基于边界曲线的拟可展曲面构造方法及在船体造型中的应用

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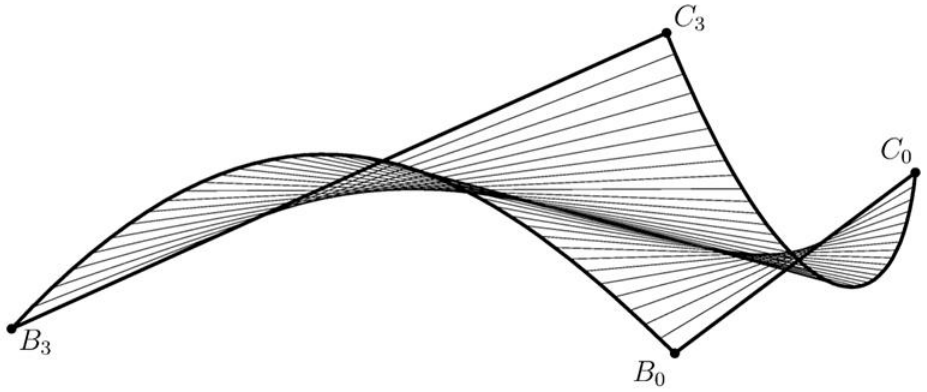
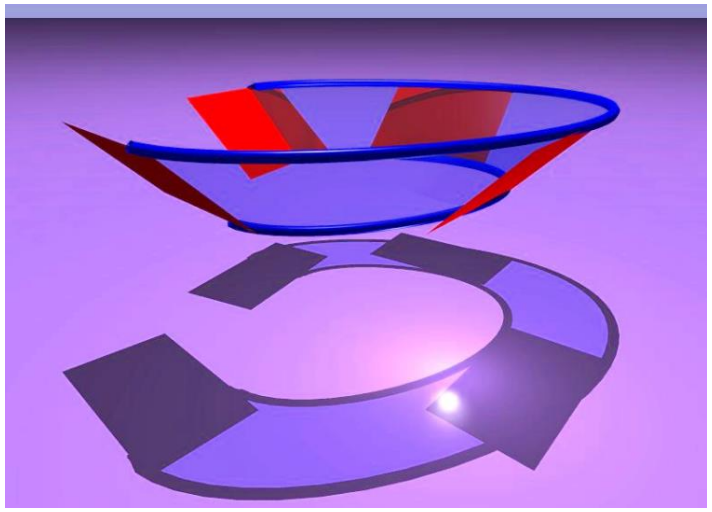
Research Background

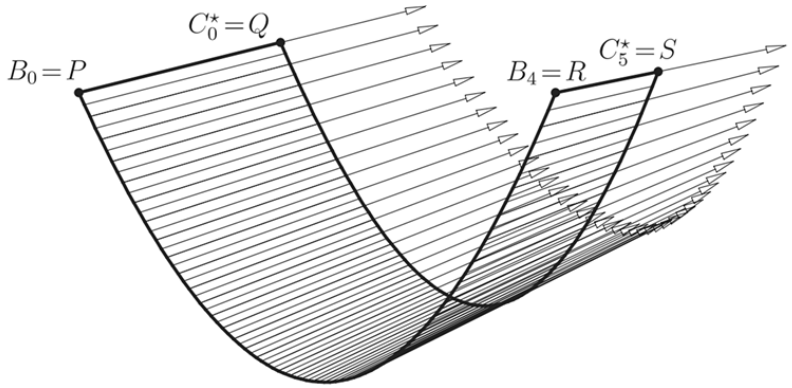
Developable Surface Construction



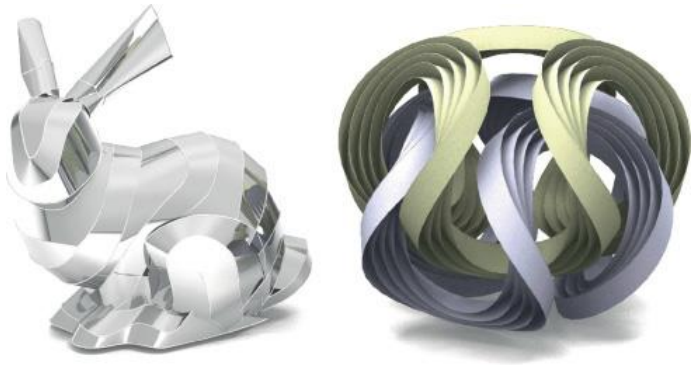
[Aumann G. 1991]



[Pottmann and Wallner. 1999]

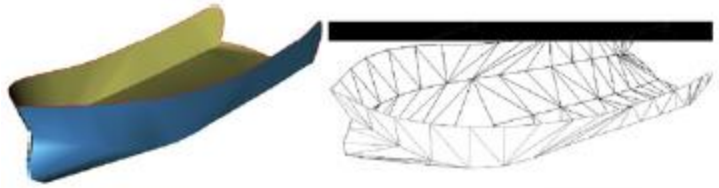


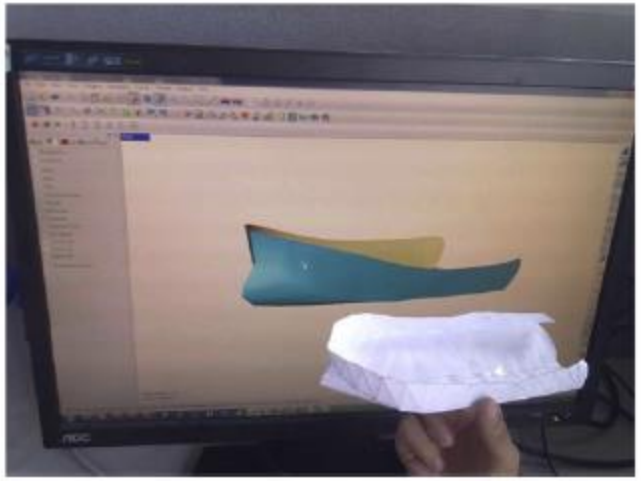
[Aumann G. 2004]



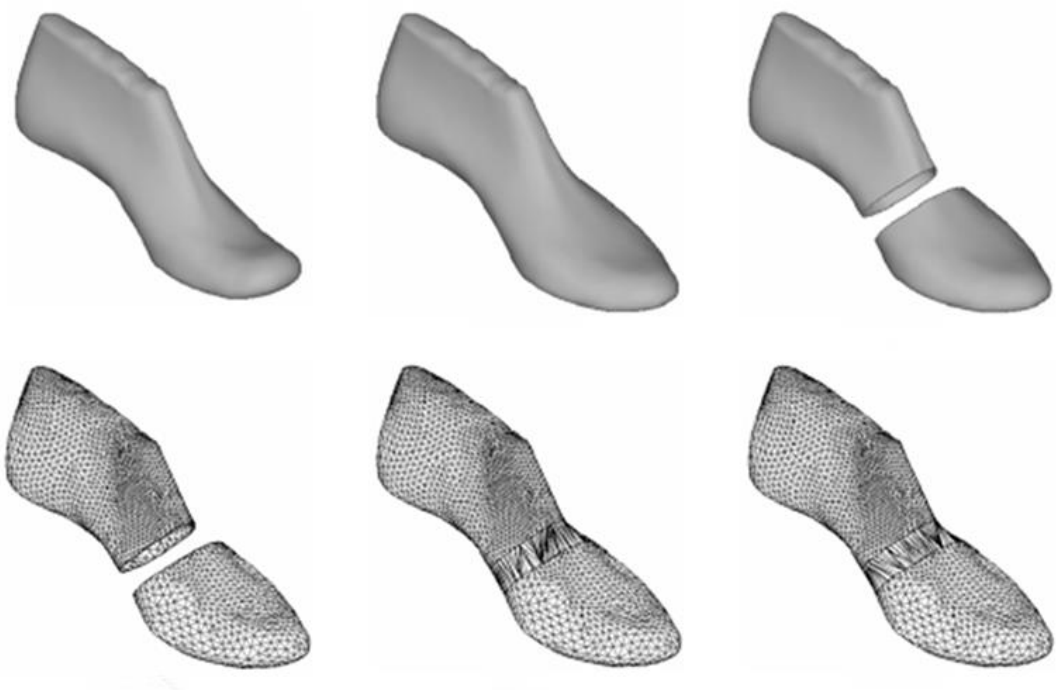
[Tang et al. 2016]

