Use of intelligent optimization techniques for wind farm layout design

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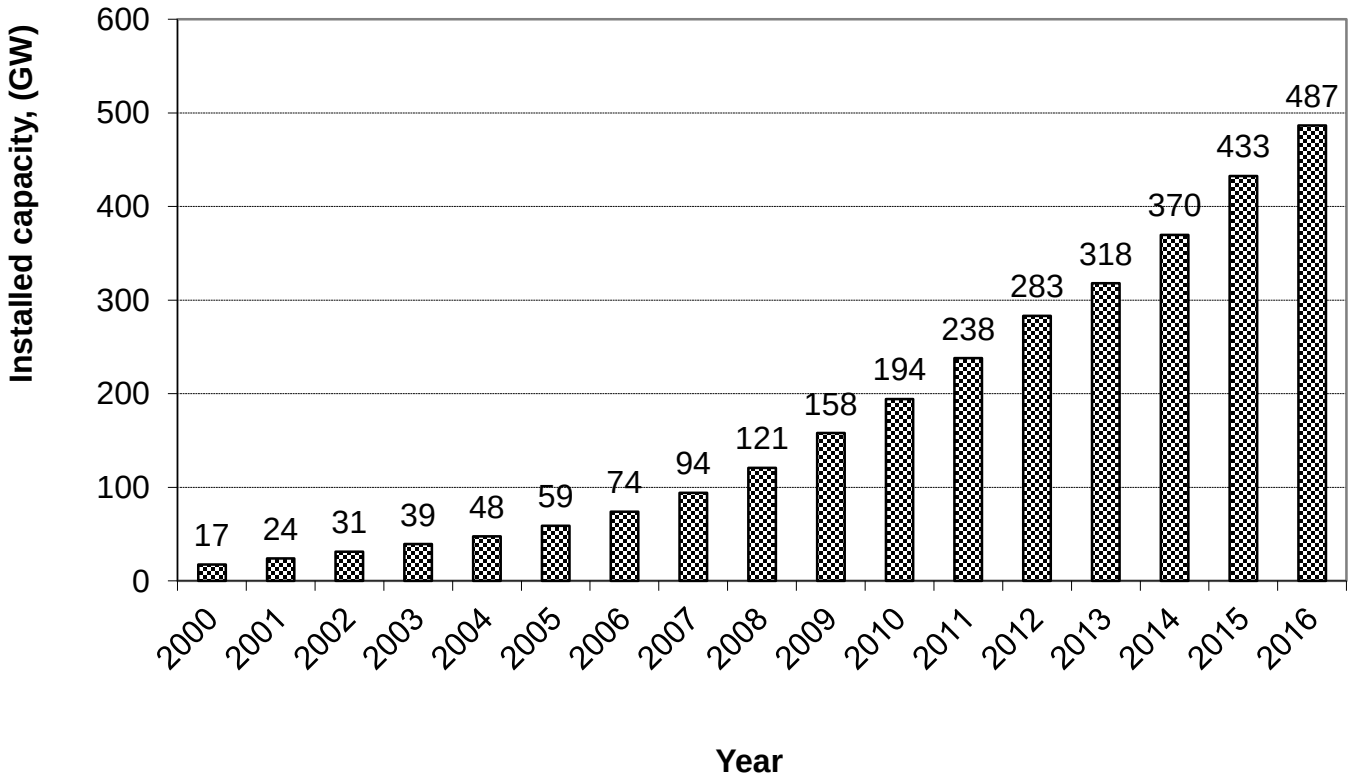
Outline

- Wind Farm Layout Design Problem
- Intelligent optimization techniques
- Observations and Research Opportunities
- Conclusion

Wind Farm Layout Design Problem

- Wind energy has emerged as strong alternative to fossil fuels for power generation.
- This energy is harnessed from on-shore or off-shore wind farms

