Application of overset grids in wind turbine blade shape optimization

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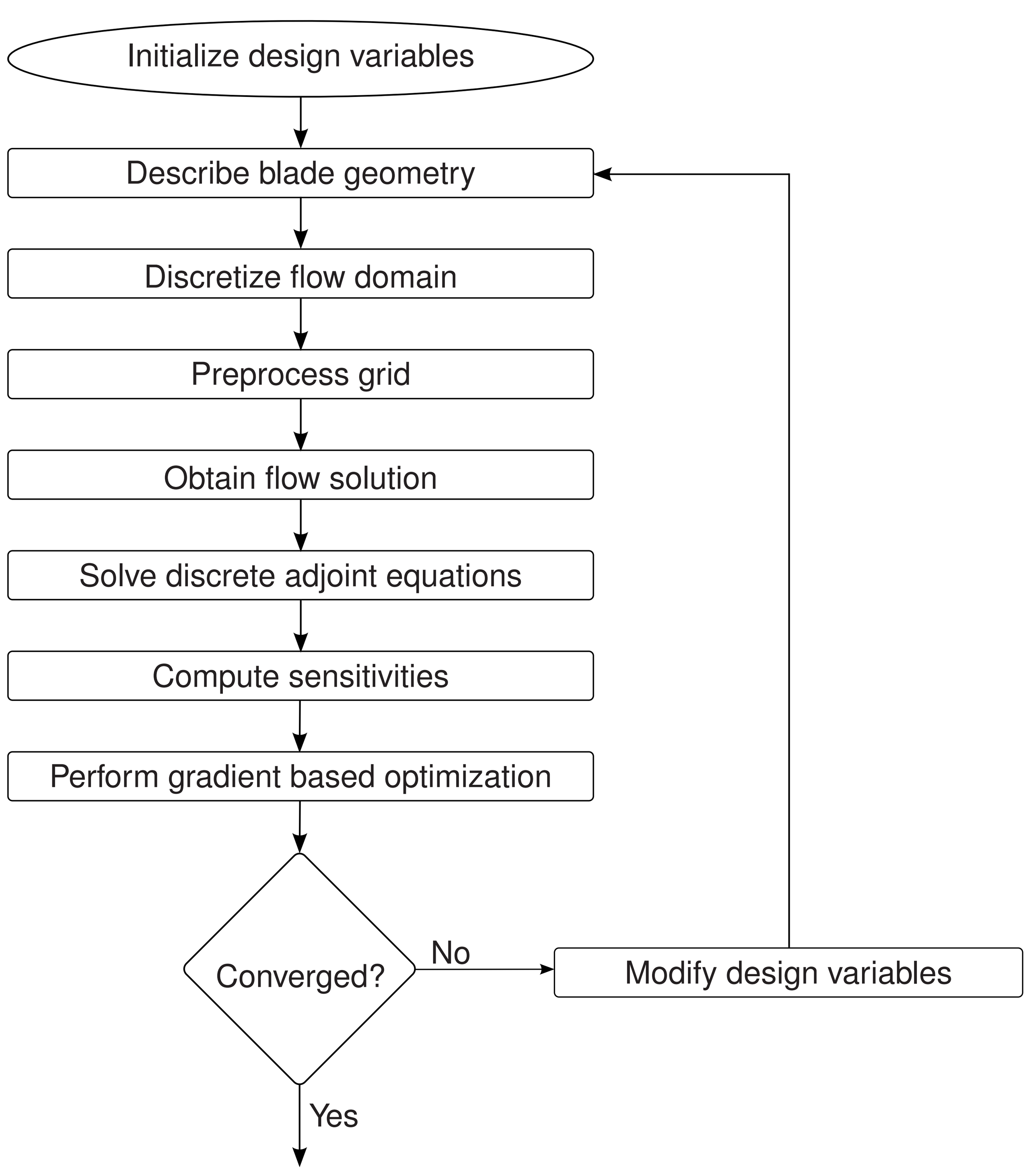
The design of a wind turbine blade is a complex matter. The aim of the present research is to relieve the task of the blade design engineer by developing a tool that can be used to perform a gradient based multidisciplinary optimization of the shape of wind turbine blades, based on the numerical simulation of the flow around these blades. In the optimization procedure the shape of the blade will change after each design iteration. To cope with this, overset grids will be employed for the discretization of the flow domain. This choice was made because it permits the application of fast grid generation techniques based on hyperbolic equations. In this way the computational time required for the discretization of the flow domain is limited, while a high grid quality is maintained throughout the optimization procedure. The overset grid strategy enables fully automated grid generation important for a functional optimization procedure.

Approach

The approach for the optimization procedure is summarized in the following flow chart.