Developable Mesh Construction





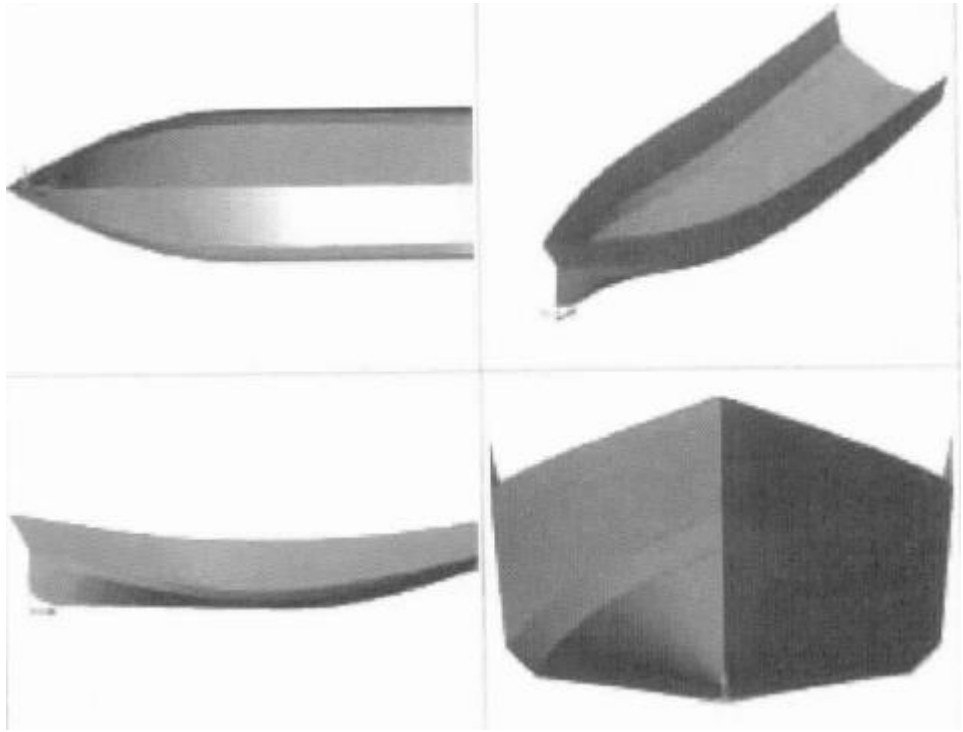
[Liu et al. 2011]



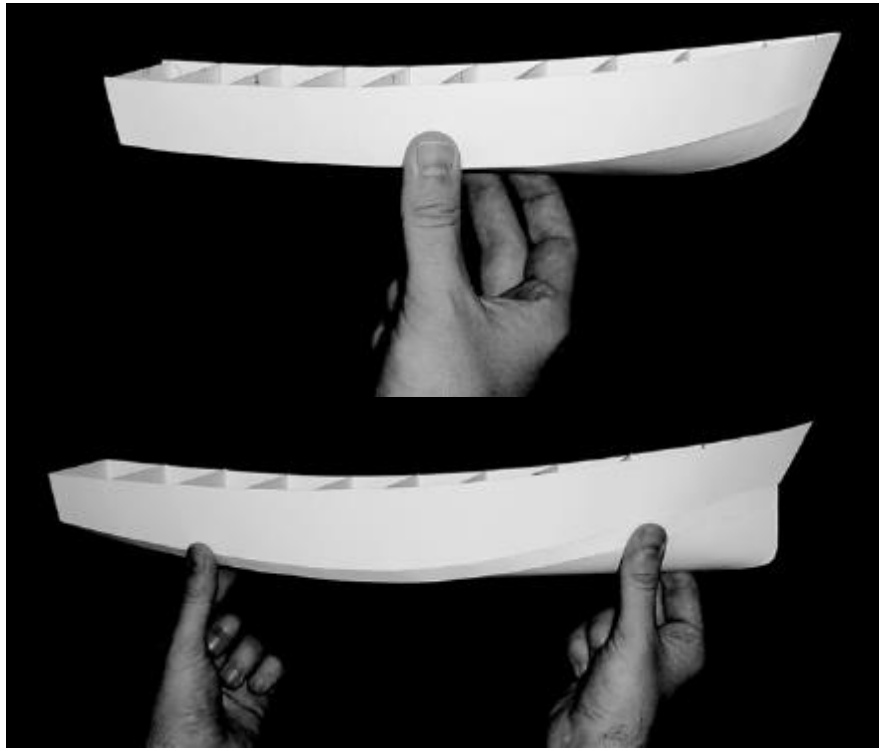
[Wang and Tang. 2005]

[Chen and Tang. 2013]

Research in Ship Hull Design

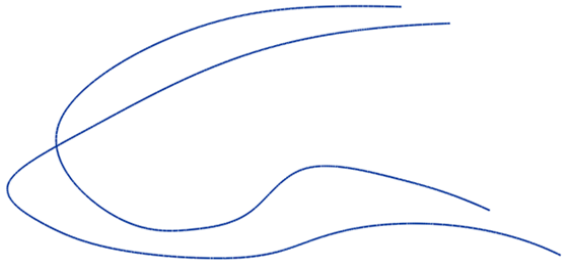


[Konesky B. 2005]



[Pérez and Suárez. 2007]

