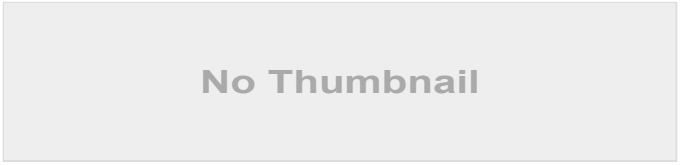
Pixel-based Wake Interaction and Power Estimation for a Wind Farm with Irregular Boundary



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Abstract
In the domain of generation of wind turbine energy, it is central to correctly estimate the interactions among the various turbines in a wind turbine farm. The spatial super-position of turbine wind wakes determines the wind conditions that each turbine in the farm is exposed to and its power output. The current state of the art represents the turbine wakes as a 2D real-valued polygonal trapezoid. The interactions among wakes imply Boolean operations among many trapezoids, producing an intractable fragmentation of the wake intersection and domain regions. The plan (2D) view of the terrain with this wake polygon fragmentation is then used to estimate the effective wind that each turbine receives. This calculation leads to cumbersome computation, which is even more impractical if 3D representations of the terrain, wakes and wind are needed. In response to these limitations, this manuscript presents a method in which the 2D turbine wakes are located on a terrain with holes and exclusion zones bounded by 2D polygons, considering wind direction and turbine array basic specifications. Then, a discretized or pixel approximation of the terrain and wake superposition is calculated using discrete levels of the turbine velocity deficits. This process allows a practical approximation of the power output of each turbine and of the full turbine set. The wake interaction and terrain boundaries are then texture - mapped onto the 3D representation of the terrain, for visualization purposes. As an application, an example of a complex polygonal terrain turbine farm is optimized for maximal power output. This discrete, image - based calculation is particularly convenient in a circumstance in which graphics hardware and GPU processors become increasingly available and efficient, in laptop and mobile devices. This investigation opens research opportunities in mixtures of turbine types, 3D modeling of wind / terrain interaction, and accelerated calculation and visualization with GPU hardware.

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