Current Status



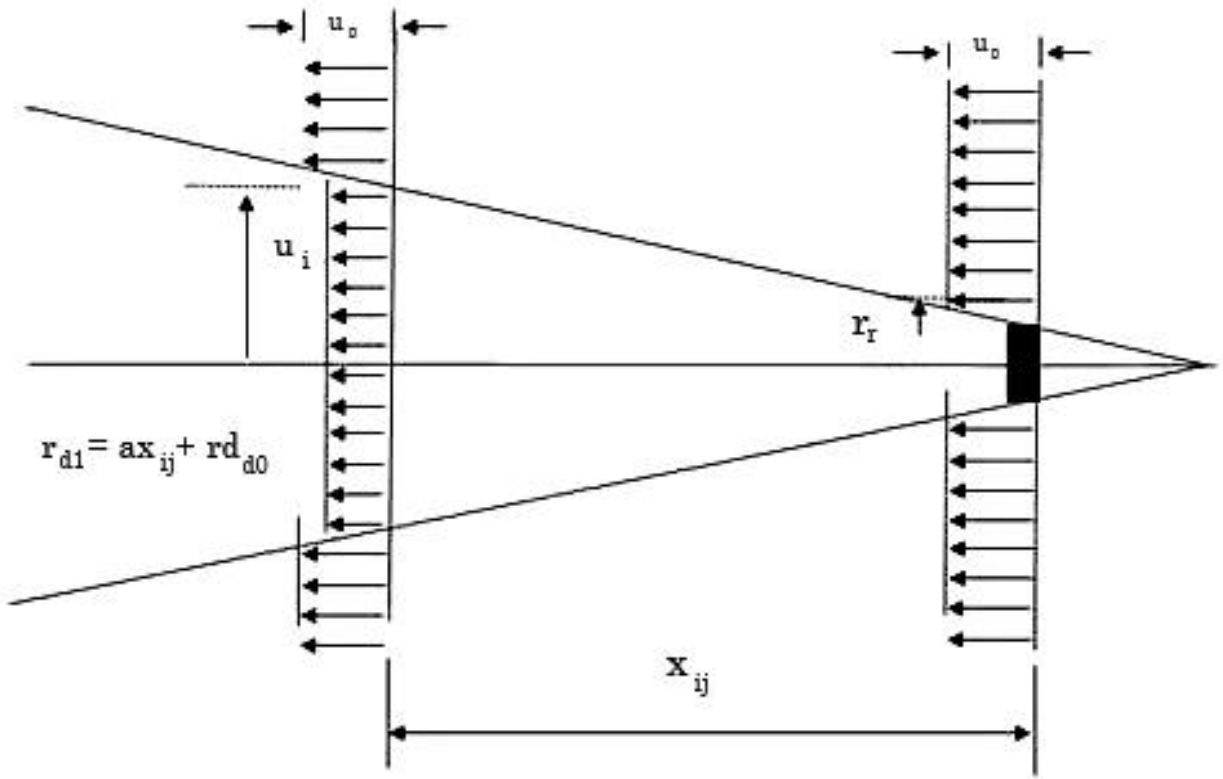
Current Status (contd.)

- China leads the global market with new addition of 23,328 MW generation capacities to the grid in 2016.
- Followed by United States, Germany, India, and Brazil which added 8,203, 5,443, 3,612 and 2,014 MW in 2016
- France, Turkey, Netherlands, United Kingdom and Canada took 6^{th} to 10^{th} places with new wind power capacity additions of 1,561, 1,387, 887, 736, and 702 MW respectively
- Africa and Middle East with small contribution.

Wind Farm Layout Design Problem

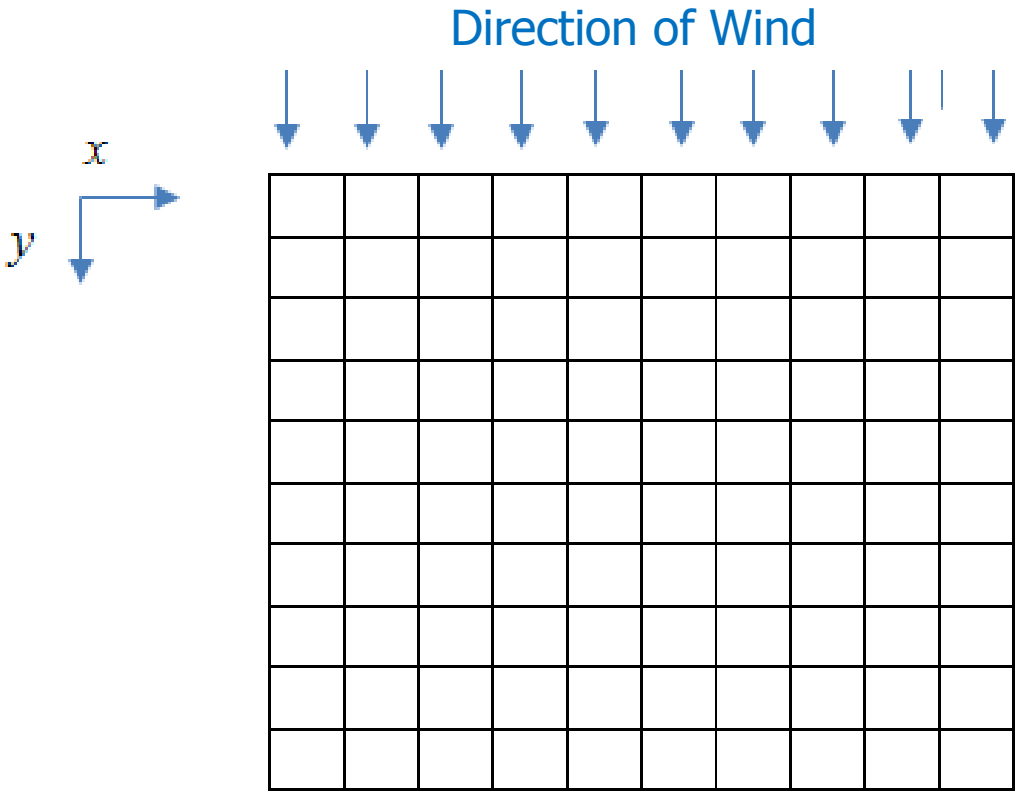
- "Optimal" placement of these wind turbines in a wind farm is complex optimization problem
  - There are a huge number of possible configurations of arranging these turbines
  - The aim is the find the best one out of these
- How simple is it?