System Overview

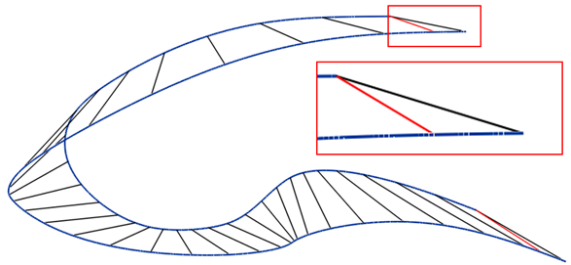


Boundary Curves

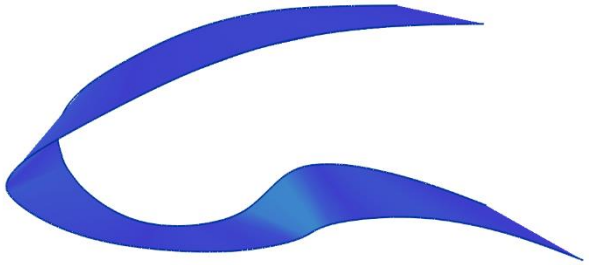
OR

Type Points

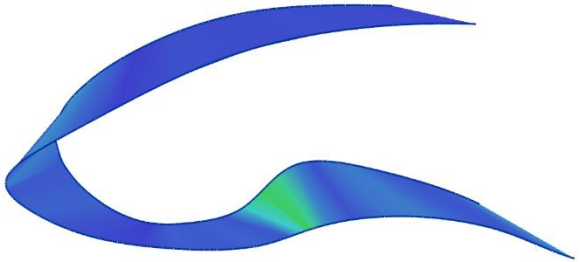
Input



Ruling Set



Approximation Result



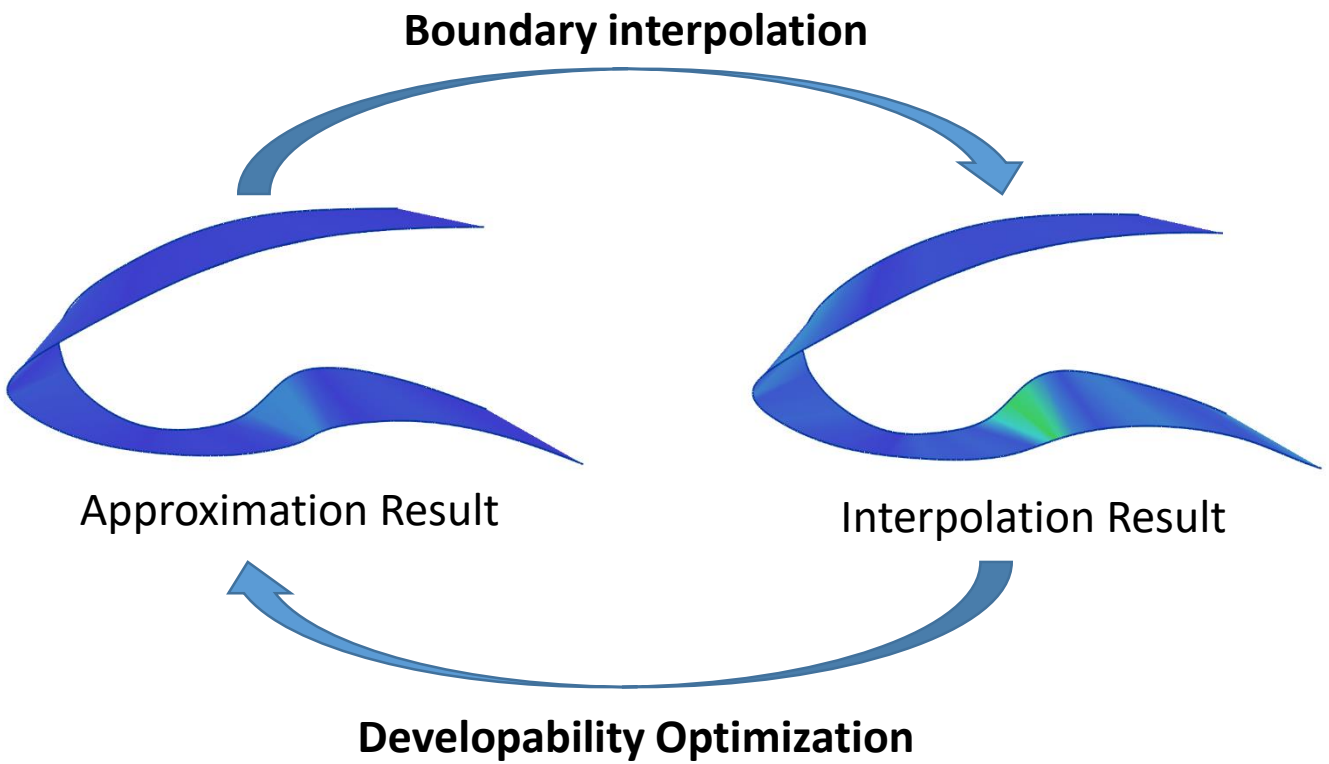
Interpolation Result

Render Result

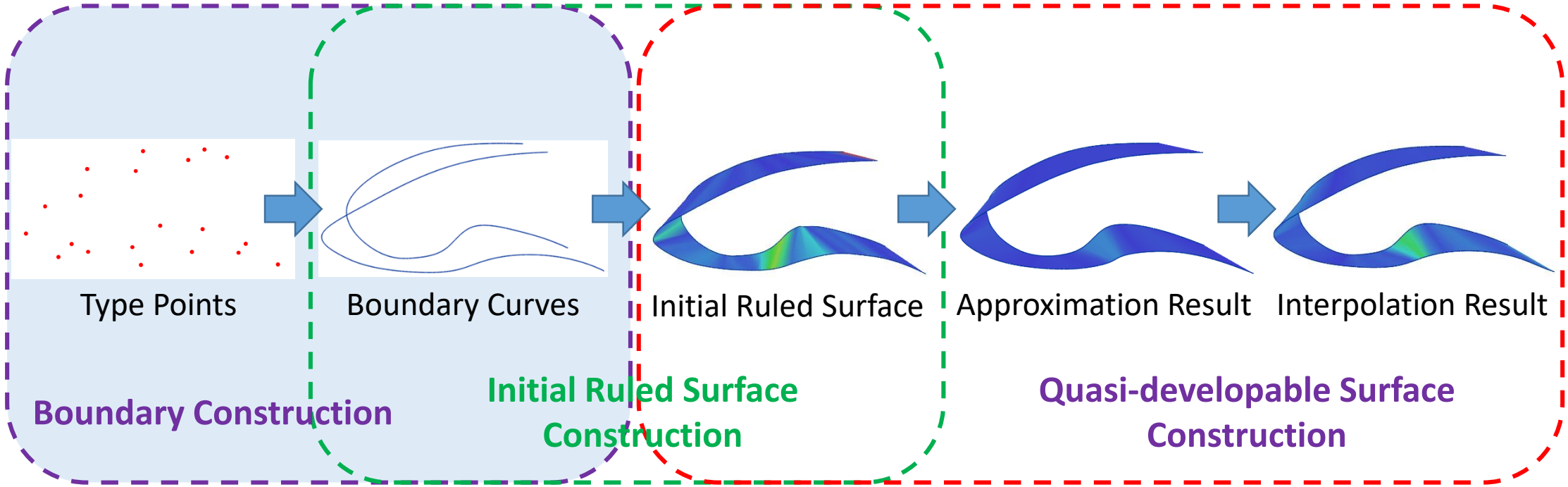
Output

Key Idea

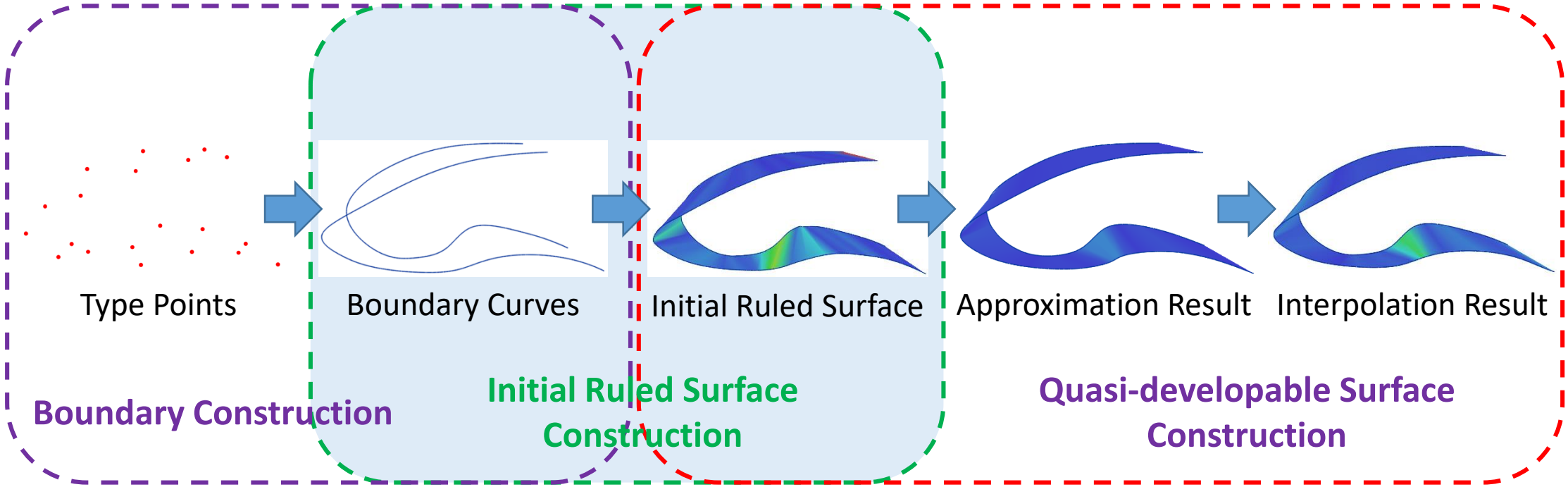
Parameterization of boundary curves driven by developability



