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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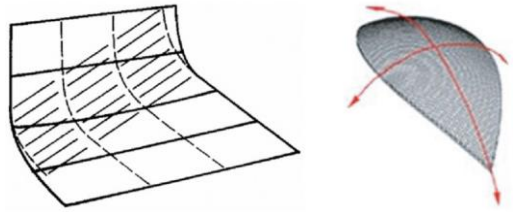
Outline

- **Research Background**
  - Developable Surface Construction
  - Developable Surface Construction
  - Developable Surface in Ship Hull Design
- System Overview
- Algorithm
- Result
- Contribution and Limitation

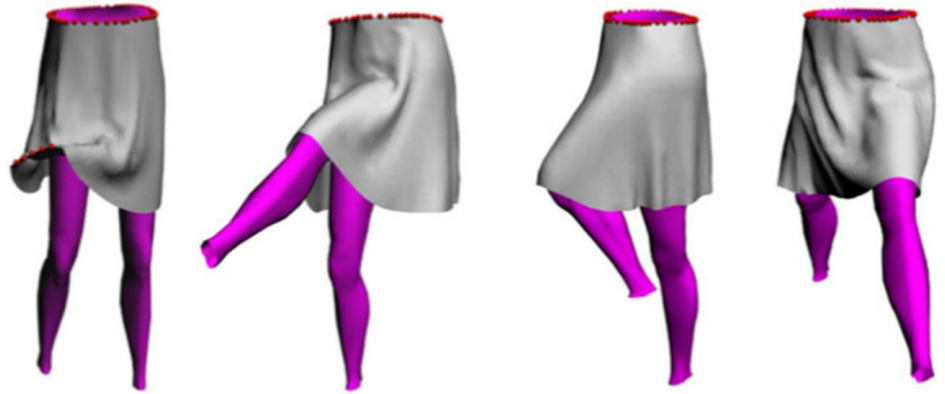
Research Background



Single and double curvature [Pérez et al. 2007]

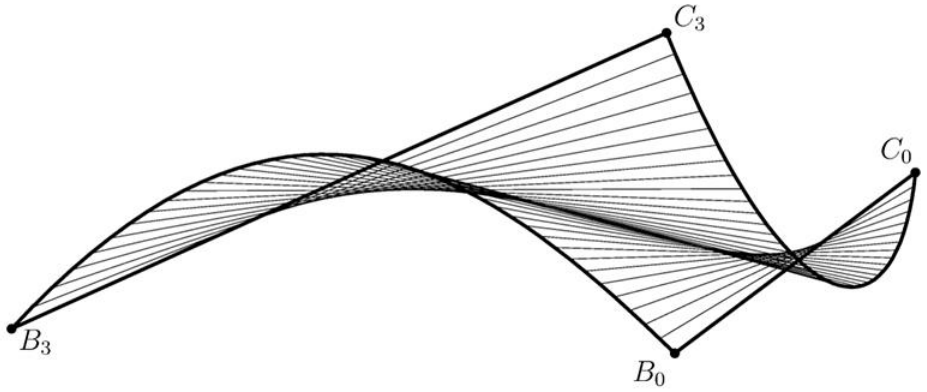
[Wayne's Blog]

Walt Disney Concert Hall
[Jerry's Motel]

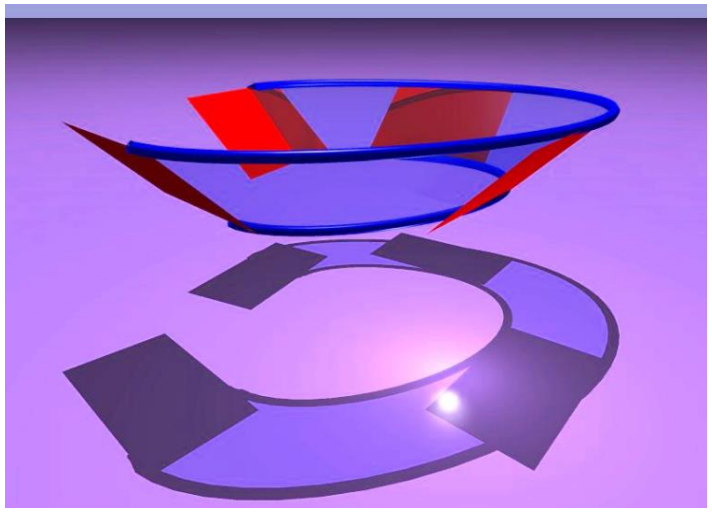


[Chen and Tang. 2010]

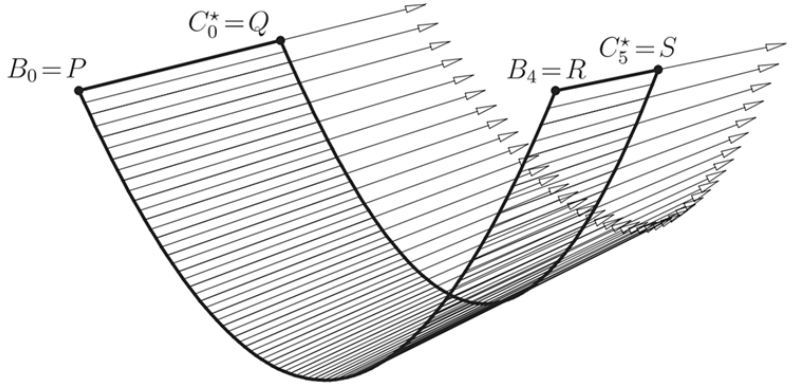
Developable Surface Construction



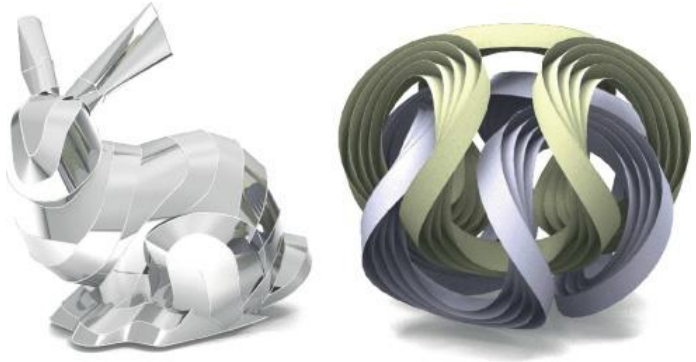
[Aumann G. 1991]



