SIGEVO Summer School 2017 Challenge

Challenge posed by Dr Una-May O'Reilly

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Question

Compare and contrast the value of three different solution concepts used in coevolutionary algorithm for network security

Response

Three solution concepts used were

- **Pareto Optimal Set - implemented in IPCA**
  - Every possible test (solution) is an objective and the subset of solutions (tests) are the Pareto set of the problem's multi-objective space.
- **Best Worst Case - implemented in MinMax**
  - A solution's fitness is its worst performance measure against the fittest test in the set of tests that it tries to solve
- **Maximization of Expected Utility - implemented in COEV**
  - A solution's fitness reflects that its tests are of equal importance.

Preliminaries - Solution concepts

- Solution concepts are fundamental to search problems
- Tells an underlying algorithm which areas of the search space are solutions/desirable
- A coevolutionary algorithm's fitness function, which determines an individual's likelihood of survival, is often linked with solution concepts, and hence introduces constraints
- The three strategies used here all belong to the class test-based or competitive solution concepts [1]

A note on the solution concepts

- The Best Worst Case strategy is specifically designed to guard against the worst-case strategy. In network attack settings, this may may not be the best strategy since its success hinges on having a robust training-dataset. It is at the risk of underperformance in real-world attacks are scarcely seen during training.
- Maximization of expected utility assumes that each opposing strategy is equally important (since its just an average) and hence is at the risk of underperformance in a real-world attack setting again.
- The Pareto Optimal Set solution concept extends the traditional multi-objective optimization setting. This maybe computationally expensive to compute as compared to the previous two algorithms.

Performance in a network security setting {Garcia et al., GECCO 2017 [2]}

- The Pareto optimal solution strategy as implemented in IPCA (and rIPCA) consistently outperforms MinMax and COEV algorithms
- In spite of intuitively being a stronger solution strategy, the IPCA performs better most likely due to the design of the underlying algorithm. It has access to archives of its population while the other algorithms do not.
- In the results, we see that the IPCA does have higher execution times as compared to the other two.
- Both, MinMax and COEV have consistently high variance on its average fitness scores across various topologies of attacks. The reason for this effect needs to be investigated.

A note on the experiment setup

- The results are not strictly apple-to-apple comparisons. The ideal way would have been to try out each algorithm with each solution strategy and then compared results. But then, the algorithms are designed in a way to be amenable to certain solution strategies than others.

References

[1] Popovici, Elena, et al. "Coevolutionary principles." Handbook of Natural Computing. Springer Berlin Heidelberg, 2012. 987-1033.

[2] Garicia, Lugo, Hemberg, O'Reilly. "Investigating Coevolutionary Archive Based Genetic Algorithms on Cyber Defense Networks", GECCO 2017