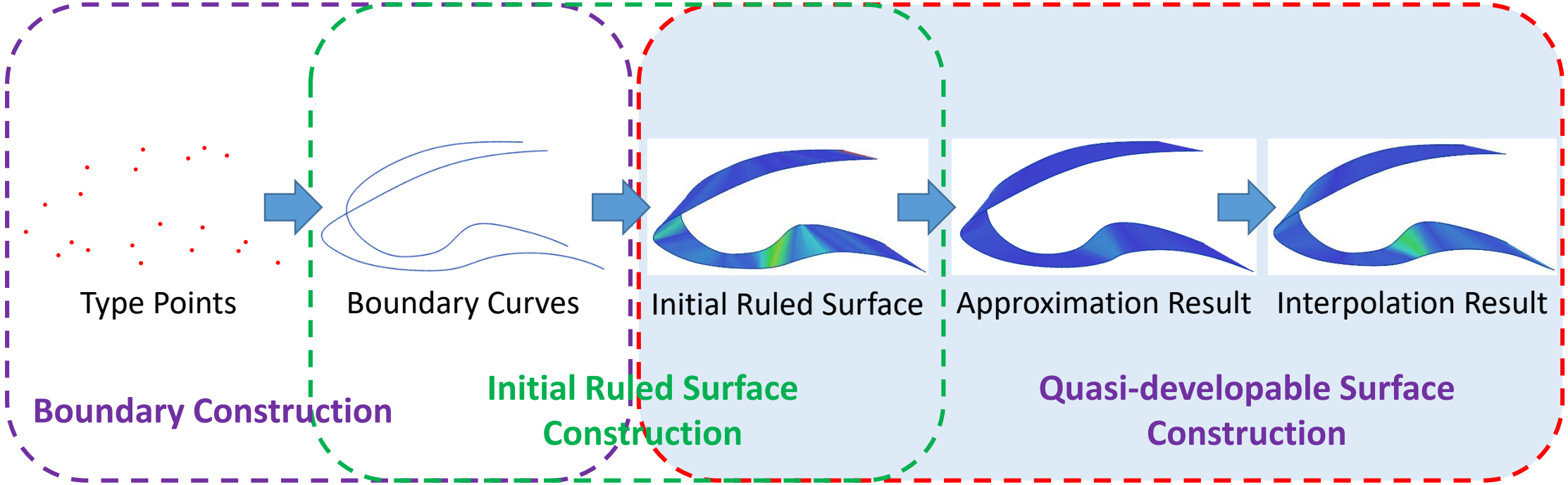
Algorithm Overview



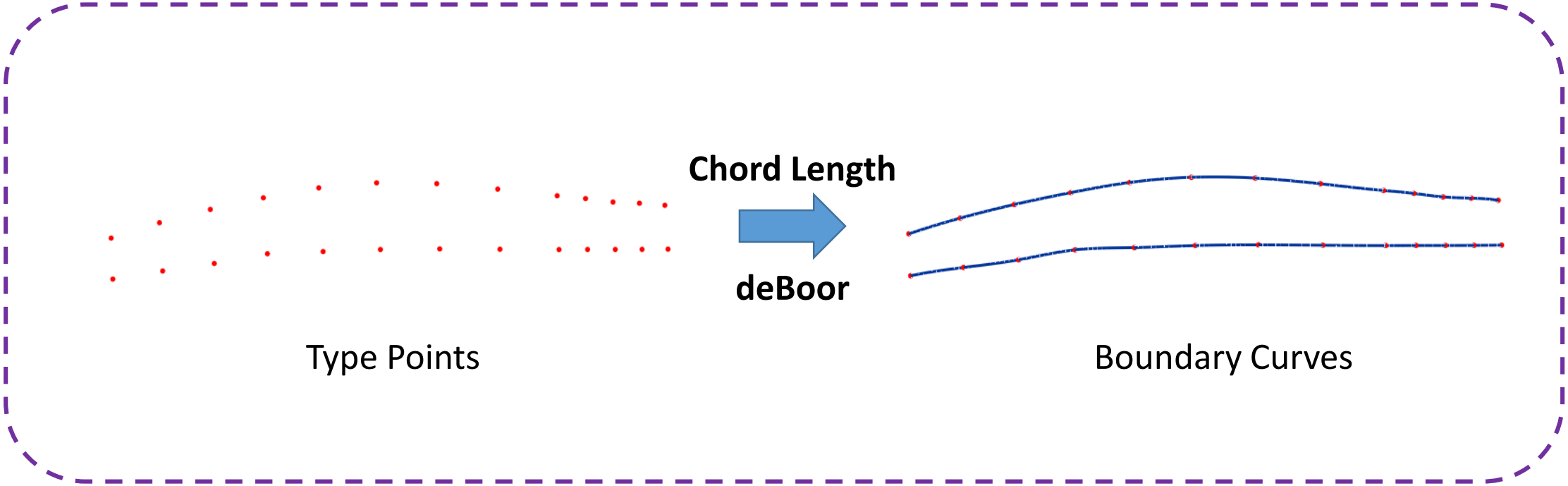
Algorithm Overview



Algorithm Overview

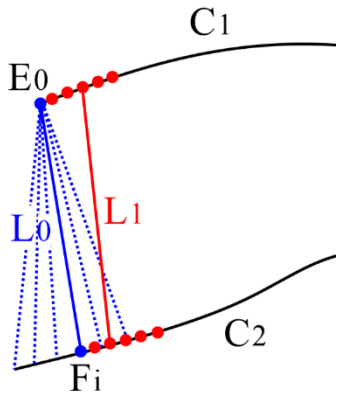


Boundary Construction

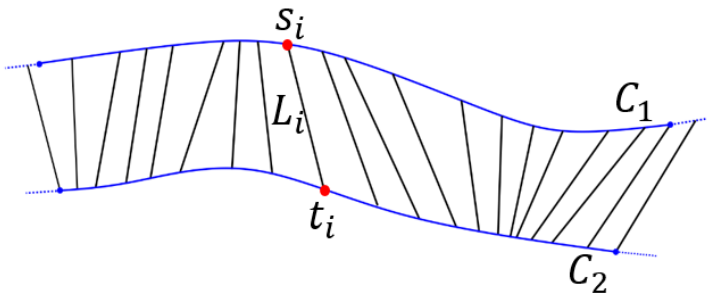


Initial Ruled Surface Construction

Search Ruling

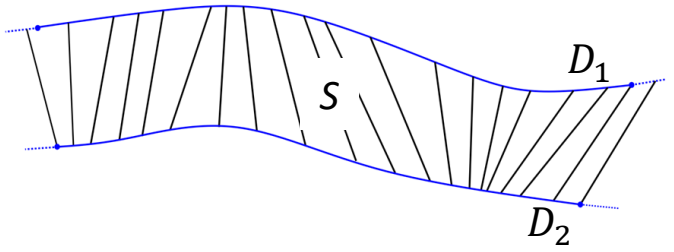


Compute Interpolation Parameter



$$v_i = \frac{1}{2}(s_i + t_i)$$

Construct Ruled Surface

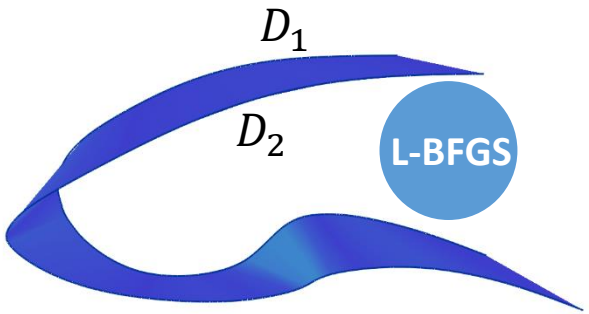


$$S(u,v) = D_1(u)(1-v) + D_2(u)v$$

$\theta\big((F_i - E_0) \times T_1(E_0), (F_i - E_0) \times T_2(F_i)\big)$ **Metal $\leq 6^\circ$** [Rolf et al. 2002]

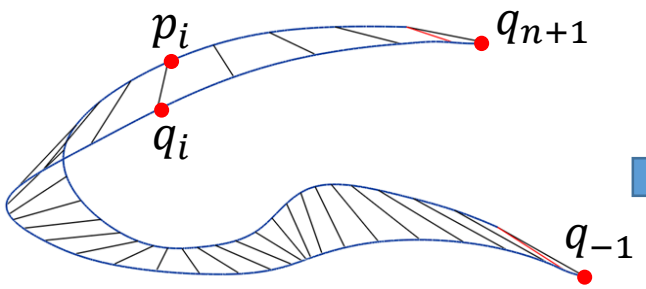
