HYBRID EVOLUTIONARY ALGORITHMS FOR THE TSP

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SUMMARY

Even if simply stated the travelling salesman problem (TSP) is one of the most studied NP-hard problems. Many algorithms have been proposed to solve TSP. Dynamic programming and branch and bound techniques provided the global optimum solution for the largest nontrivial instance of TSP with 7397 cities. However, 4 years of CPU time was required on a network of computers.

A recent approach included a variant of inver-over [6] called multi-inver-over to exploit the features of the intervening contributors of a new solution in the search space [7]. Under this approach a number, $n_1 \geq 1$ of inver-over operations are applied to each solution for improvement. In that work the results showed advances when compared with other search techniques.

A further enhancement, the Hybrid Multi-inver-over Evolutionary Algorithms (HMEAs), considered hybridising of multirecombinated evolutionary algorithms with simulated annealing (SA) [8]. In this algorithm, SA is inserted in different stages of the evolutionary process. Besides, different parameter settings were chosen for simulated annealing [9]. To determine the performance of these novel algorithms we tested them on the hardest set of the test suite chosen in previous works. Details on implementation, experiments and results were discussed.

The multirecombinative approaches are part of a wider family of EAs: those including multiplicity of contributors and operators to exchange genetic material. They are called *Multiplicity Feature Evolutionary Algorithms* (MFEAs). With a new perspective due to the nature of the operator, MFEAs can also be devised for the inver-over operator [7]. The idea is to continue applying on the same current individual, for a predetermined number n_1 of times, the inver-over operation expecting to find better solutions. In other words, when comparing the evaluations of the new individual (S') and the original individual (S_i), if S' does not improves S_i then the loop for the inver-over operation is repeated (S_i again undergoes inver-over), for a maximum number n_1 of times. In this case, we favour that many other individuals of the population compete as donors until eventually a better offspring is created. As a subclass of MFEAs, in previous works these algorithms were called *multiple inver-over evolutionary*

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algorithms (MEAs) and according to the number of operations to be applied to a single solution they were identified as IO-n_1 (standing for ¨Inver Over n_1 times¨).

Simulated annealing (SA) suggested initially by Metropolis [5] is based on the observation of the cooling process for melted metals. This cooling process should be carefully controlled to ensure a minimum energy state. We could say that in a minimization problem, SA cools a solution until reaching the lowest value of the objective function. This means that for each evaluation of a solution in the neighbourhood we choose a movement, which improves the solution.

Nevertheless SA allows, making movements which increments the cost of a solution within a given probability value. This feature allows an extensive search in the problem space to escape from local optima. The probability function depends on the change in the cost of a candidate movement and the current system temperature. At high temperatures any movement is equally allowed but at low temperature few movements increasing the cost of the solution are allowed. The planning of the reduction of temperature is important because a balance must be established among efficiency (computing time) and quality of results (effectiveness). In this algorithm the termination condition checks if the thermal equilibrium was achieved. The temperature t is gradually reduced through the function $g(t,n)$. The stop criterion controls if the system is frozen, and in this case the algorithm ends. SA was successfully applied to the TSP[1, 2, 3, 4].

The Hybrid Multi-inver-over Evolutionary Algorithms (HMEAs) discussed here incorporates SA to the IO-n_1 versions, in distinct stages of the evolutionary process, as follows:

- HMEA-IP. Applies SA to each individual of the initial population and the EA begins from this improved population.
- HMEA-MP. Applies SA to some individuals of intermediate populations. The decision to apply SA is taken according to the following policy. After a given number φ of generations, a control of the convergence begins. From that point in the evolutionary process, when after a given number λ of consecutive generations no improvement is detected in the best solution, then SA is applied. This approach applies SA to the 10% or 20%, respectively, of the best, worst and random individuals in the population.
- HMEA-FP. Applies SA to individuals of the final population. Similarly to HMEA-MP.

CONCLUSIONS AND FUTURE WORKS

We show a hybridization of evolutionary algorithms based on multiple applications of the inver-over operator (MEAs) by means of simulated annealing (SA). This allowed to refine the best solutions found by the evolutionary process by applying a local search in different stages of the search process. All the hybrid approaches improve results obtained by MEAs with diverse extra effort. HMEA-IP helps the evolutionary process by providing a better starting population but its contribution is not so significant when contrasted with the other variants. Application of local search to individuals of the final population (HMEA-FP) showed to be the most efficient approach obtaining solutions of similar quality than when local search is applied to individuals of intermediate populations (HMEA-MP), but at lower computational cost.

When we apply static changes in the temperature parameter and its reduction functions, improvements are no so significant as expected.

Future work will be devoted to other hybridization schemes, combining different local search techniques as tabu and neighbourhood search with evolutionary algorithms in NP-hard combinatorial problems.

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