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**CIFO PROJECT**

*Sports League Optimization*

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# **Formal Definition of the Problem**

In this project, we attempt to form balanced teams based on a set/dataset of players. The goal of this project is to group players in a way that maximizes the overall performance of teams while ensuring that the teams are balanced. The space for possible solutions to an optimization problem is very large. Our goal is to find a combination that maximizes the evaluation function (fitness).

There are five teams representing each solution (individual), with a goalkeeper, two defenders, two midfielders, and two attackers. Players are aggregated into Team objects, so the vector has a length of five teams, and each element has a length of seven players. Based upon an analysis of the teams and a comparison of the requirements of each team, an integrated function, is\_valid (), determines if the individual is valid.

The search space corresponds to the set of all possible valid combinations of players distributed across five teams, without repetitions and with the correct positional composition. Also, each team may not exceed the budget limit of 750 million euros. Solutions that do not comply with these conditions will be automatically considered invalid and penalized.

The fitness function can be predefined using function toolkit predefined that has the ability of allowing the user to dynamically set the fitness function based on multiple criteria by forming two bins based on the average. If there is an equal division between two different solutions. If there is a larger deviation between the splits. You also must specify the performance of various metric goals like the recall, an f score and decide if you are looking to minimize false positive rate or maximize true positive.

It is ensured that composition and budget constraints are met through internal methods that ensure: Per team, there is one goalkeeper, two defenders, two midfielders, and two forwards; There is only one team for each player; The maximum amount per team is € 750 M. In this model, selection, crossover, and mutation operate effectively, preserving solutions and exploring the space with search and diversity.

# **Description of Selection and Genetic Operators**

During the different developmental phases, a set of selection and genetic modification operators were developed and implemented. One of the main goals was to construct balanced teams abiding by all assumed constraints, including position budgets at different hierarchical levels of the organization. Consequently, these operators and their selection strategies modify – often in an adverse manner – the fitness landscapes of the solutions evolving by the genetic algorithm.

* 1. **Selection Strategies**

Different selection strategies were used during reproduction that differed in genetic diversity and selective pressure. We chose these strategies: In the tournament selection, a few (2-3) individuals are selected, and the best one is selected. Providing selective moderation and preventing too fast convergence. Roulette wheels select participants based on their fitness level. All candidates have a chance, but the best performer is more likely to be chosen. A random individual from the top 30% of the population is selected in a truncation selection to direct evolution to integer-based solutions. Furthermore, rank ordering can counteract stronger variation between individuals that could harm evolution. By placing options more randomly, SUS reduces chance-related variance. Evolutionary elitism ensures that high-quality solutions will endure through the preservation of the finest individuals at each generation's start.

* 1. **Crossovers Operators**

There are several strategies developed for crossbreeding using positional rosters. Team Swap involves swapping entire teams between two parents. Therefore, the proposed solution can be greatly altered. A player swap involves exchanging players from different countries occupying the same position, so the positional arrangement is maintained. A uniform team has a 50-50 chance of being able to identify either parent's child. Hence, descendants are produced with different parents. A position-based crossing replaces one position holder with someone else. The Gene Level Crossing balances the composition of teams without repeating players. Players from both parents are combined with stylistic rules, and many different techniques increase fragmentation.

* 1. **Mutation Operators**

To avoid local convergence, some mutation operators were applied: Random Substitution consists of changing players that have not been put to some position with other players. Team Swap: exchange players that have the same position in different teams. Team Replacement is the process of replacing a valid team with another valid one under specified conditions. Most Expensive Player Replacement identifies the least cost effective one and replaces him with a cheaper one. Cross Position Swap replaces the players from distinct teams but assigns them players who occupy the same position. The younger players are to replace the older players in respective positions once they become eligible as strikers. A team rotation might happen on an individual when the teams are restructured within individual which will influence crossover operations afterwards.

