Comparison of Results and Selection Techniques in Evolutionary Optimization

1. Overview of Selection Techniques

Selection plays a critical role in evolutionary optimization, as it determines how parents are chosen to generate offspring for the next generation. The three selection techniques used in this experiment—**Tournament Selection, Rank Selection, and Roulette Wheel Selection**—each have distinct characteristics that influence the convergence, diversity, and performance of the evolutionary process.

- **Tournament Selection**: A subset of individuals is randomly selected from the population, and the best individual (based on fitness) is chosen as a parent. This method maintains high selective pressure and is good at quickly converging to high-quality solutions.

- **Rank Selection**: Individuals are ranked based on their fitness, and selection probabilities are assigned based on their ranks rather than raw fitness values. This helps in preventing premature convergence but may slow down optimization.

- **Roulette Wheel Selection**: Each individual is assigned a selection probability proportional to its fitness. Fitter individuals have a higher chance of being selected, but this can lead to premature convergence if diversity is lost.

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2. Analysis of Results

Selection Method	Final Reward	Population	Observations
Tournament Selection	1426.41	150	High selective pressure, rapid convergence, best-performing
Rank Selection	261.83	150	Low selective pressure, too much diversity, slow convergence
Roulette Wheel Selection	757.36	100	Moderate selective pressure, better than rank but worse than tournament

Experiment 1: Tournament Selection

```
pop_size=150, generations=170, mutation_rate=0.125, crossover_rate=0.9,
keyframe_count=6, tournament_size=12, step_limit=6000, elite_count=50, stagnation_limit=50
selection_strategy="tournament"
```

Final Reward (Average over 5 runs): 1426.41

Key Observations

- Highest final reward achieved due to strong selection pressure**.**
- Large tournament size (12/150) meant that fitter individuals were frequently selected, accelerating convergence.
- High crossover rate (0.9) promoted strong gene exchange, allowing high-reward strategies to be combined.
- Moderate mutation rate (0.125) prevented premature convergence while preserving high-reward key frames.
- Elite count (50) ensured the best individuals were preserved across generations.

Why Tournament Performed Best?

- **Fast convergence**: Since only the best individuals from each tournament were selected, the population improved rapidly.

- **Efficient exploitation**: Strong solutions dominated quickly, leading to a high-performing final model.

Experiment 2: Roulette Selection

```
pop_size=100, generations=170, mutation_rate=0.125, crossover_rate=0.9,
keyframe_count=6, tournament_size=12, step_limit=6000, elite_count=50, stagnation_limit=50
selection_strategy="roulette"
```

Final Reward (Average over 5 runs): 757.36

Key Observations

- Better than rank selection but worse than tournament selection.
- Roulette prioritizes fitter individuals, which helped in achieving a higher final reward than rank selection.
- Moderate selective pressure: Unlike tournament selection, roulette doesn't guarantee that the fittest individuals are always picked.
- Smaller population (100) helped balance exploitation and exploration.

Why Roulette Performed Better than Rank but Worse than Tournament?

- **Some randomness:** allows weak individuals to be chosen, maintaining diversity.
- **Better exploitation than rank selection**: Unlike rank-based selection, roulette assigns a selection probability based on fitness, allowing strong individuals to be picked more often.
- **Lack of guaranteed best selection**: Unlike tournament selection, where the best individuals dominate, roulette still allows weaker individuals a chance to survive.

Experiment 3: Rank Selection

```
pop_size=150, generations=170, mutation_rate=0.125, crossover_rate=0.9,
keyframe_count=6, tournament_size=12, step_limit=6000, elite_count=50, stagnation_limit=50
selection_strategy="rank"
```

Final Reward (Average over 5 runs): 261.83

Key Observations

- Worst-performing selection method among the three.
- Rank-based selection gives more individuals a chance to be selected, which increases diversity but significantly slows convergence.
- Large population (150) diluted selective pressure, leading to suboptimal solutions persisting for longer.
- Rank-based selection prevents dominance of top individuals, which in this case led to weaker overall solutions.

Why Rank Selection Performed Poorly?

- **Slow learning**: It prevents the best individuals from taking over too soon, but in this case, it resulted in a much lower final reward.
- **Too much diversity**: With high diversity and a large population, good solutions were not reinforced quickly enough.
- **Poor exploitation**: Unlike tournament selection, which consistently selects stronger individuals, rank selection focuses more on maintaining diversity.

3. Impact of Parameters on Results

Mutation Rate (0.125)

- Helped maintain diversity, but a higher mutation rate might have benefited rank selection to accelerate optimization.

Crossover Rate (0.9)

- High crossover rate meant strong solutions mixed effectively, especially in tournament selection.

Population Size

- Larger populations (150) benefited tournament selection but hurt rank selection, as rank-based selection with high diversity slowed convergence.
- Smaller population (100) helped roulette wheel selection because it allowed strong individuals to be picked more frequently.

Tournament Size (12)

- Large tournament size (12) increased selective pressure**,** leading to fast convergence in tournament selection.

Elite Count (50)

- Guaranteed that top solutions were retained, which was especially helpful for tournament selection.

4. Conclusion

Best Performing Method: Tournament Selection

- High selective pressure ensured rapid convergence and strong final solutions.
- Elite preservation and strong crossover helped accelerate optimization.

Worst Performing Method: Rank Selection

- Encouraged too much diversity, leading to slow improvement.
- Was outperformed by both tournament and roulette selection.

Middle Ground: Roulette Wheel Selection

- Provided moderate selective pressure, allowing strong solutions to emerge while maintaining diversity.
- Smaller population (100) helped it perform better than rank selection.

5. Conclusion

Tournament selection significantly outperformed rank and roulette selection due to its ability to quickly converge towards high-reward solutions**.** Rank selection suffered from slow convergence**,** while roulette wheel selection provided **a** good balance between exploration and exploitation but was still weaker than tournament selection**.**