Quasi-developable Surface Construction

Optimization



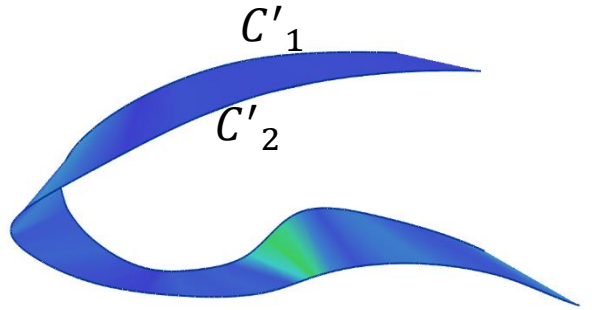
$$\min_{P,N} F_{dist} + \lambda F_{fair} + \gamma F_{dvlp} + \beta F_{regular}$$

Projection



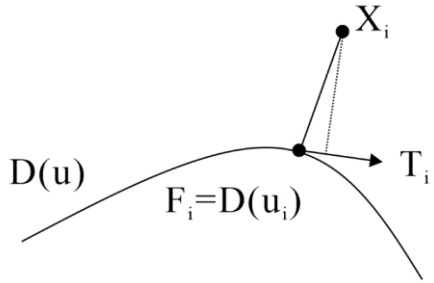
$$p_{-1} = D_1(0), p_0, \cdots, p_n, p_{n+1} = D_1(1)$$
$$q_{-1} = D_2(0), q_0, \cdots, q_n, q_{n+1} = D_2(1)$$

Interpolation



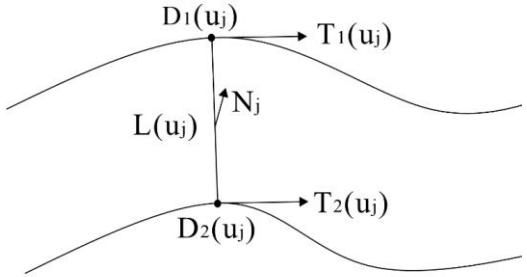
$$S(u,v) = C'_1(u)(1-v) + C'_2(u)v$$

Optimization



$$\sum_{D_1,D_2}\sum_{i=0}^{n}\left(\alpha_i(d_i^*)^2+(1-\alpha_i)\left(d_i^1\right)^2\right)$$

F_{dist}



$$\sum_{j=0}^{K}\left(\left(L(u_j)\cdot N_j\right)^2+\left(T_1(u_j)\cdot N_j\right)^2+\left(T_2(u_j)\cdot N_j\right)^2\right)$$