# **Performance Analysis**

* 1. **Global Comparison of Selection Methods**

Comparison of selection techniques within a genetic algorithm is presented in two figures. *Fig. 1* *shows the best individual over several generations while Fig. 2* shows average fitness by generation with confidence intervals demonstrating method consistency. The elitism method, as shown in *Fig. 1*, achieves and maintains a maximum fitness value of 1000 from approximately the 6th generation onwards. Both initial exploration and conservation of best solutions occurs based on the portrayed behavior. Optimal fitness may be attained by the rank method as well, but the curve is much shallower and takes many generations to reach optimal fitness. Truncation, tournaments, and roulette achieve these intervals faster; fitness values are achieved slower yet converge far later. The SUS method depicts the most irregular and slowest curve illustrating increased variability and less stability. Along with this analysis, *Fig. 2* depicts the average trends over thirty generations for each individual methodology. Regardless of best execution, all methods overly converge by the 15th generation with slight advantages led by elitism and truncation. Retention of best individuals is aided by intervention alongside confidence variables.

* 1. **Analysis of Fig. 3 - 33**

The performance of a genetic algorithm is affected by the interplay of selection, crossover, and mutation operators under all six selection schemas. Mutation operators were random\_*player, replace\_*team, cross\_*position, as well as team\_*swaps and player swaps. Rank selection guarantees stability and avoidance of stagnation. Due to the high recombination and mutation rate, roulette worked well. It excelled at uniform\_*team and team\_*swaps. Multi-runs with maximum fitness enabled by tournament selection. In combination with strong mutation and crossovers of structure such as uniform\_*team,* *team\_*swap, and player\_swap, truncation selection can be extremely robust. These combinations achieved a fitness of 1000 rapidly and consistently, cementing them as global strategies. This one incorporates elitist selection blended with pressure-based selection (truncation or tournament) and high recombination crossovers with intensive mutation, set to 100% over a small number of generations, interleaved by rest phases. We can observe these results with Fig. 3 – 33.

* 1. **Analysis of Selection, Crossover, Mutations, and Genetic Rates**

Evolutionary operators are strongly correlated with empirical data. In Figure 34, Rank (992.30), Truncation (991.64), and Tournament (990.87) turned out to have the best mean fitness scores, surpassing SUS (990.01), Roulette (989.91), and Elitism (989.43). Most effective methods showed improved robustness and higher convergence stability, demonstrating stronger tighter distribution with less outliers (Figs. 35 and 36). Figure 35 shows that team\_*swap\_*crossover, player\_*swap\_*crossover, and uniform\_team\_crossover achieve optimum fitness without fail. Gene\_level\_crossover is less robust, as evidenced by a lower median and higher outcome variability. In Figure 36, random\_*player\_*mutation, and replace\_*team\_*mutation results are almost optimal. Expensive\_*player\_*mutation and forward\_*reset\_*mutation result in high variation for strategies that require rapid convergence and rigid consistency. Figure 37 shows uniform\_team\_crossover and rotate\_*teams\_*mutation outperforming team\_*swap\_*crossover and replace\_*team\_*mutation, where all methods scored over 1000 with little deviation. Crossovers possess high recombination and structural diversity needed to escape local optima. Both pair plots of fitness against genetic rates (Fig. 38) and mutation rate against fitness area show.

1. **Justification of Decisions**

This section outlines our extensive work with various combinations of evolution strategies and modifications made to the genetic algorithm. For decision making, fitness averages, system stability, and convergence velocity metrics were employed. Main efforts were devoted to adjusting the balance between selective pressure, population diversity, and the search space exploration. Implementing these strategies will yield optimal outcomes. We can observe/find the information in [**TABLE A**](#TableA).

* 1. **Selection Method**

The values achieved, such as Truncation 1000.00, Classification 999.50 and Tournament 999.00, represented mean effectiveness. High selective pressure was exhibited while coupled with highly conservative solution removal. Solutions encouraged convergence towards the target. Stable and efficient evolution is demonstrated by the visual representations described earlier in this article.

* 1. **Crossover Type**

Ranked by averages, Truncation 10000, Classification 999.50, and Tournament 999.00 achieved the best averages. Increased selective pressure removed poorly adapted solutions and accelerated convergence to resolved solutions. In previous sections, the provided visualizations showcased stable and efficient evolution. The order of reliability and speed in evolution was enhanced. Successful crossovers included players\_*swap*\_crossover, uniform\_*team*\_crossover, and team\_s*wap\_*crossover. One combination achieved maximum fitness (1000.00) by using uniform\_team\_crossover in the first two combinations in the table. As a result, this operator encourages significant recombination within individuals, preventing local optima stagnation. The traits chosen were genetic diversity and adaptability.