Wind Farm Layout Design Problem



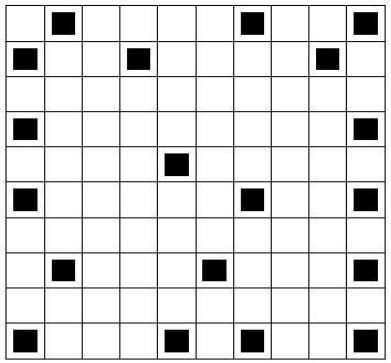
Schematic of a Wake model

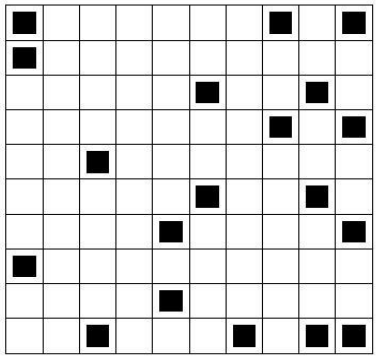
Wind Farm Layout Design Problem



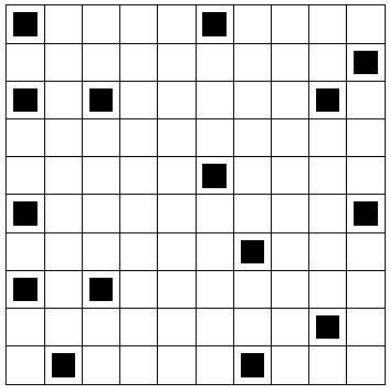
Wind Farm Grid of 10 X 10

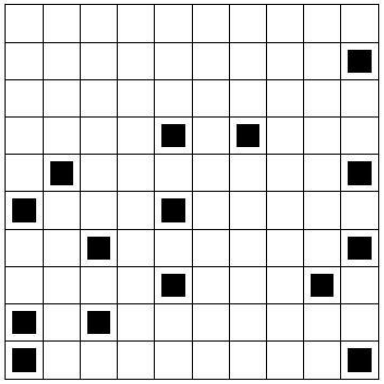
Wind Farm Layout Design Problem





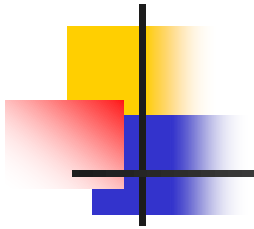
Two configurations with 19 turbines





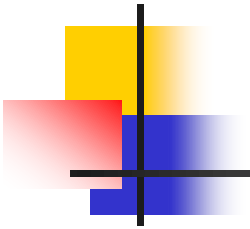
Two configurations with 15 turbines

How complex is the problem?



- Up to 2^{100} possible configurations
- Need to
  - Maximize power output
  - Minimize cost
  - Both
- Trying all possible configurations (exhaustive search) and finding the best configuration is computationally expensive
- Search intelligently !

Intelligent optimization techniques



- Artificial Intelligence techniques to solve complex optimization problems.
- Intelligently search for a limited number of solutions, rather than all solutions
  - Still able to find the best (optimal) solution in many cases
  - Otherwise, give solutions which are very close to optimal solutions

Various Intelligent optimization techniques

- Genetic algorithm – based on the theory of reproduction
- Particle swarm optimization – how birds search for food source
- Simulated Annealing – based on phenomenon of metal cooling
- Ant colony optimization – based on how ants search for food source
- Honey bee colony optimization – how honey bees search for food
- Cuckoo search – based on behavior of cuckoos

Observations and Research Opportunities

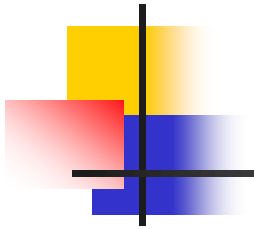
- Research publications from 1992 to 2016 were analyzed
- Genetic algorithm was used in more than 70 % publications.
  - Researchers need to focus on other recent algorithms
- Most applications only considered either cost or power in the optimization process ⟹ Single-objective optimization
  - More realistic approach is multi-objective optimization
- No standard test suites available for comparative studies
  - Researchers need to focus on development of benchmark test cases

Observations and Research Opportunities

- Basic versions of algorithms were used
  - Need to develop better and more efficient algorithms
    - Hybridization of algorithms
    - Dynamic assignments of parameters
    - Hyperheuristics
    - Parallelization
- Lack of comparative studies
  - Multiple algorithms should be applied and compare to a given problem

Conclusions

- Wind energy has a lot of potential for clean energy worldwide.
- Optimal layout design of a wind farm can maximize its performance, both in terms of power generation and financial savings.
- Due to high computational complexity involved in the process, Intelligent algorithms play a key role in determining the best layout in reasonable computational time



Thank you