Wind Turbine Blade Design Optimization using OpenFOAM and DAKOTA software

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- The shape Optimization of S809 airfoil
- Results and Discussion
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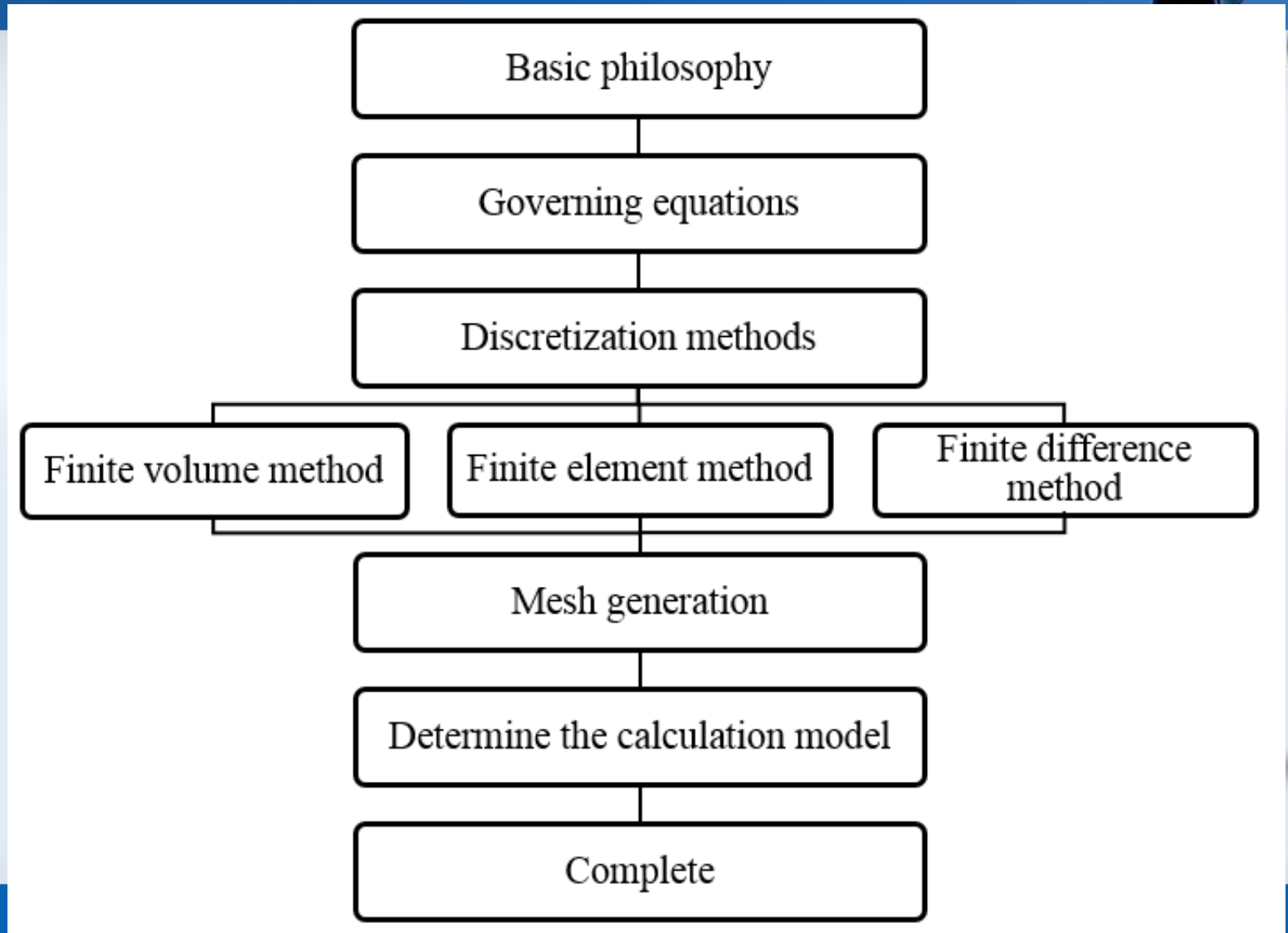
Introduction (1/1)

- This paper presents a focused and structured process for optimization problem formulation, design of optimal shape for S809 airfoil, one of the most popular designs for wind turbine blade design.
- The aim of this optimization model is not to revise the final design, just to give an accurate hint for the designer at the beginning of the offer preparation stage.
- Finally, this model can be used for initial approximations to improve the aerodynamic behavior of a given shape. CFD simulation can make an accurate prediction of how a given shape will perform under different boundary conditions, making this method more attractive.

