundamentals and Applications, Dr. D. K. Pratihar, IIT Kharagpur

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Important GA Operations

1. Encoding
2. Selection
3. Crossover
4. Mutation

GA Selection

- After deciding an encoding scheme, the second important things is how to perform selection from a set of population, that is, how to choose the individuals in the population that will create offspring for the next generation and how many offspring each will create.
- The purpose of selection is, of course, to emphasize **fittest** individuals in the population in hopes that their offspring will in turn have even higher fitness.

Selection operation in GAs

Selection is the process for creating the population for next generation from the current generation

To generate new population: Breeding in GA

- Create a mating pool
- Select a pair
- Reproduce

Selection Schemes in GAs

Different strategies are known for the selection:

- **Roulette Wheel selection** (also called proportionate-based selection)
- **Rank-based selection** (also called as ordinal-based selection)
- **Tournament selection**
- **Steady-state selection**

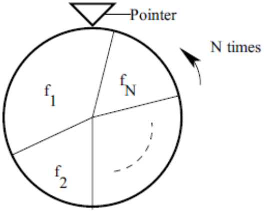
Roulette-Wheel selection

- In this scheme, the probability for an individual being selected in the mating pool is considered to be **proportional to** its **fitness**.
- It is implemented with the help of a wheel as shown.

$i \longrightarrow f_i$

$j \longrightarrow f_j$

$f_i > f_j \Rightarrow i$ (Preferable than j)



[Wheel Game (Rotate and See the Pointer)]

Roulette-Wheel selection mechanism

- The top surface area of the wheel is divided into N parts in proportion to the fitness values $f_1, f_2, f_3 \cdots f_N$.
- The wheel is rotated in a particular direction (either clockwise or anticlockwise) and a fixed pointer is used to indicate the winning area, when it stops rotation.
- A particular sub-area representing a GA-Solution is selected to be winner probabilistically and the probability that the $i-th$ area will be declared as

$$p_i = \frac{f_i}{\sum_{i=1}^{N} f_i}$$

- In other words, the individual having higher fitness value is likely to be selected more.

Roulette-Wheel selection mechanism

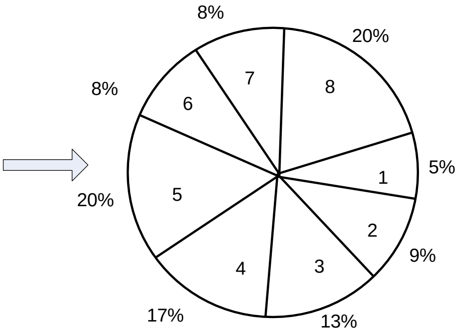
The wheel is rotated for N_p times (where $N_p = p\%N$, for some p) and each time, only one area is identified by the pointer to be the winner.

Note :

- Here, an individual may be selected more than once.
- Convergence rate is fast.

Roulette-Wheel selection mechanism: An Example

Individual	Fitness value	p_i
1	1.01	**0.05**
2	2.11	**0.09**
3	3.11	**0.13**
4	4.01	**0.17**
5	4.66	**0.20**
6	1.91	**0.08**
7	1.93	**0.08**
8	4.51	**0.20**



Roulette-Wheel selection : Implementation

Input: A Population of size N with their fitness values
Output: A mating pool of size N_p

Steps:

1. Compute $p_i = \frac{f_i}{\sum_{i=1}^{N} f_i}$, $\forall i = 1, 2 \cdots N$
2. Calculate the cumulative probability for each of the individual starting from the top of the list, that is
   $P_i = \sum_{j=1}^{i} p_j$ for all $j = 1, 2 \cdots N$
3. Generate a random number say r between 0 and 1.
4. Select the j-th individual such that $P_{j-1} < r \leq P_j$
5. Repeat Step 3-4 to select N_p individuals.
6. End

Roulette-Wheel selection: Example

The probability that i-th individual will be pointed is

$$p_i = \frac{f_i}{\sum_{i=1}^{N} f_i}$$

Example:

Individual	p_i	P_i	r	T
1	0.05	0.05	0.26	I
2	0.09	0.14	0.04	I
3	0.13	0.27	0.48	II
4	0.17	0.44	0.43	I
5	0.20	0.64	0.09	II
6	0.08	0.72	0.30	
7	0.08	0.80	0.61	
8	0.20	1.0	0.89	I

p_i = Probability of an individual

r = Random Number between 0..1

P_i = Cumulative Probability

T=Tally count of selection

Roulette-Wheel selection

Following are the point to be noted:

1. The bottom-most individual in the population has a cumulative probability $P_N = 1$
2. Cumulative probability of any individual lies between 0 and 1
3. The i-th individual in the population represents the cumulative probability from P_{i-1} to P_i
4. The top-most individual represents the cumulative probability values between 0 and p_1
5. It may be checked that the selection is consistent with the expected count $E_i = N \times p_i$ for the i-th individual.