Flow model

- Considering isolated rotor, i.e. the effect of the presence of tower and ground plane is neglected.
- Assuming rotor plane perpendicular to the steady wind so that the flow is periodic, i.e. it suffices to consider the steady flow around a single blade in a co-rotating frame of reference.
- Using Reynolds-averaged Navier-Stokes equations to model the flow around the wind turbine blade.

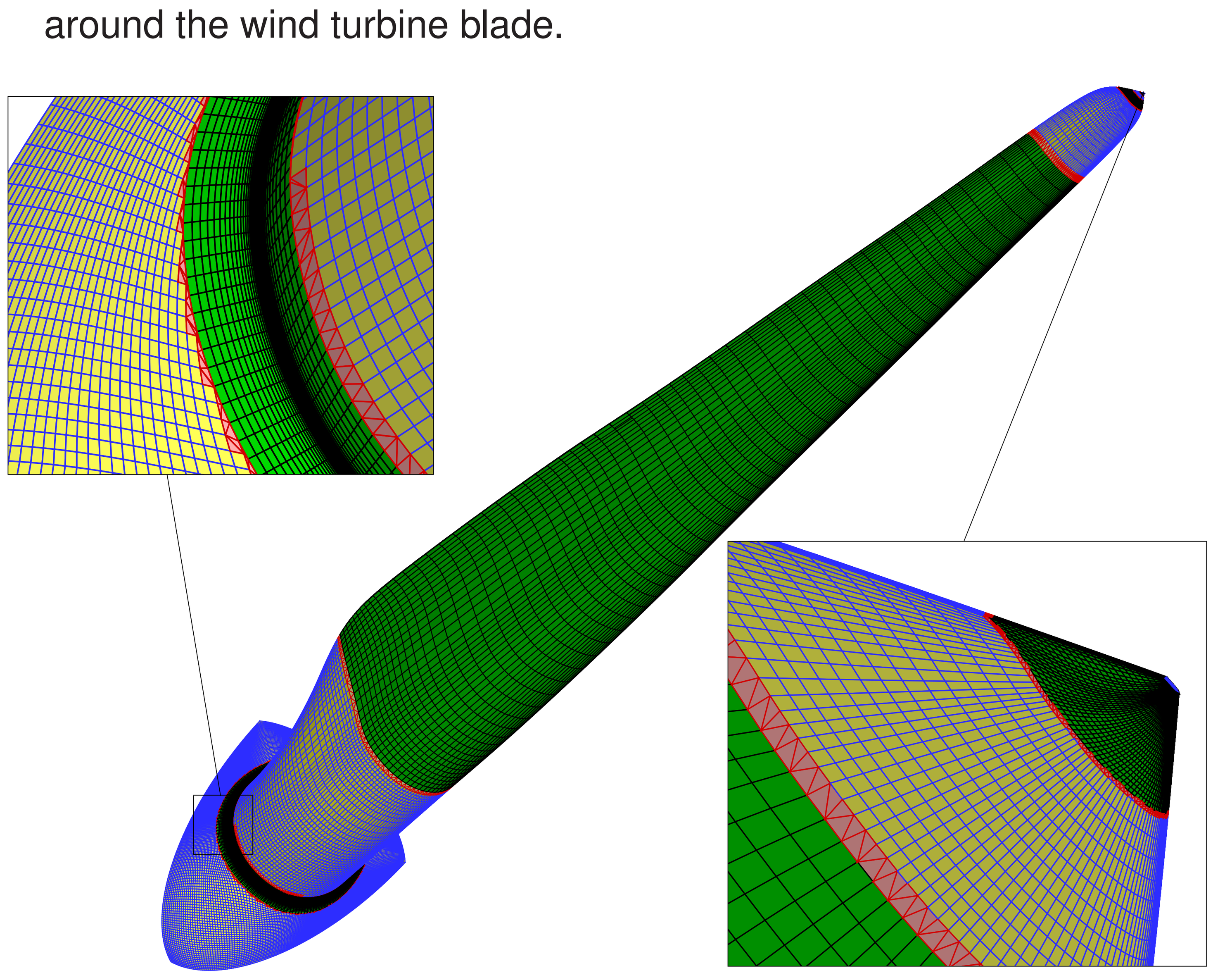


Figure 1: Surface grid on one blade and $\frac{1}{3}$ part of the nose cone.

Flow domain discretization

Surface grids are generated using:

- Linear transfinite interpolation.
- Elliptical smoothing.

Volume grids are computed by solving hyperbolic equations resulting from conditions on:

- Orthogonality of grid lines.
- Cell volume.