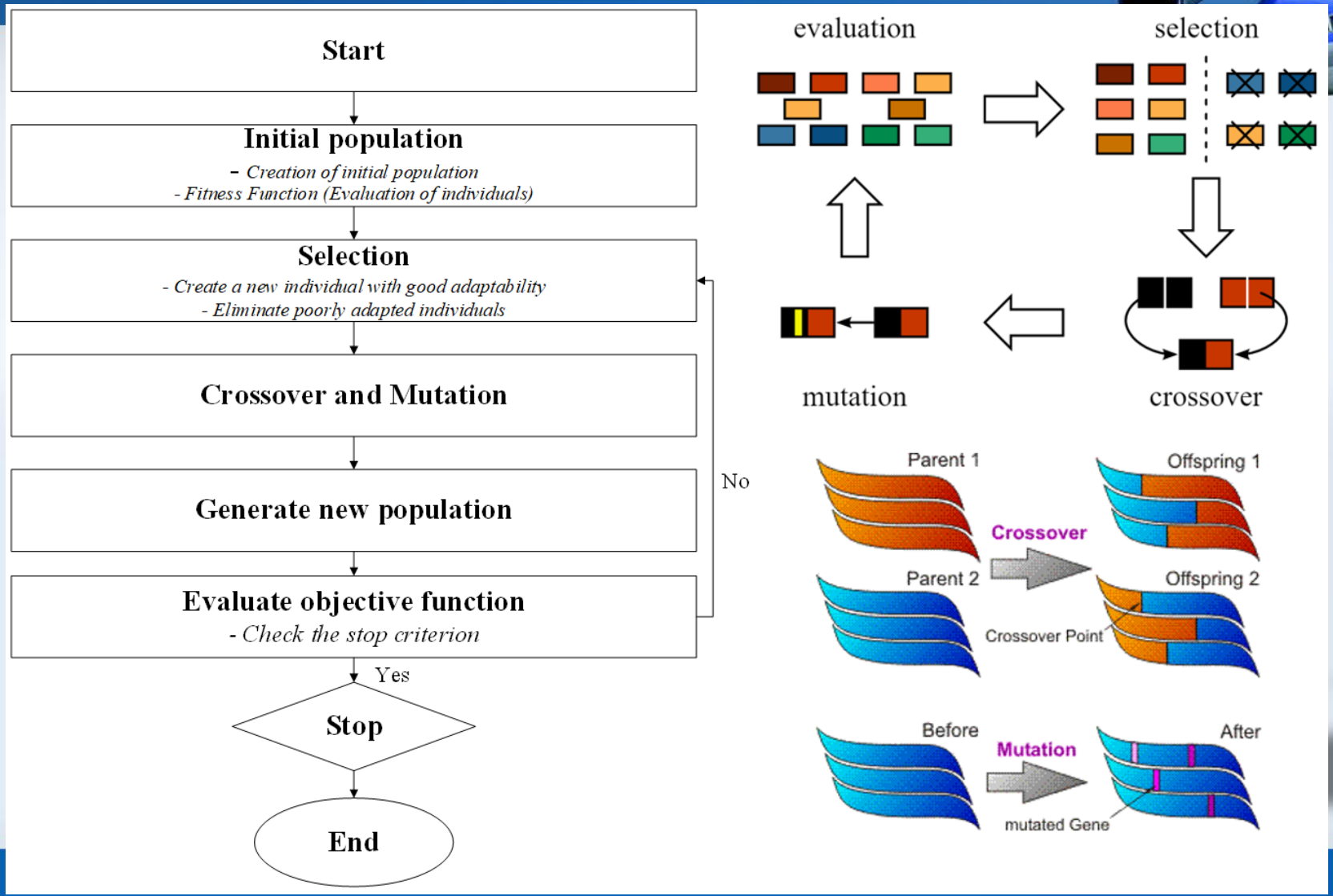
Definition (1/5)

- Basic Definitions of CFD



Definition (2/5)

- A brief introdution about Genetic Algorithms



Definition (3/5)

- Objective Function

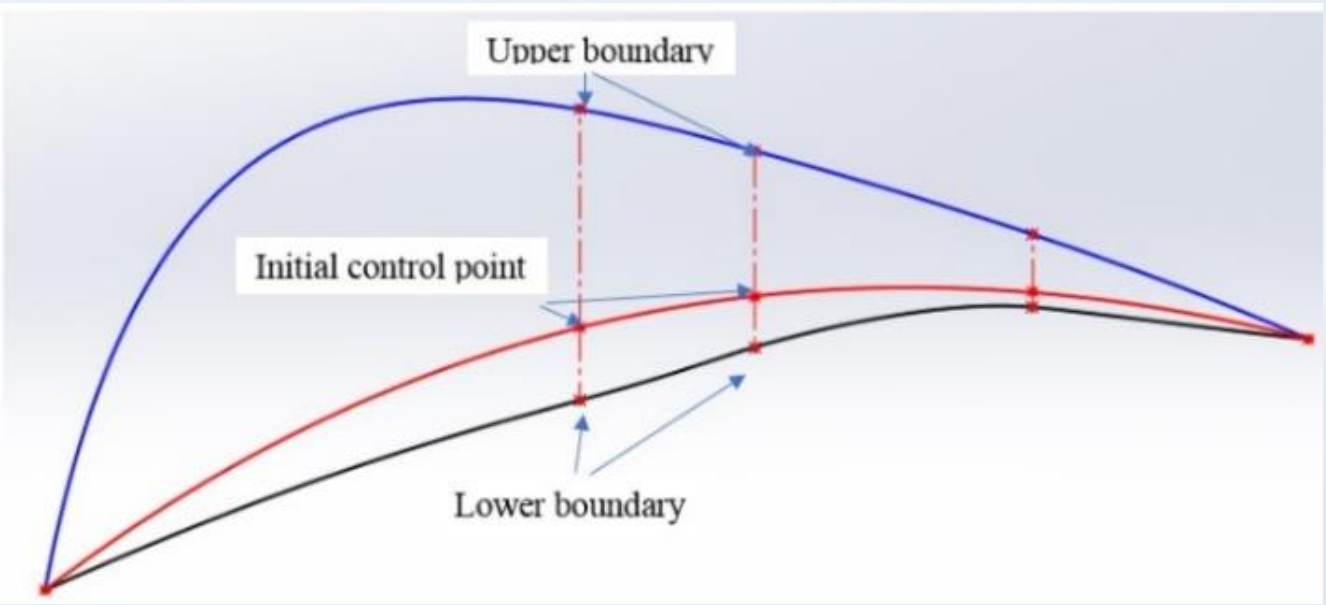
$$\text{maximize or minimize } F = \sum_{j=1}^{n} c_j X_j$$

