Proposal Wind Farm Layout Optimization with Particle Swarm Optimization

L. Nies (s4136748) & G. Zuidhof(s4160703)

20 April 2015

Abstract

In this proposal we introduce the Wind Farm Layout Optimization problem and suggest an possible approach to this problem that might provide interesting results. We will submit our algorithm to the Wind Farm Layout Optimization competition of which we will also use the APIs.

1 Introduction

With an increasing need for alternative forms of energy, wind energy is increasing in popularity. Huge wind farms are being build to accommodate for this need. An issue in with these wind farms is the placement of the wind turbines in such a way that is maximizes the cost/energy trade off, which is an non-trivial problem. Several factors must be taken into account: wind direction: wake interactions between wind turbines, land availability, etc. Several methods have been applied to optimize this layout, but these is still some room for improvement [6]. We try to contribute to this problem by using Swarm Particle Optimization to find a (close to) optimal solution. We will submit the resulting algorithm to the *Wind Farm Layout Optimization Competition*[3].

2 Problem

We opted for the *Problem* type of project. We chose the Wind Farm Layout Optimization problem, in which we try to optimize the layout of windmills to maximize the best cost/energy. We found this problem when we stumbled upon the The 2nd Edition of the *Wind Farm Layout Optimization Competition*[3]. We will submit our solution to this competition.

2.1 Wind Farm Layout Optimization Competition

The 2nd Edition of the *Wind Farm Layout Optimization Competition*[3] is part of the collection of competitions hosted for the 24th *GECCO (Genetic and evolutionary computation)* conference[2].

The goal of this challenge is to optimize the wind farm layout of 5 unknown scenarios which differ in wind forces, layout shapes, ect. The fitness of the layout is determined by the function given in figure 1. This cost function is based on the production price of a kilowatt, so it provides a realistic representation of the actually fitness of a real wind farm.

Large layouts will be rewarded with a better cost, but optimizing the placement of the windmills becomes more complex, so that the algorithm solving this problem needs to find a good balance between these two criteria. Another difficulty is the problem of obstacles: this years' competition introduces obstacles to the layout so that is it discontinuous and the windmills cannot be placed everywhere.

T o test the algorithm, a large number of layouts are provided: a global set of 10 000 layouts for all the 5 scenarios.

$$fitness = \frac{\overbrace{\left(c_t * n + c_s * floor(\frac{n}{m})\right)}^{\text{Construction cost}}\overbrace{\left(\frac{2}{3}+\frac{1}{3} * e^{-0.00174n^2}\right)}^{\text{Economies of scale}} + \overbrace{c_{OM} * n}^{\substack{\text{Yearly}\\\text{operating}\\\text{costs}}}}{\underbrace{\left(1-(1+r)^{-y}\right)/r}_{\text{Interests}}} * \frac{1}{\underbrace{8760 * P}_{\substack{\text{Yearly}\\\text{power}\\\text{output}}}} + \frac{\overbrace{0.1}^{\substack{\text{Farm size}\\\text{coefficient}}}}{n}$$

$c_t = 750{,}000$ turbine cost (usd)

$c_s = 8{,}000{,}000$ substation cost (usd)

$m = 30$ turbines per substation

$r = 0.03$ Interest rate

$y = 20$ Farm lifetime (years)

$c_{OM} = 20{,}000$

n Number of turbines

P Farm energy output

Figure 1: The fitness function of a layout

2.2 Technicalities

APIs and Interfaces An API is provided in C++, Java and MATLAB for interacting with an open source wind evaluation model, which can be found on GitHub[1]. The evaluation part of the API is to be called with a n-by-2 matrix, where n is the amount of matrix and the columns are the coordinates of the turbines. Returned is the fitness of the entire layout (the so called *Wake free ratio* and some other evaluated variables.

Competition deadline Submission deadline is the 15th of June, and the results will be published during GECCO 2015 (July 11-15).

3 Approach

The approach we will be taking to tackle this problem is *Particle Swarm Optimization* (PSO). We plan on modeling the wind mills as separate swarms of particles, which we presume should be modelled as having repulsive forces on each other for a good windmill layout. Likely some other neighborhood forces should also be applied, for instance, boids-like alignment may help performance (although it seems the windmills are rotation invariant, so this may be nonsensical).

A big challenge for this particular problem is that a solution consists of multiple locations. We can tackle this by first 'placing' one windmill, and then another in a world where the first one is fixed, although a better approach may be to simulate the swarms simultaneously. Although then it is not clear how many windmills make for an optimal fitness.

4 Related research

Rašuo et. al. state that there is little work that has tackled the Wind Farm optimisation problem. They suggest that there is a lot of potential in finding improvements on existing solutions. With the rising need for alternative forms of energy the need for more efficient wind farms is obvious [6].

Chowdhury et al. [4] employed a particle swarm algorithm to determine the key factors which influence the power generation of wind farm layouts. This did not investigate the layout as much as it did the individual characteristics of the windmills (such as the rotor diameter), it does however give insights into the influence of the number of turbines on the cost per kilowatt of power produced.

Samorani [7] provides a survey of the existing approaches and applications, and provides some overview of the practical issues that are typical for specific layouts.

Non-PSO, natural computing approaches The following approaches are not particle swarm algorithm approaches, but may still yield valuable insights into how to best approach the problem. Eroglu et al.[5] used an Ant Colony Optimization approach to maximize the energy output of a wind farm layout. Rašuo et al.[6] used an evolutionary algorithm approach.

References

[1] https://github.com/d9w/WindFLO. WindFLO API.

[2] Genetic and evolutionary computation conference. http://www.sigevo.org/gecco-2015/. Accessed: 2015-04-20.

[3] Wind farm layout competition. http://www.irit.fr/wind-competition/. Accessed: 2015-04-20.

[4] Souma Chowdhury, Jie Zhang, Achille Messac, and Luciano Castillo. Unrestricted wind farm layout optimization (uwflo): Investigating key factors influencing the maximum power generation. *Renewable Energy*, 38(1):16–30, 2012.

[5] Yunus Eroğlu and Serap Ulusam Seçkiner. Design of wind farm layout using ant colony algorithm. *Renewable Energy*, 44:53–62, 2012.

[6] Boško P Rašuo and Aleksandar Č Bengin. Optimization of wind farm layout. *FME Transactions*, 38(3):107–114, 2010.

[7] Michele Samorani. The wind farm layout optimization problem. In Panos M. Pardalos, Steffen Rebennack, Mario V. F. Pereira, Niko A. Iliadis, and Vijay Pappu, editors, *Handbook of Wind Power Systems*, Energy Systems, pages 21–38. Springer Berlin Heidelberg, 2013.