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Probability Modeling and Genetic Algorithms in Small Wind Turbine Design Optimization: Mentored Interdisciplinary Undergraduate Research at LaGuardia Community College

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Abstract : This presentation is a progress report on a faculty-student research collaboration at CUNY LaGuardia Community College (LaGCC) aimed at designing a small horizontal axis wind turbine optimized for the wind patterns on the roof of our campus. Our project combines statistical and engineering research. Our wind modeling protocol is based upon a recent wind study by a faculty-student research group at MIT, and some of our blade design methods are adopted from a senior engineering project at CUNY City College. Our use of genetic algorithms has been inspired by the work on small wind turbines' design by David Wood. We combine these diverse approaches in our interdisciplinary project in a way that has not been done before and improve upon certain techniques used by our predecessors. We employ several estimation methods to determine the best fitting parametric probability distribution model for the local wind speed data obtained through correlating short-term on-site measurements with a long-term time series at the nearby airport. The model serves as a foundation for engineering research that focuses on adapting and implementing genetic algorithms (GAs) to engineering optimization of the wind turbine design using Blade Element Momentum Theory. GAs are used to create new airfoils with desirable aerodynamic specifications. Small scale models of best performing designs are 3D printed and tested in the wind tunnel to verify the accuracy of relevant calculations. Genetic algorithms are applied to selected airfoils to determine the blade design (radial cord and pitch distribution) that would optimize the coefficient of power profile of the turbine. Our approach improves upon the traditional blade design methods in that it lets us dispense with assumptions necessary to simplify the system of Blade Element Momentum Theory equations, thus resulting in more accurate aerodynamic performance calculations. Furthermore, it enables us to design blades optimized for a whole range of wind speeds rather than a single value. Lastly, we improve upon known GA-based methods in that our algorithms are constructed to work with XFoil generated airfoils data which enables us to optimize blades using our own high glide ratio airfoil designs, without having to rely upon available empirical data from existing airfoils, such as NACA series. Beyond its immediate goal, this ongoing project serves as a training and selection platform for CUNY Research Scholars Program (CRSP) through its annual Aerodynamics and Wind Energy Research Seminar (AWERS), an undergraduate summer research boot camp, designed to introduce prospective researchers to the relevant theoretical background and methodology, get them up to speed with the current state of our research, and test their abilities and commitment to the program. Furthermore, several aspects of the research (e.g., writing code for 3D printing of airfoils) are adapted in the form of classroom research activities to enhance Calculus sequence instruction at LaGCC.

Keywords : engineering design optimization, genetic algorithms, horizontal axis wind turbine, wind modeling
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