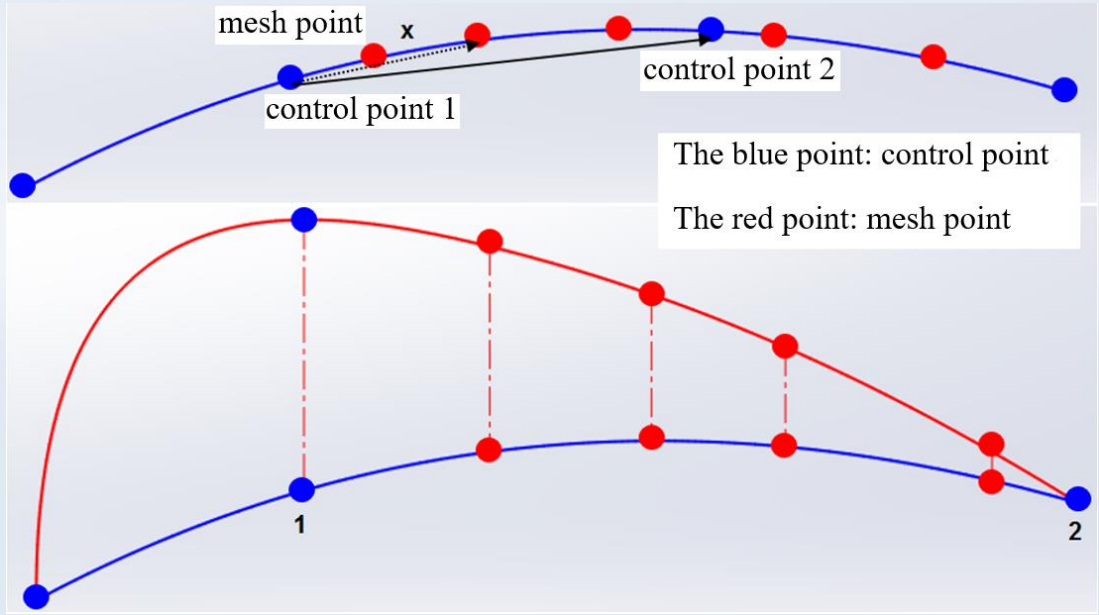
where: X_j: the j^{th} decision variable

c_j: the weighted coefficient corresponding to the j^{th} variable.

Definition (4/5)

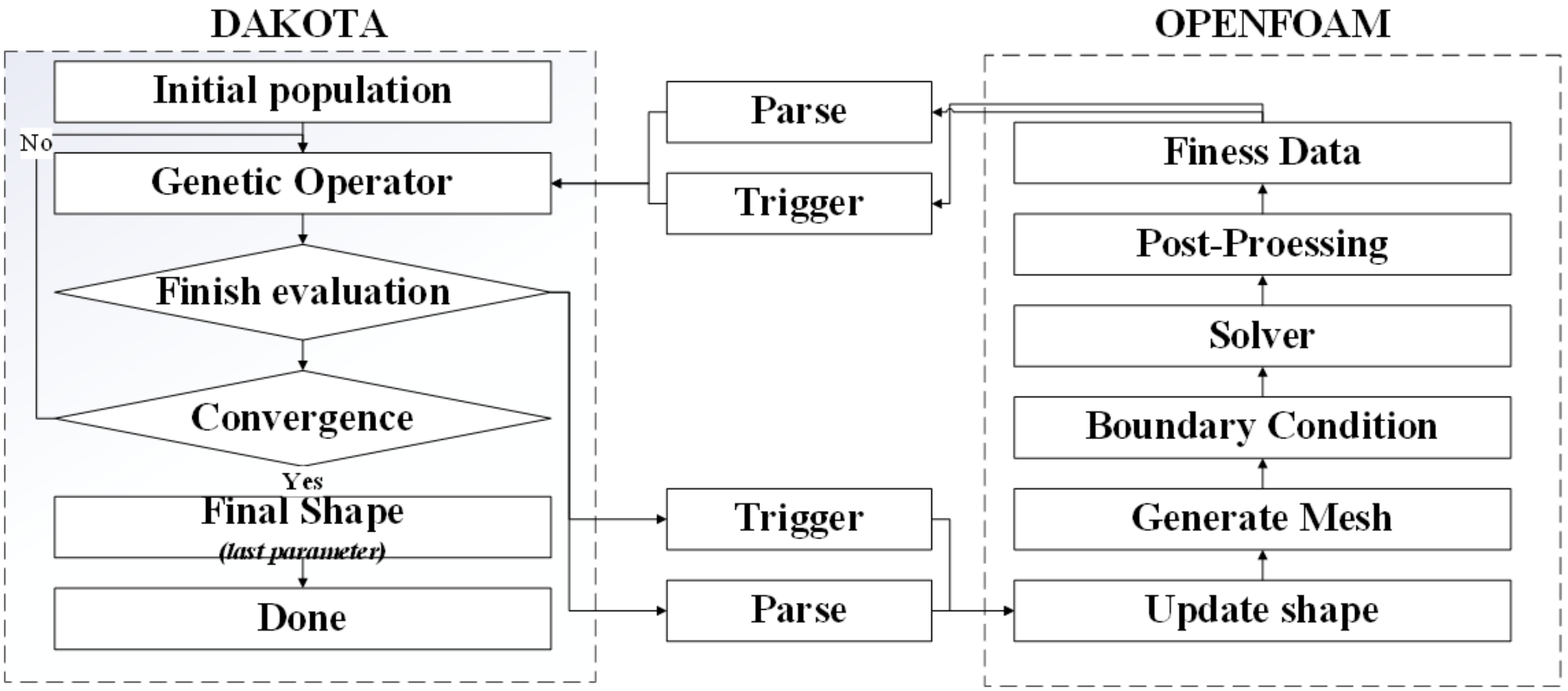
- Change and update shape





Definition (5/5)

- CFD coupled GA for geometric optimization



The shape Optimization of S809 airfoil (1/4)

- Công cụ thực hiện
  - Simulation Program: OpenFOAM.
  - Optimization Program: DAKOTA.
  - Optimization Algorithm: Genetic algorithms (GA).