Does the selection is sensitive to ordering, say in ascending order of their fitness values?

Drawback in Roulette-Wheel selection

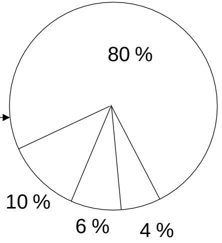
- Suppose, there are only four binary string in a population, whose fitness values are f_1, f_2, f_3 and f_4.
- Their values 80%, 10%, 6% and 4%, respectively.

What is the expected count of selecting f_3, f_4, f_2 or f_1?

Problem with Roulette-Wheel selection scheme

The limitations in the Roulette-Wheel selection scheme can be better illustrated with the following figure.

Individual (i)	Fitness (fi)	RW (Area)
1	0.4	80 %
2	0.05	10 %
3	0.03	6 %
4	0.02	4 %



The observation is that the individual with higher fitness values will guard the other to be selected for mating. This leads to a lesser diversity and hence fewer scope toward exploring the alternative solution and also premature convergence or early convergence with local optimal solution.

Rank-based selection

- To overcome the problem with Roulette-Wheel selection, a rank-based selection scheme has been proposed.
- The process of ranking selection consists of two steps.
  1. Individuals are arranged in an ascending order of their fitness values. The individual, which has the lowest value of fitness is assigned rank 1, and other individuals are ranked accordingly.
  2. The proportionate based selection scheme is then followed based on the assigned rank.

Note:

- The % area to be occupied by a particular individual i, is given by

$$\frac{r_i}{\sum_{i=1}^{N} r_i} \times 100$$

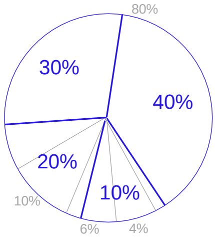
where r_i indicates the rank of $i-th$ individual.

- Two or more individuals with the same fitness values should have the same rank.

Rank-based selection: Example

- Continuing with the population of 4 individuals with fitness values: $f_1 = 0.40, f_2 = 0.05, f_3 = 0.03$ and $f_4 = 0.02$.
- Their proportionate area on the wheel are: 80%, 10%, 6% and 4%
- Their ranks are shown in the following figure.

Individual (i)	Fitness (fi)	RW (Area)	Rank	RS (Area)
1	0.4	80 %	4	40 %
2	0.05	10 %	3	30 %
3	0.03	6 %	2	20 %
4	0.02	4 %	1	10 %



It is evident that expectation counts have been improved compared to Routlette-Wheel selection.

Rank-based selection: Implementation

Input: A population of size N with their fitness values
Output: A mating pool of size N_p.

Steps:

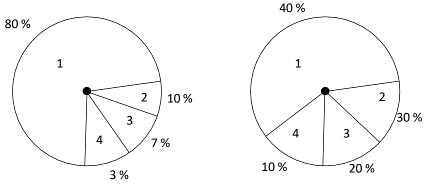
1. Arrange all individuals in ascending order of their fitness value.
2. Rank the individuals according to their position in the order, that is, the worst will have rank 1, the next rank 2 and best will have rank N.
3. Apply the Roulette-Wheel selection but based on their assigned ranks. For example, the probability p_i of the i-th individual would be

$$p_i = \frac{r_i}{\sum_{j=1}^{i} r_j}$$

4. Stop

Comparing Rank-based selection with Roulette-Wheel selection

Individual	% Area	f_i	Rank (r_i)	% Area
1	80 %	0.4	4	40 %
2	10 %	0.05	3	30 %
3	7 %	0.03	2	20 %
4	4 %	0.02	1	10 %



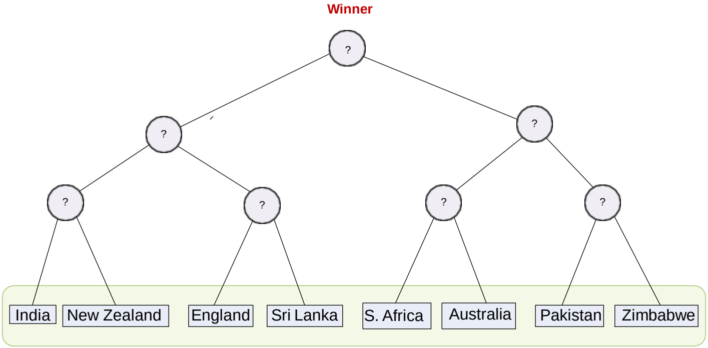
Roulette-Wheel based on proportionate-based selection

Roulette-Wheel based on ordinal-based selection

A rank-based selection is expected to performs better than the Roulette-Wheel selection, in general.

