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Evolutionary Wind Turbine Placement Optimization with Geographical Constraints

Abstract

Wind energy plays an important role in achieving a green energy supply. In con-trast to conventional gas or coal power plants, the power output of wind turbines strongly depends on their location. The optimization of the locations of the wind turbines is a real-world problem. In this thesis, the focus is set to the optimization approaches for the problem. As the turbine placement optimization problem is not solvable in an analytical way, heuristic optimization approaches are motivated and applied. As with every real-world problem, the approaches solve a model which rep-resents the planning situation and behavior of the different relevant participants from the real-world. To represent solutions for the real-world problem – so called candi-date solutions – two kinds of representation are proposed: binary and real-valued. The real-valued representation induces interesting reflections on solution space which are demonstrated in this thesis. To evaluate solutions, a wind model based on a proven approach from the field of optimization is employed, which is significantly improved from an optimization view. Additionally, data from the German Weather Service and the characteristic of a wind turbine from Enercon are integrated into the model. Geographical data determine if a solution is feasible. This is the most impor-tant point, especially for a real-world problem. Only feasible candidate solutions can be implemented in real-world scenarios. In this thesis, various real-world scenarios are proposed that represent real planning situations. For scenarios based on prior-ity areas for wind energy, existing areas are taken into account based on data from the Lower Saxony Ministry for Nutrition, Agriculture, and Consumer Protection. As not all turbines are located in a priority area for wind energy, high flexible scenarios based on a topological map service are proposed. The scenarios are able to handle several thousand constraints with individual minimum distances. These scenarios are the framework for the heuristic optimization algorithms. In the first step, various ap-proaches are proposed, employed, and deeply analyzed. These approaches help to get a deep knowledge of the optimization problem. To be able to fully focus on the al-gorithms, a basic constraint handling method is applied that prevents the algorithms from selecting infeasible solutions. This is changed in the next step, where the more advanced penalty functions are applied to the problem. Various proposed penalties code the real-world scenarios for penalty functions. In the last step, the gained knowl-edge is employed to develop highly advanced evolutionary heuristics especially for the turbine placement optimization problem. The heuristics are deeply analyzed and are able to demonstrate their strength. They not only create highly optimized solu-tions: they also create significantly different solutions to give the decision maker the possibility to choose.