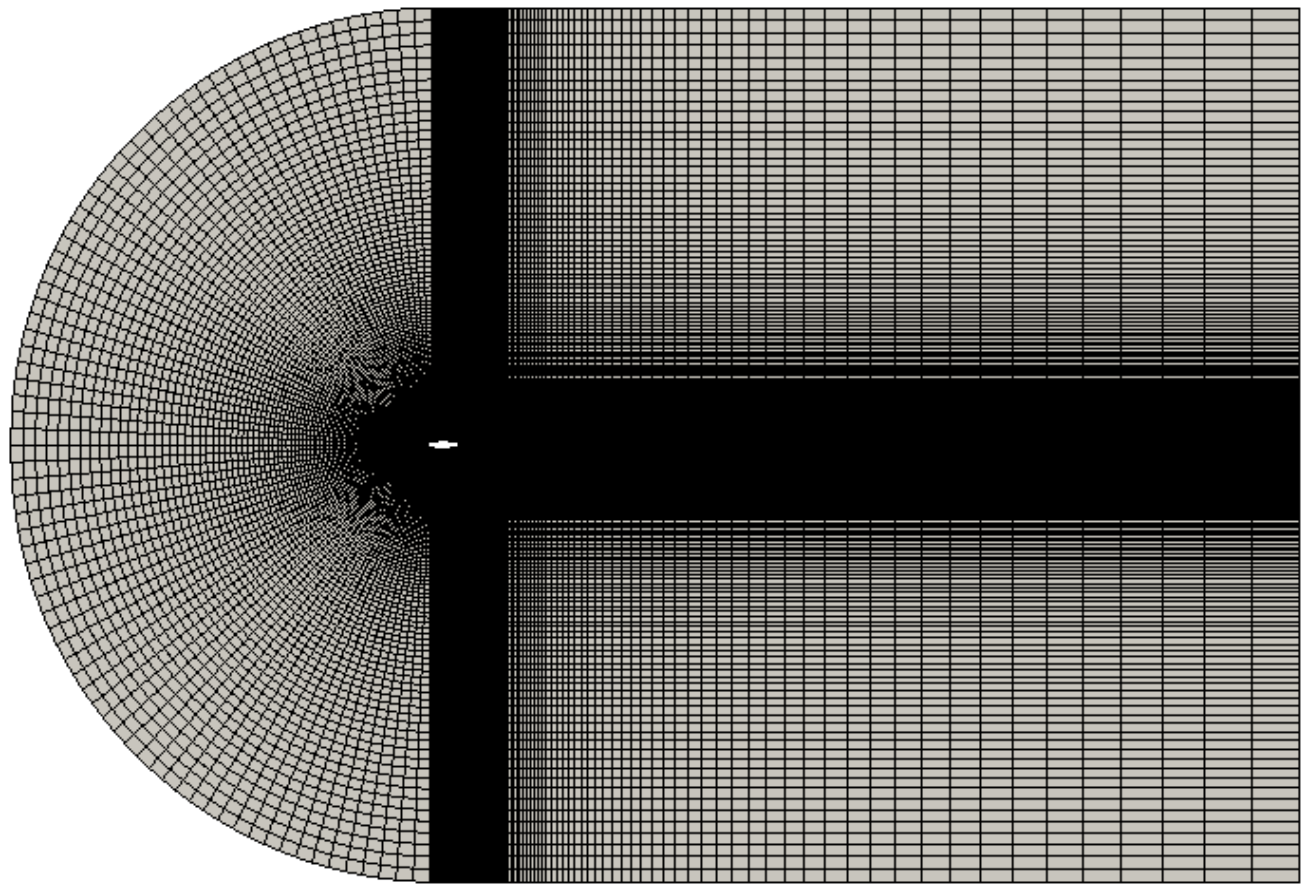
Hàm mục tiêu

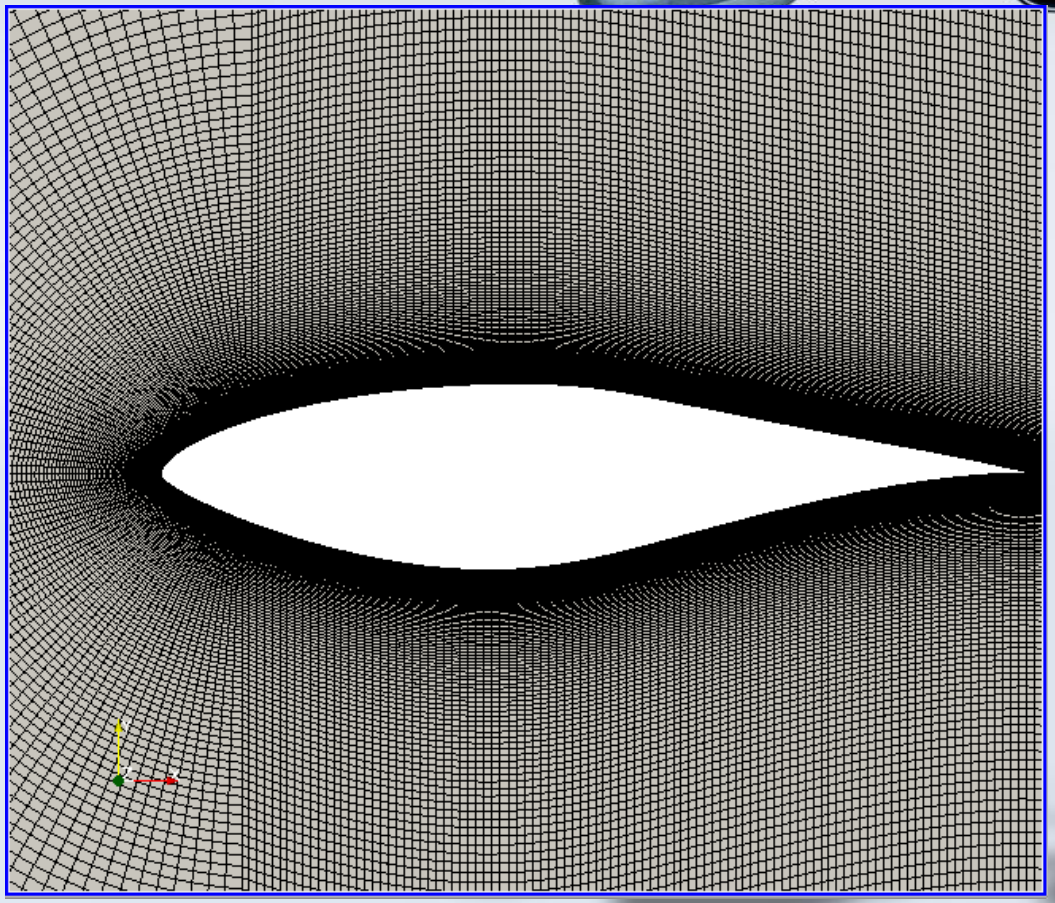
$$\text{Maximum}\left(C_l = \frac{L}{\frac{1}{2}\rho V_{ref}^2 A_{ref}}, \forall x, y \in N\right); \text{ maximum}\left(\frac{C_l}{C_d}, \forall x, y \in N\right);$$