Basic concept of tournament selection

Who will win the match in this tournament?



Tournament selection

1. In this scheme, we select the tournament size n (say 2 or 3) at random.
2. We pick n individuals from the population, at random and determine the best one in terms of their fitness values.
3. The best individual is copied into the mating pool.
4. Thus, in this scheme only one individual is selected per tournament and N_p tournaments are to be played to make the size of mating pool equals to N_p.

Note :

- Here, there is a chance for a good individual to be copied into the mating pool more than once.
- This techniques founds to be computationally more faster than both Roulette-Wheel and Rank-based selection scheme.

Tournament selection : Implementation

The tournament selection scheme can be stated as follows.

Input : A Population of size N with their fitness values
Output : A mating pool of size $N_p (N_p \leq N)$

Steps:

1. Select N_U individuals at random $(N_U \leq N)$.
2. Out of N_U individuals, choose the individual with highest fitness value as the winner.
3. Add the winner to the mating pool, which is initially empty.
4. Repeat Steps 1-3 until the mating pool contains N_p individuals
5. Stop

Tournament selection : Example

$$N = 8, N_U = 2, N_p = 8$$

Input :

Individual	1	2	3	4	5	6	7	8
Fintess	1.0	2.1	3.1	4.0	4.6	1.9	1.8	4.5

Output :

Trial	Individuals	Selected
1	2, 4	4
2	3, 8	8
3	1, 3	3
4	4, 5	5
5	1, 6	6
6	1, 2	2
7	4, 2	4
8	8, 3	8

If the fitness values of two individuals are same, than there is a tie in the match!! So, what to do????

Tournament selection

Note :

There are different twists can be made into the basic Tournament selection scheme:

1. Once an individual is selected for a mating pool, it can be discarded from the current population, thus disallowing the repetition in selecting an individual more than once.

- Replace the worst individual in the mating pool with those are not winners in any trials.

Steady-State selection algorithm

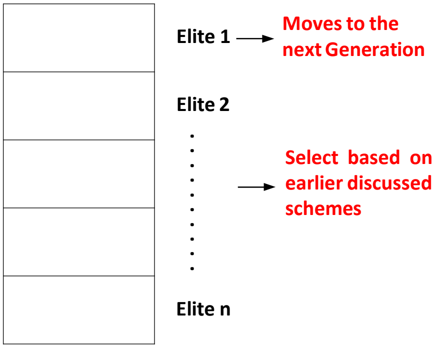
Steps :

1. N_U individuals with highest fitness values are selected.
2. N_U individuals with worst fitness values are removed and N_U individuals selected in Step 1 are added into the mating pool.

This completes the selection procedure for one iteration. Repeat the iteration until the mating pool of desired size is obtained.

Elitisms

- In this scheme, an elite class (in terms of fitness) is identified first in a population of strings.
- It is then directly copied into the next generation to ensure their presence.



This is done because the already found best string may be lost, if it is not selected during reproduction using any one of the above schemes.

Comparing selection schemes

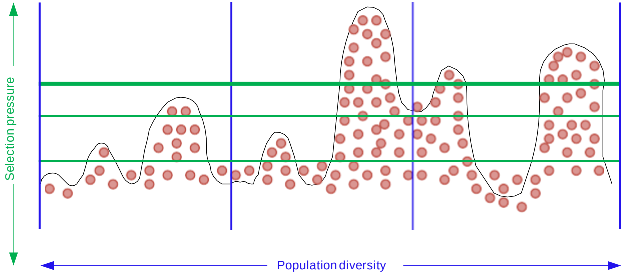
- Usually, a selection scheme follows Darwin's principle of "Survival of the fittest".
- In other words, a selection strategy in GA is a process that favours the selection of better individuals in the population for the matting pool (so that better genes are inherited to the new offspring) and hence search leads to the global optima.

There are two issues to decide the effectiveness of any selection scheme.

- Population diversity
- Selection pressure

Analyzing a selection schemes

- More population diversity means more exploration
- Higher selection pressure means lesser exploitation



Effectiveness of any selection scheme

Population diversity

- This is similar to the concept of exploration.
- The population diversity means that the genes from the already discovered good individuals are exploited while permitting the new area of search space continue to be explored.

Selection pressure

- This is similar to the concept of exploitation.
- It is defined as the degree to which the better individuals are favoured.

Thank you.