Grid preprocessing

Implicit hole cutting [3] will be applied to establish the block connectivity. Furthermore, ray casting is applied to eliminate cells that reside in the blade or nose cone geometry. To accommodate the ray-casting [1], a non-overlapping surface grid is obtained by employing a zipper grid [2] in the region of overlap.

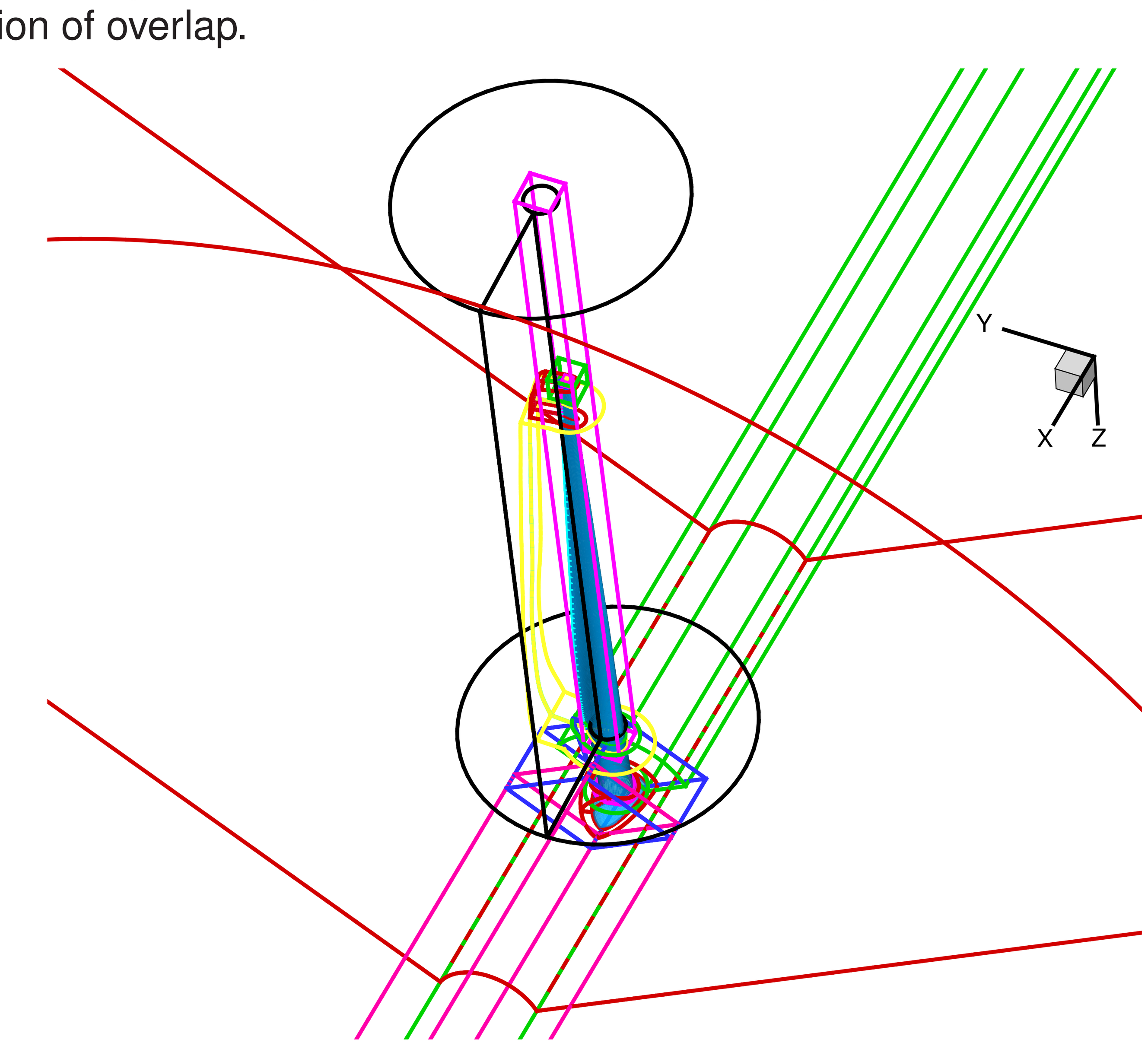


Figure 2: Edges of the different grid blocks in the region around the blade.

Optimization procedure

Blade shape parameterization by means of NURBS:

- Number of design variables is limited.
- Provides great flexibility.
- Compatible with CAD software.

Computation of derivatives using discrete adjoint equation method:

- Accurate.
- Efficient.

Future work

Future work will include:

- Completing implementation of hole cutting procedure.
- Investigation of suitable objective functions for blade shape optimization.
- Development of solution method for discrete adjoint equations.
- Performing 3D wind turbine blade shape optimization.

Acknowledgements

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