N *is the size of search space of the control point*

The shape Optimization of S809 airfoil (2/4)

- Mesh





The shape Optimization of S809 airfoil (3/4)

- Mesh

Table 3: Results of mesh evaluation

Evaluation criteria	Value	Result
Max aspect ratio (< **1000**)	149.8804	Excellent
Non-orthogonality max (< **70**)	40.89682	Good
Non-orthogonality average (< **40**)	7.013414	Excellent
Max skewness (< **4**)	0.5537326	Excellent
The number of cell	96600	-

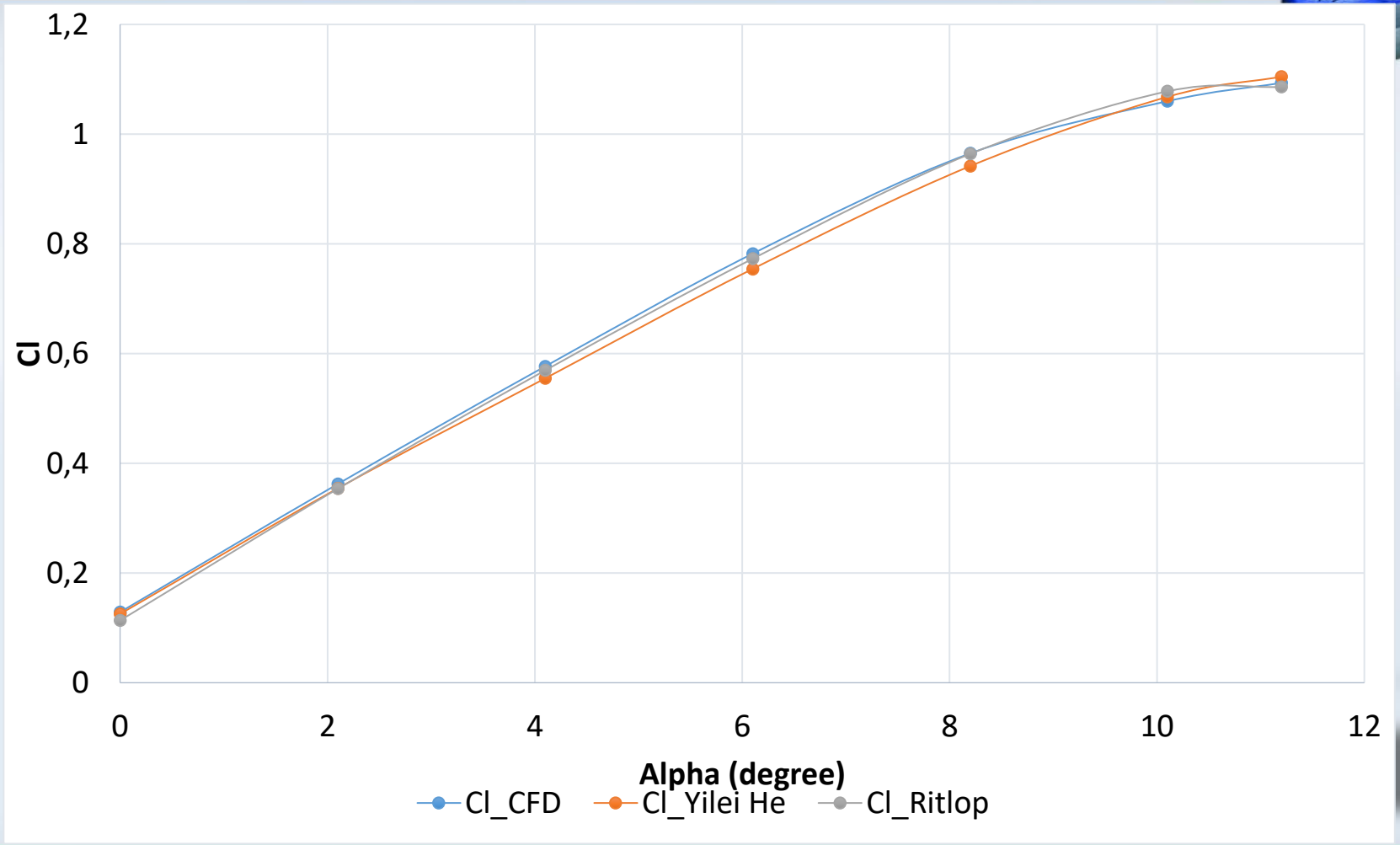
The shape Optimization of S809 airfoil (4/4)