* 1. **Mutation Type**

The rotate\_*team*\_mutation was found to occur in three of the five top combinations and was strongly linked to optimal result achievement. Also performing strongly was replace\_*team*\_mutation. Both examples make structural alterations to dependents that add to diversity and shift away from a local optimum.

* 1. **Genetics Rates**

Churn of mutation rates at 100% achievement of peak fitness scores is almost synchronized. Additionally, the persistently best combinations showed an 80% crossover rate. In this case, variety is actively preserved while effective recombination of the best population members ensures a high degree of genetic activity.

# **Conclusions**

In this examination, genetic algorithms solved a multifaceted optimization dilemma concurrently with selection, crossover, mutation, and other genetic metrics considering all parameters. According to statistics, all required performance metrics, in proportions to balance, visualization and cross comparative analysis, have optimal precise value. Greater exertion on selection criteria increases effective evaluation of the described space, for example, structural recombination crossover, truncation, classification and tournament selection, uniform team mutations transformations. The configuration described, with the application of truncation selection, uniform team crossover, 100% mutation and 80% crossover with a genetic rate maintained a peak fitness of “1000.00.” Verification through empirical and comparing analysis on model validation is equally important. These algorithms justify their optimization, demonstrating accuracy in the parameters set. The described mechanistic approach describes a solid foundation for combinatorial optimization, demonstrating flexible adaptability across various disciplines.

**Appendix A**

|  |  |  |  |
| --- | --- | --- | --- |
| *Selection* | *Crossover* | *Mutation* | *Fitness* |
| *truncation* | uniform\_team\_crossover | rotate\_teams\_mutation | 1000.0 |
| *rank* | uniform\_team\_crossover | rotate\_teams\_mutation | 999.5 |
| *tournament* | team\_swap\_crossover | rotate\_teams\_mutation | 999.0 |
| *elitism* | team\_swap\_crossover | replace\_team\_mutation | 999.05 |
| *roulette* | player\_swap\_crossover | replace\_team\_mutation | 998.9 |

**Table A: Top Fitness Combinations**

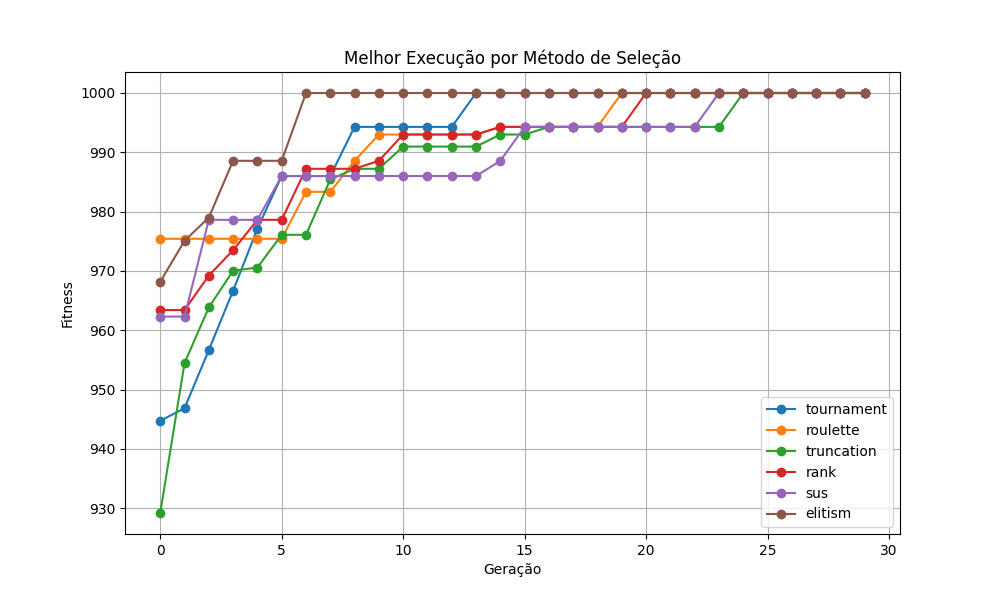
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Figure : Best Comparation Per Selection

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