

EVOLUTIONARY OPTIMIZATION OF WIND TURBINES THROUGH CFD SIMULATIONS AND GENETIC ALGORITHMS

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1. Introduction

Humanity has caused a lot of damage to the Earth over the years, mostly due to technological progress which required huge amounts of power generated by ecologically unfriendly power plants. Considering wind turbines as a sustainable alternative to power plants, I recognized a high level of diversity as they could be perceived as beings with DNA and in some sense **evolve**. I realized that this idea can be brought to life using genetic algorithms and simulations. **The goal of this project was to develop an algorithm that will, through CFD simulations, conduct an evolutionary optimization of wind turbines' designs.**

2. Method of work

Basis of this project is set upon a modern theory of evolution where individuals with better gene combination stay alive long enough to pass on those attributes to their children. The process also incorporates mutation, or a random change of some beings. Every animal has DNA or code that describes it, and like them, my turbines have to have their genes stored in some variable. To achieve this, I decided to divide their geometry in sections that results in an array of points that, when connected, represent the shape of the wings. Coordinates are stored in **polar form** because it automatically curves around the center and wing can easily be copied and rotated to form a turbine. Also, this form is important for recombination and mutation because the skeleton of wings again analogically curves around the center of the coordinate system. When units can be described they have to be evaluated and sorted before selection begins. Evaluation means finding the fitness parameter that represents the efficiency of the turbine and its chance of survival. The criterion is well defined as how well this geometry converts fluid flow energy to useful work, and to measure this I decided to use **computational fluid dynamics** or **CFD**. This process realistically simulates the flow of the fluid (air) using complex tensor fluid mechanics, so it simulates the behavior of wind around the geometry of the turbine and takes in account the turbulent flow which is the main reason of energy loss on turbines. Due to simple energy conservation law, theoretical maximum of a wind turbine efficiency is 59.3% (Betz's limit). To conduct a simulation, I chose **algebraic yPlus**, which is less precise but much faster method than commonly used k-e turbulence model. My software of choice was **COMSOL Multiphysics** which gives solid results, has great compatibility with various hardware and software and can easily be automated using **Java**

programming language unlike other solutions (ANSYS Fluent, Autodesk CFD). Automation is necessary for this project because for each turbine, geometry has to be calculated and changed, and after that, model has to be computed. The problem with COMSOL is that it does not support **6DOF** (6 degrees of freedom), process used to calculate rigid bodies reaction to fluid, but this can easily be solved by rotating the turbine geometry and measuring pressure of fluid directly on its surface. After numerically integrating values given for every time step, algorithm gets a usable fitness value for that turbine. Next step is selection that deletes worse half of the generation which leads to isolation of better genes, but there is also a random element. Sometimes algorithm removes a good turbine and keeps one in the 2nd (bad) half to sustain gene diversity, the basis of evolution. Empty places in the array are filled in process of recombination where units from previous generation are combined by joining selected groups of genes from two turbines to give a new one. Also, some genes are randomly changed or mutated to widen the pool and ideally improve results.

3. Result of work

After running the algorithm for a few weeks with population of 20 units on my computer with Intel i7 7700K, turbines started looking like today's best vertical axis designs. So even with small population, single processing node and relatively short simulation time my method has shown good results and a huge potential in the field of Computer science.

4. Conclusion

In the future I want to improve the algorithm by adding more diverse conditions for finding the fitness parameter, better way to generate geometry and evolve more DNA data. This just wasn't possible because of computing power limitations, but I'm looking forward to working with Belgrade Institute for physics and running my program on their computer cluster.

5. References

- [1.] Analysis of Cost Effective Vertical Axis Wind Turbine : <https://www.comsol.de/paper/analysis-of-cost-effective-vertical-axis-wind-turbine-cevawt-19455>
- [2.] Kramer, O. (2017) "Genetic Algorithm Essentials" Retrieved from https://books.google.rs/books?id=NxLcDQAAQBAJ&dq=genetic+algorithm&source=gbs_navlinks_s