- Boundary conditions and turbulence model

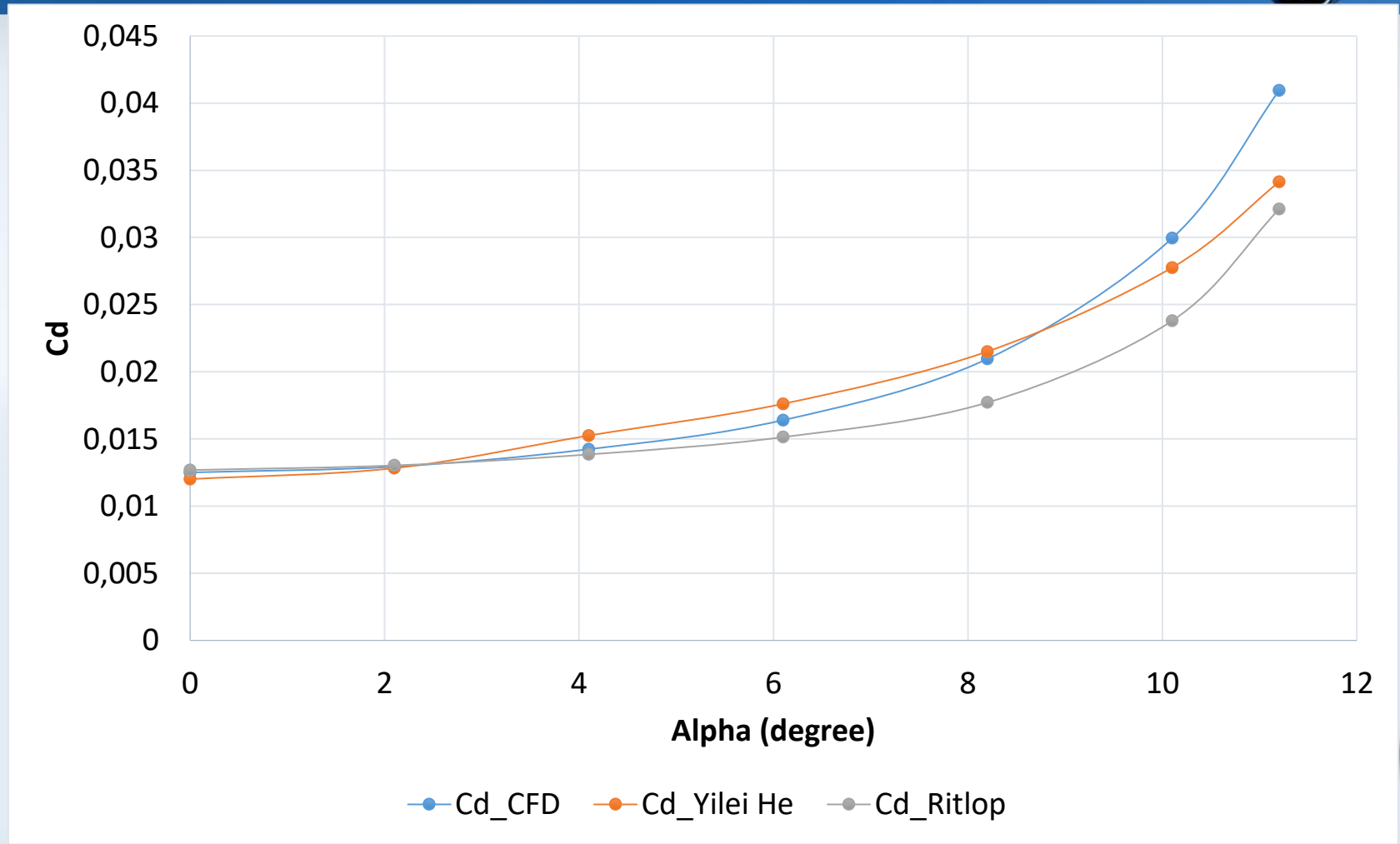
Table 4: Boundary condition and turbulence model

Parameter	Value	Unit
Velocity Inlet	17,8	m/s
Wing Chord	1	m
Air Density	1.225	kg/m^3
Kinematic viscosity	1.7894×10^{-5}	m^2/s
Turbulence model	$k-\omega$ SST	

Results and Discussion (1/7)



Results and Discussion (2/7)