F_{dvlp}

L-BFGS

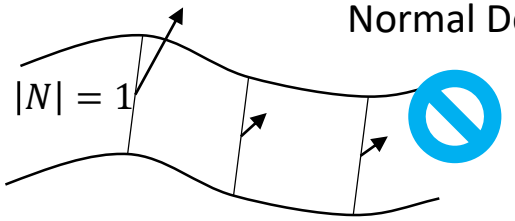
F_{fair}

Regression Curve

$$\sum_{i=1,2}\omega\int|D_i'(u)|^2du+\int|D_i''(u)|^2du$$

F_{regular}

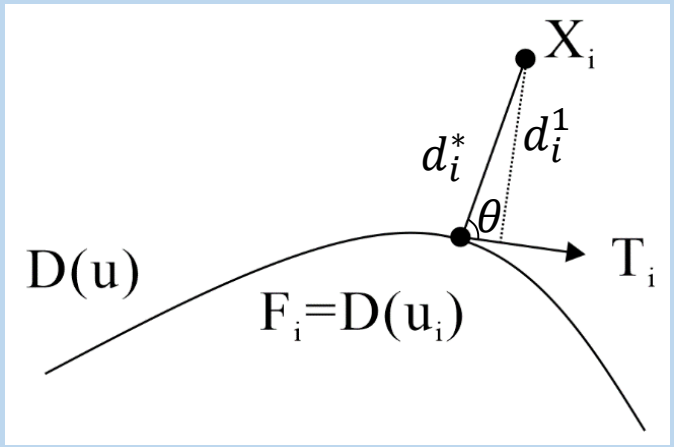
Normal Degeneration

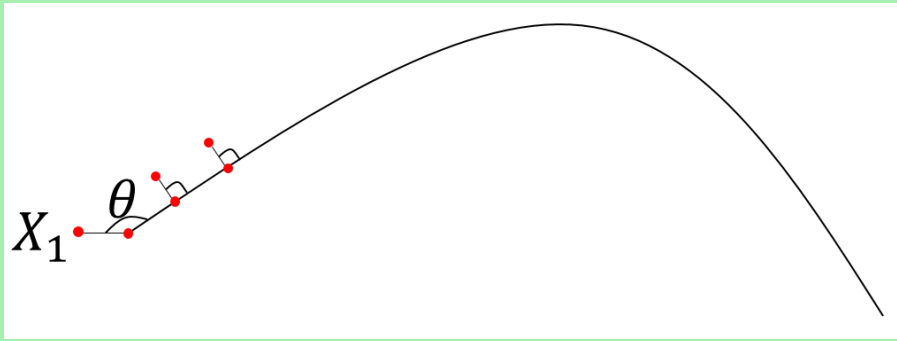


$$\sum_{j=0}^{K}\left(|N_j|^2-1\right)^2$$

Optimization-Boundary Constraint

$$F_{dist} = \sum_{D_1,D_2} \sum_{i=0}^{n} \left(\alpha_i (d_i^*)^2 + (1-\alpha_i)\left(d_i^1\right)^2\right)$$



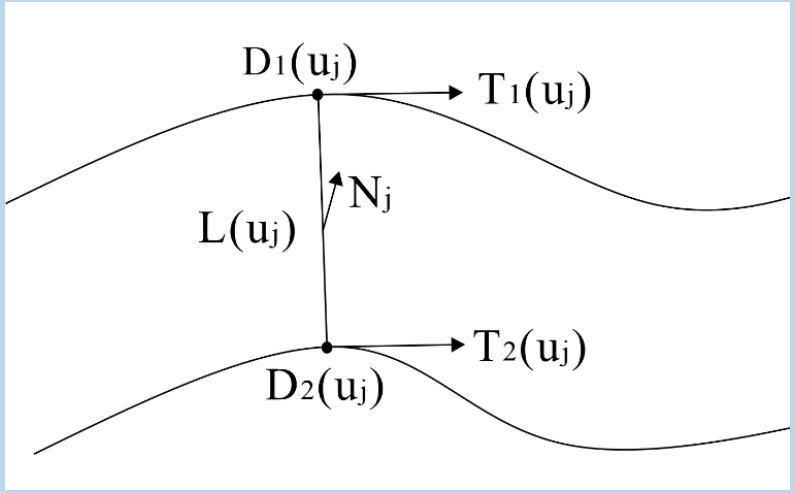


$$\alpha_i = \cos\theta = \left|\frac{X_i - F_i}{|X_i - F_i|} \cdot T_i\right|$$

$$d_i = \alpha_i (d_i^*)^2 + (1-\alpha_i)\left(d_i^1\right)^2$$

Optimization-Developability Constraint

$$F_{develop} = \sum_{j=0}^{K} \left(\left(L(u_j) \cdot N_j \right)^2 + \left(T_1(u_j) \cdot N_j \right)^2 + \left(T_2(u_j) \cdot N_j \right)^2 \right)$$



$$N_i(u_j) = \frac{L(u_j) \times T_i(u_j)}{|L(u_j) \times T_i(u_j)|}, i = 1,2$$

$$N_1(u_j) - N_2(u_j) = 0$$

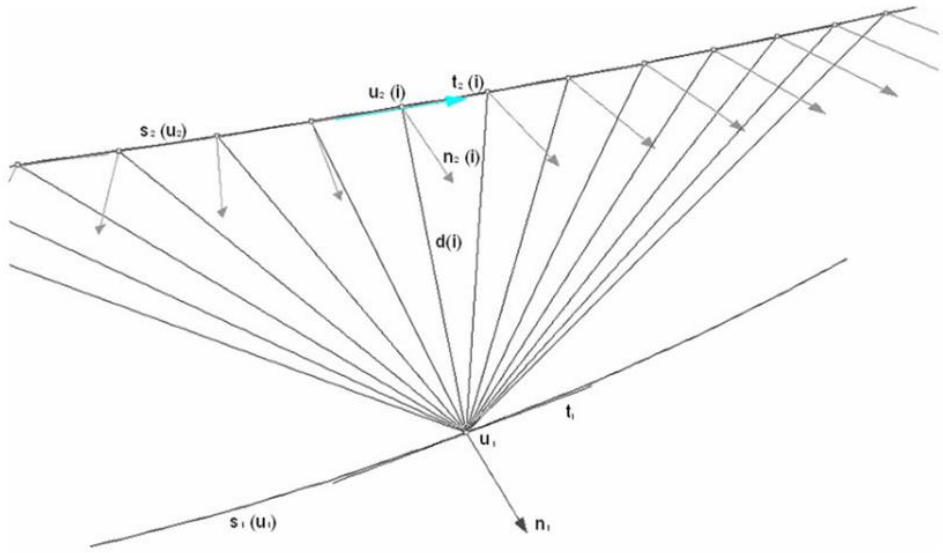
Nonlinear Constraint

$$\begin{cases} N(u_j) \cdot T_1(u_j) = 0 \\ N(u_j) \cdot T_2(u_j) = 0 \\ N(u_j) \cdot L_1(u_j) = 0 \end{cases}$$

