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Automated geometry and mesh generation for kilometer-scale atmospheric flow simulations

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ABSTRACT

The Computational Fluid Dynamics (CFD) simulation process begins by geometry domain creation and spatial discretization, i.e. *meshing*. The geometry creation step must address both the level of detail in 2D or 3D and the spatial extent of modeling, which influence the boundary conditions imposed later in the CFD simulation process. A high-quality mesh, on the other hand, is characterized by a $y+$ value compatible with the turbulence model, smooth and gradual inter-cell size changes, as well as reasonable skewness, aspect ratio and orthogonal quality metrics. Not only is a high-quality mesh a pre-requisite for accurate and physically realistic results, but it can also facilitate a lower CFD simulation execution time. Vice versa, a poor-quality mesh can result in solver convergence problems and extensive memory use, among others. It is clear that geometry and mesh creation cannot be treated in isolation of each other in the CFD simulation process.

Many CFD applications today depend on algorithms for *rapid and automatic generation of computational geometries and associated high-quality meshes*. This article is focused on automatic generation of geometries and meshes for kilometer-scale atmospheric flow simulations, with topography and elevation. The objective is to devise a simulation method, which, based on given terrain geometry point cloud data and mesoscale weather forecasts, can rapidly produce an accurate localized wind forecast for the geometry domain. Building on the author's earlier work [4], we propose a template morphing approach for automatic geometry and CFD mesh generation that facilitates the following items *programmatically*:

- Interpolation of scattered point cloud terrain data on a template geometry domain, with a controlled level of spatial detail and resolution;
- Morphing of a structured hexahedral template mesh for the interpolated geometry, displaying a refined mesh zone at the centre and controlled vertical edge growth rate for a given $y+$ value target.
- Changing wind flow direction and atmospheric boundary layer structure at the boundary conditions.

We illustrate the proposed method by CFD-based localized wind forecasts for the Turku Archipelago, Finland, using open-source scattered point cloud data from National Land Survey of Finland. The main application of those forecasts is in assisting autonomous ship operation in complex environments. However, the proposed automatic geometry and mesh creation method may also be useful for wind farm design (e.g. [2, 3, 1]) and ship wind load analyses (e.g. [6, 7]) in harbor and fairway conditions. Moreover, the proposed methodology may be useful for CFD-based shape optimization applications (e.g. [4, 5]), which typically require automated mesh adaptation to a changing geometry.

Keywords: Automatic geometry creation, automatic meshing, spatial discretization, CFD, atmospheric flow

REFERENCES

[1] Avila, M., Gargallo-Peiró, A., and Folch, A. A cfd framework for offshore and onshore wind farm simulation. In *Journal of Physics: Conference Series* (2017), vol. 854, IOP Publishing, p. 012002.

[2] FANG, H.-F. Wind energy potential assessment for the offshore areas of taiwan west coast and penghu archipelago. *Renewable Energy 67* (2014), 237–241.

[3] GARGALLO-PEIRÓ, A., AVILA, M., OWEN, H., PRIETO, L., AND FOLCH, A. Mesh generation for atmospheric boundary layer simulation in wind farm design and management. *Procedia Engineering 124* (2015), 239–251.

[4] IMMONEN, E. A parametric morphing method for generating structured meshes for marine free surface flow applications with plane symmetry. *Journal of Computational Design and Engineering 6*, 3 (2019), 348–353.

[5] IMMONEN, E. Optimal design for disc golf by computational fluid dynamics and machine learning. *Structural and Multidisciplinary Optimization 65*, 1 (2022), 1–17.

[6] JANSSEN, W., BLOCKEN, B., AND VAN WIJHE, H. Cfd simulations of wind loads on a container ship: Validation and impact of geometrical simplifications. *Journal of wind engineering and industrial aerodynamics 166* (2017), 106–116.

[7] PAWELSKI, J., PIOTRZKOWSKI, W., ŚNIEGOCKI, H., AND WILCZYŃSKI, P. Factors affecting safety of handling ultra large container vessels in port of gdańsk. *Autobusy: technika, eksploatacja, systemy transportowe 20* (2019).