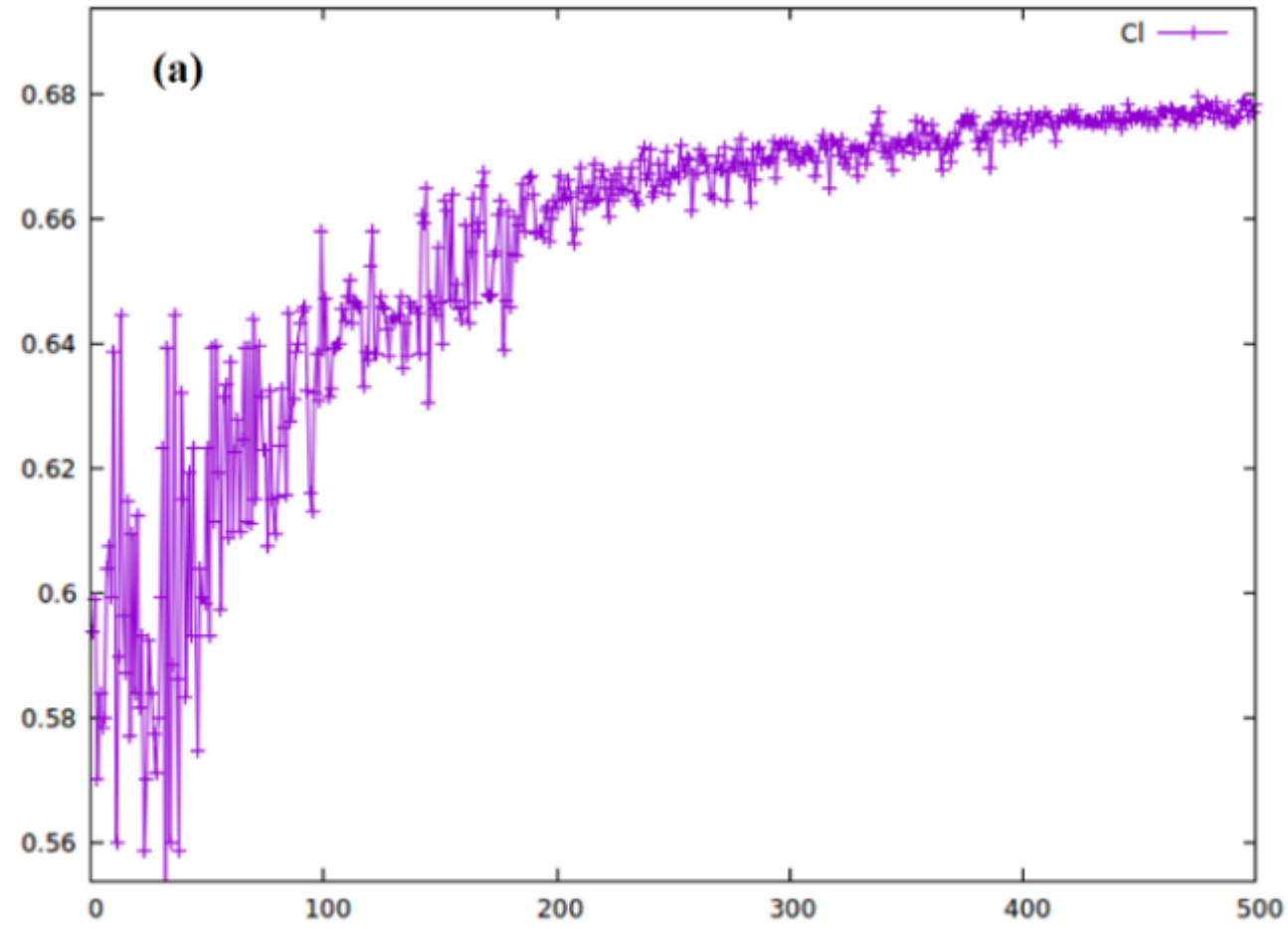


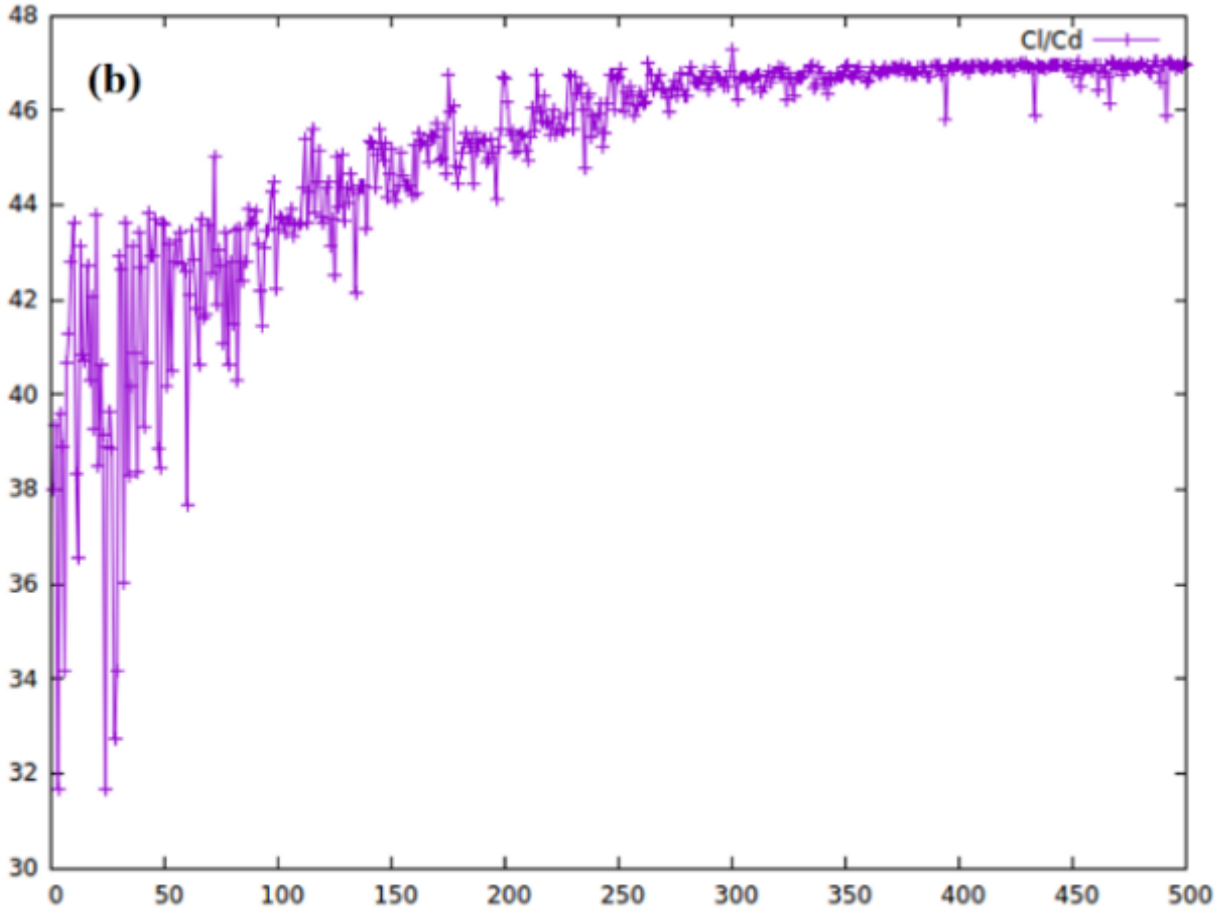
Results and Discussion (4/7)