Linear Constraint

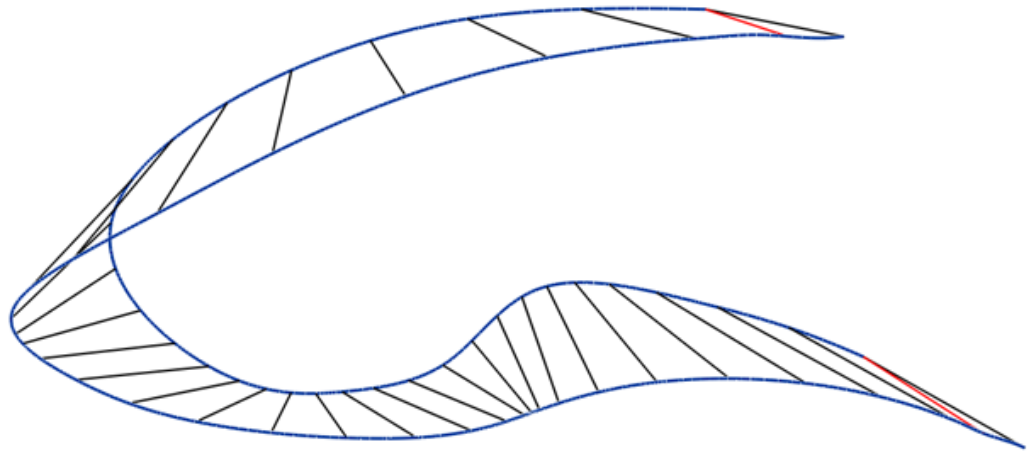
Continuous Projection

Finite Rulings



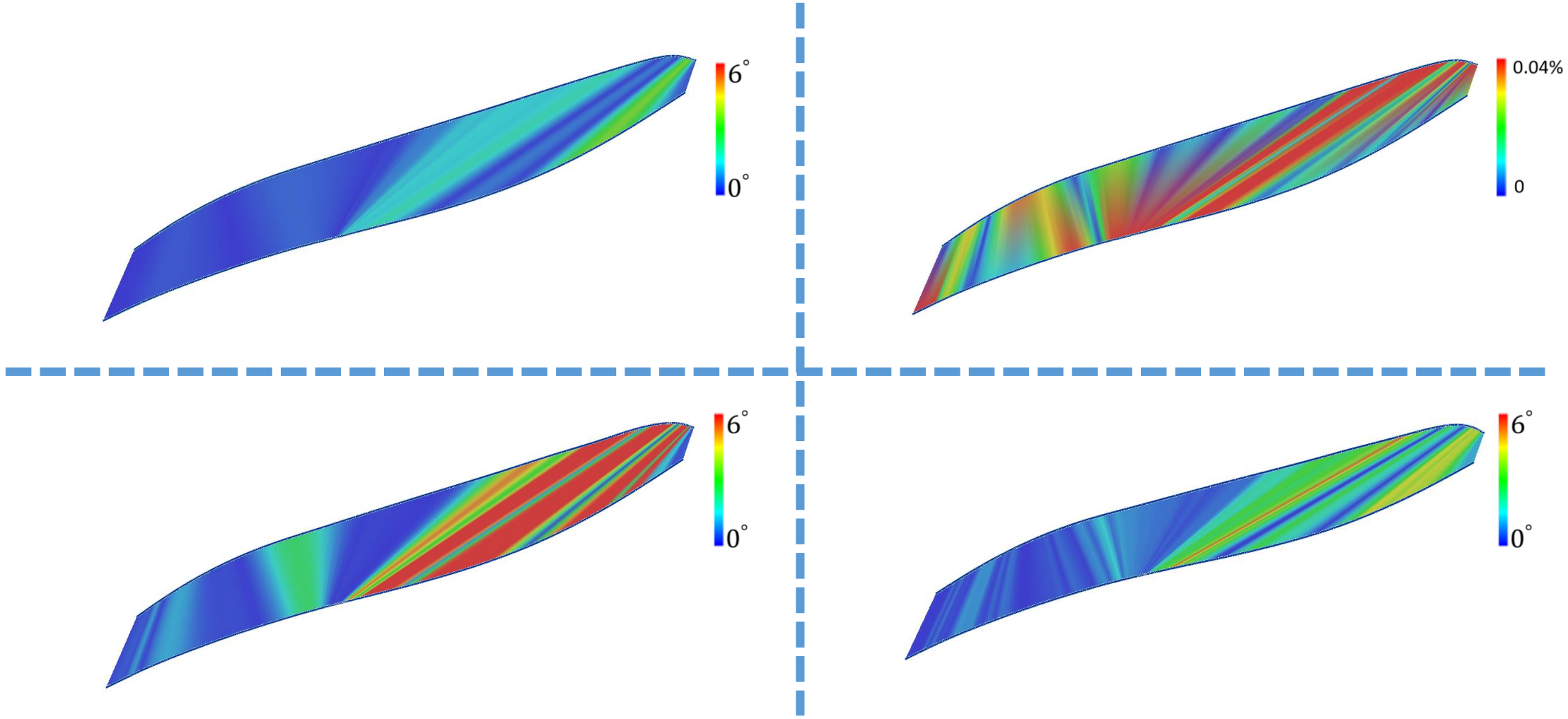
Traditional

Infinite Rulings

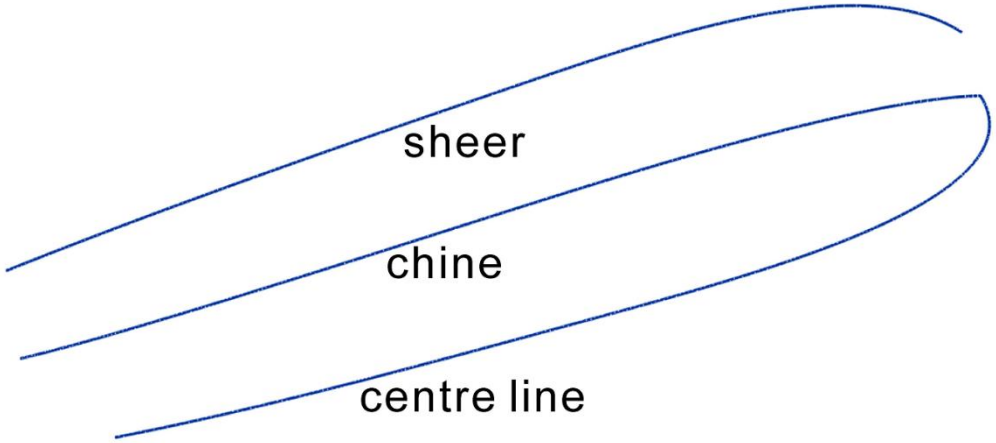


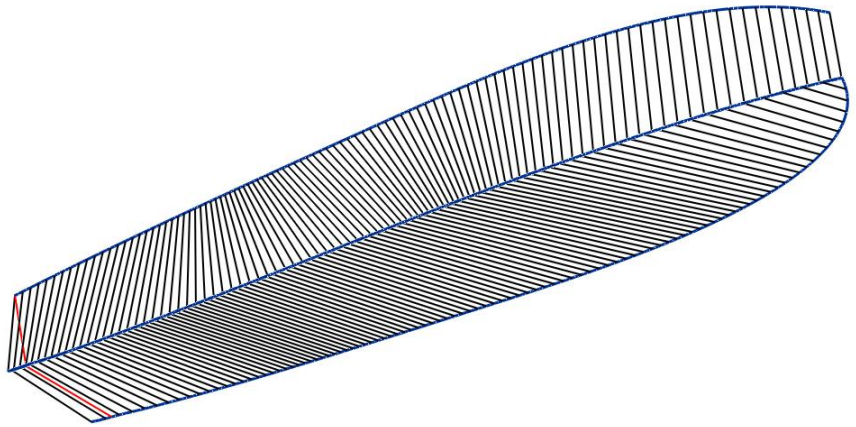
Ours

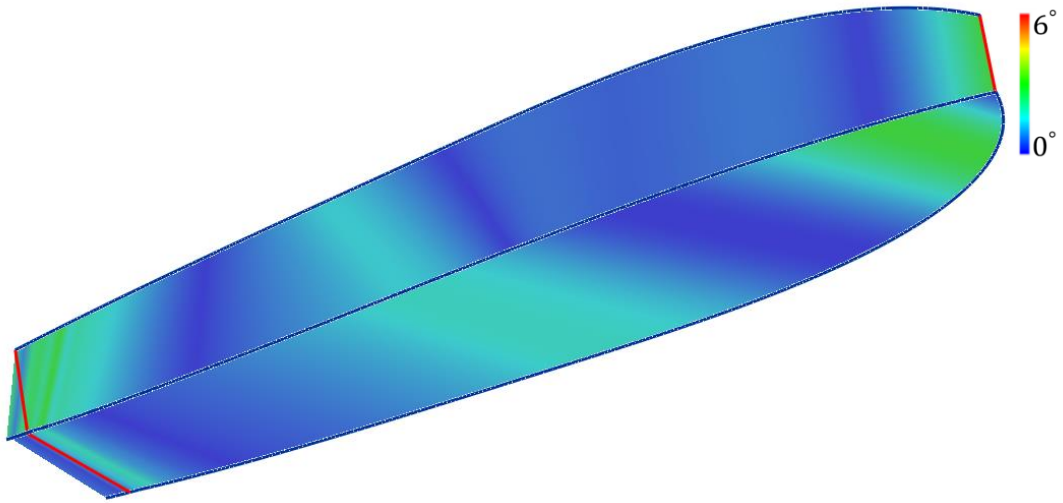
Error Controllable Data Point Modification