Table 5: the optimal results of S809 airfoil at 5 degree angle of attack

AoA = 5 độ	C_l	C_d	C_l/C_d	
Original	0.6717552	0.01500891	44.75709	
Case 1: Maximum C_l (GA_C_l)	0.679786	0.014979	45.38121	C_l improve by: 1.2 %
Case 2: Maximum C_l/C_d (GA_C_l/C_d)	0.654209	0.013835	47.28737	C_l/C_d improve by: 5.65 %

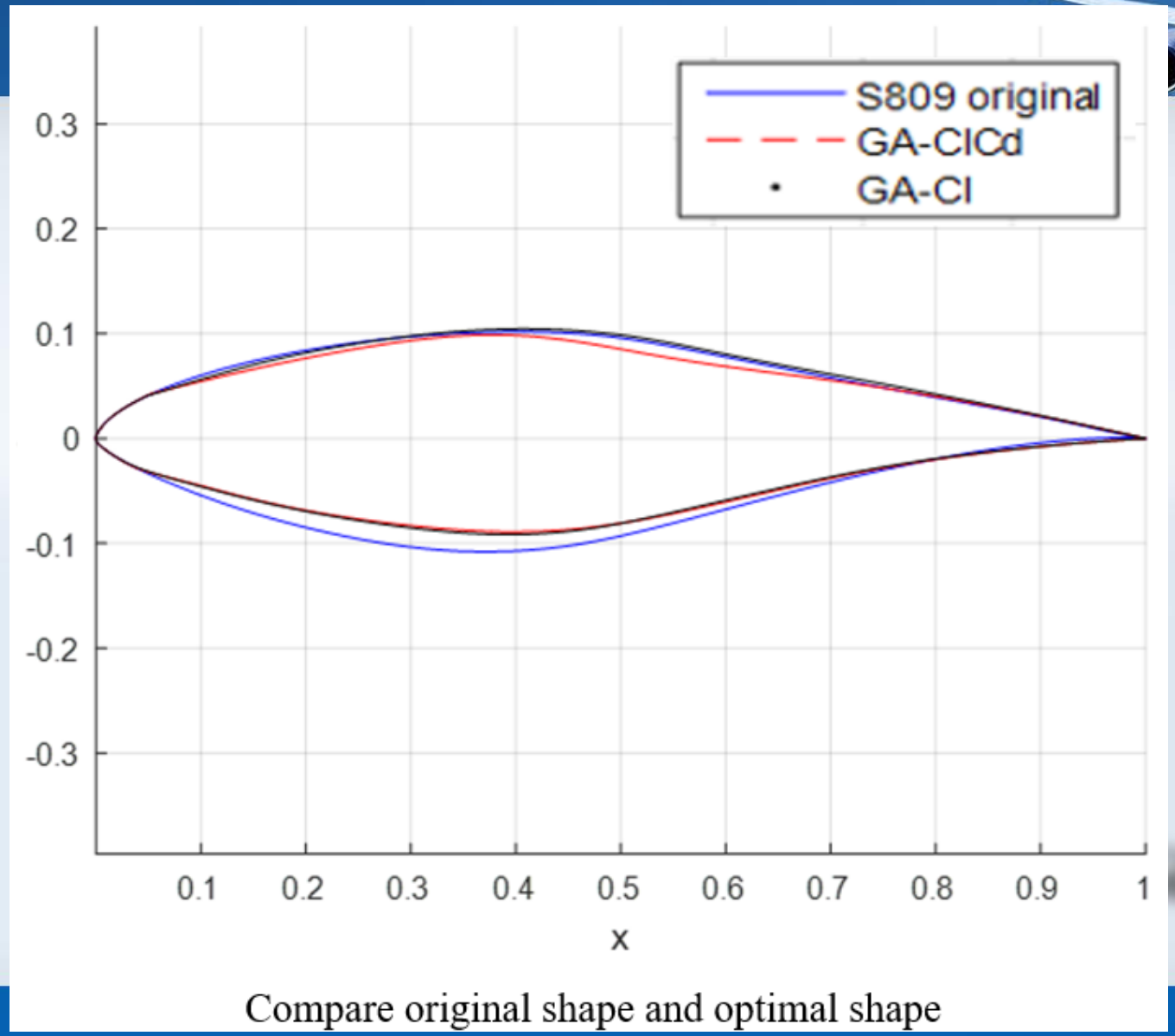
Results and Discussion (5/7)





The graph in the optimization process: (a) lift coeffcient; (b) lift to drag ratio

Results and Discussion (6/7)



Compare original shape and optimal shape

Conclusions and Future Work (1/2)

❑ Conculsions

- A CFD-based optimization framework that couples a CFD block and a GA block has been employed to optimize the shape of a well-known wind turbine airfoil S809 to improve it's aerodynamic.
- The methodology is still in its infancy and exhibits some shortcomings, like optimizing 2D profiles alone doesn't guarantee the increased performance and aerodynamic characteristics of wind turbines due to the influence of wing tip vortex in the 3D models.

Conclusions and Future Work (1/2)

❑ Future Work

- Further validation and testing with more complex shapes are required to prove the flexibility of the model, towards applying to 3D models.
- Since the optimum shape reached is highly dependent on the operation conditions (derived from the CFD boundary conditions or the control parameter of GA), an interactive process to select these conditions would prove itself useful.
- Develop shape optimization problems with different optimization algorithms and other methods.
- Building optimal models with multiple objective functions at the same time.

THANK YOU

FOR YOUR ATTENDTION!!