Result-Hard Chine

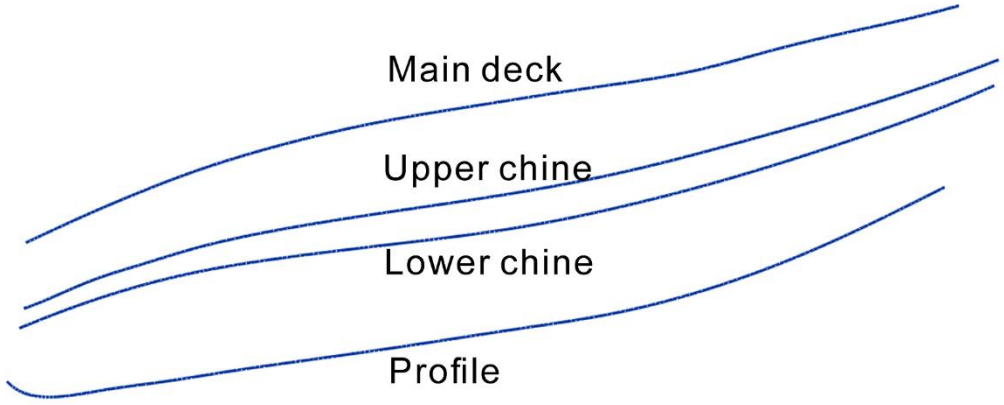


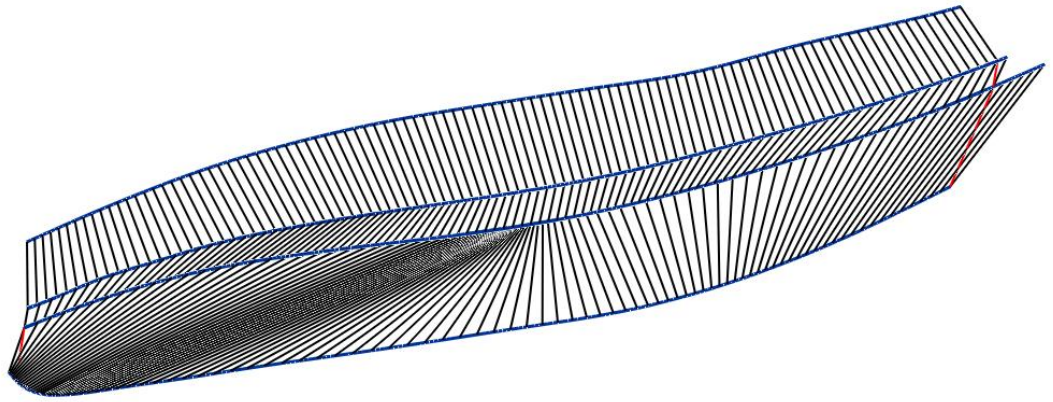


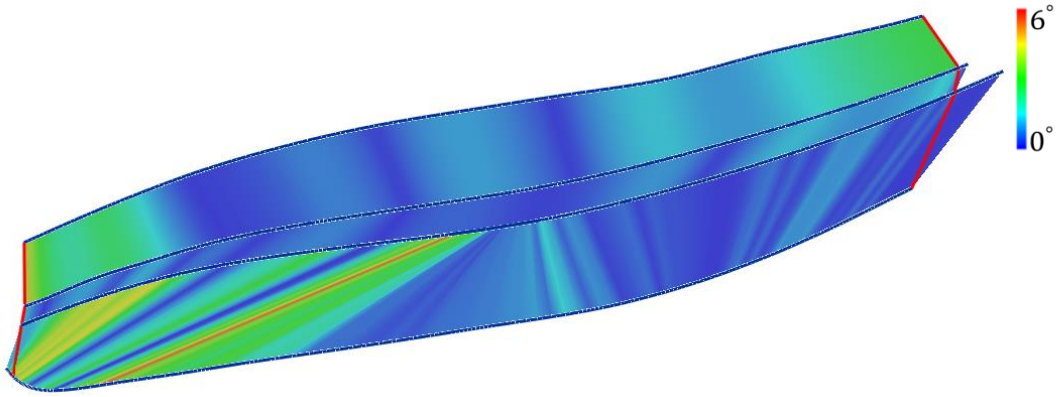


Ave_error	Max_error	Modif_dist
0.45°	3.08°	0.00%

Result-UBC Fishing Vessel







Ave_error	Max_error	Modif_dist
0.52°	5.60°	0.04%

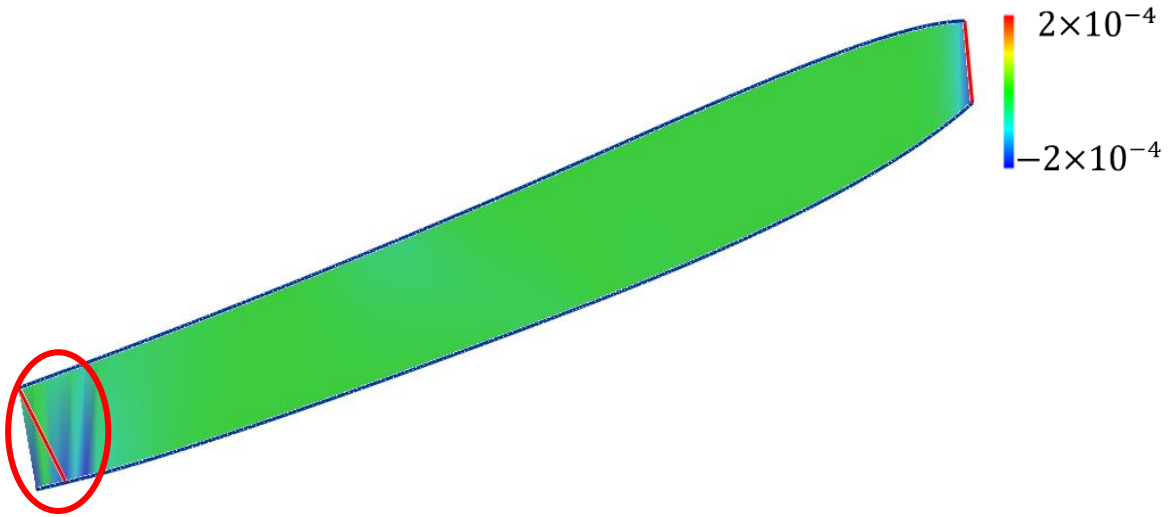
Limitation

Efficiency

	Surface	Time
Hard chine	2	7.65s
UBC fishing vessel	4	66.4s

Difficult to converge

Gaussian Curvature



Strict boundary interpolation

Thank you