[Pottmann and Wallner. 1999]

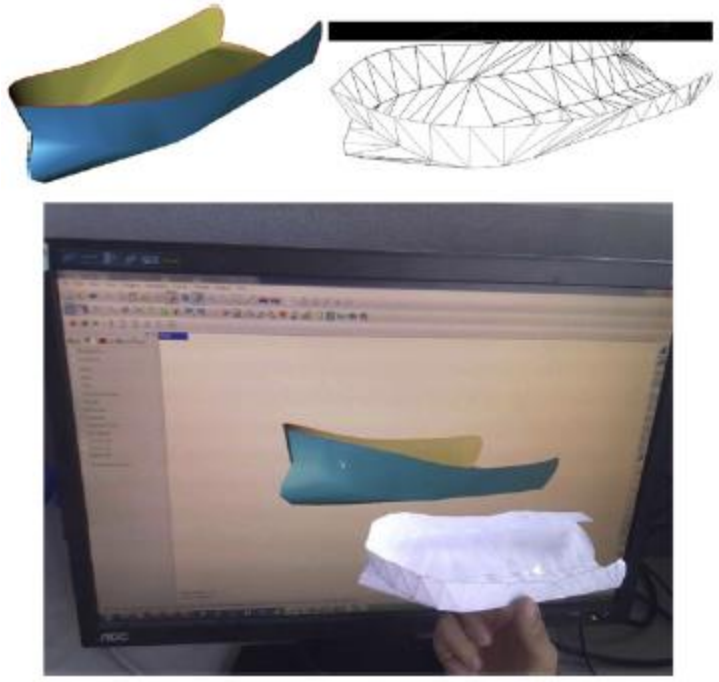


[Aumann G. 2004]

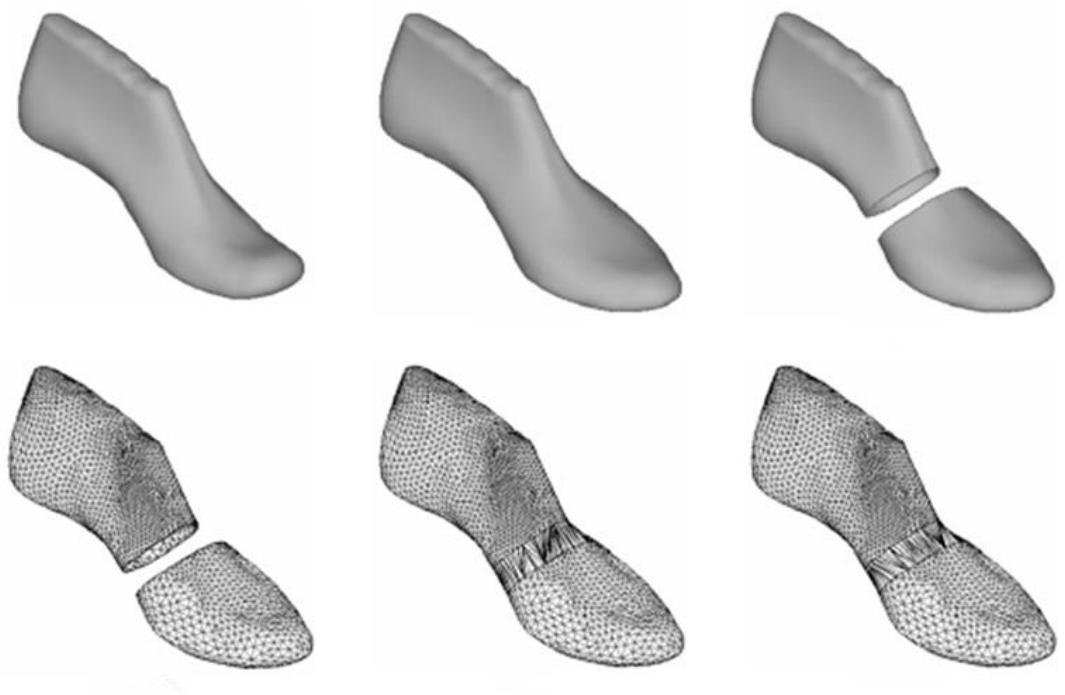


[Tang et al. 2016]

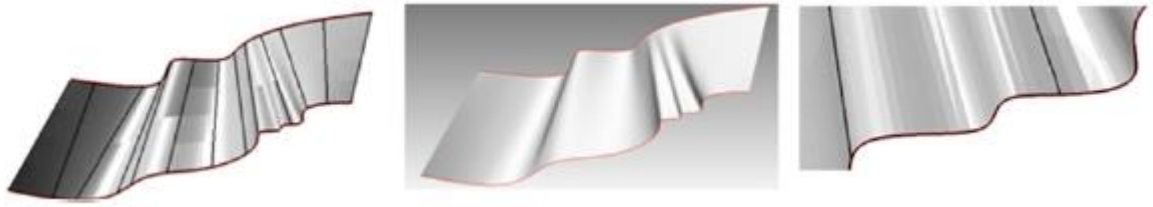
Developable Surface Construction



[Liu et al. 2011]

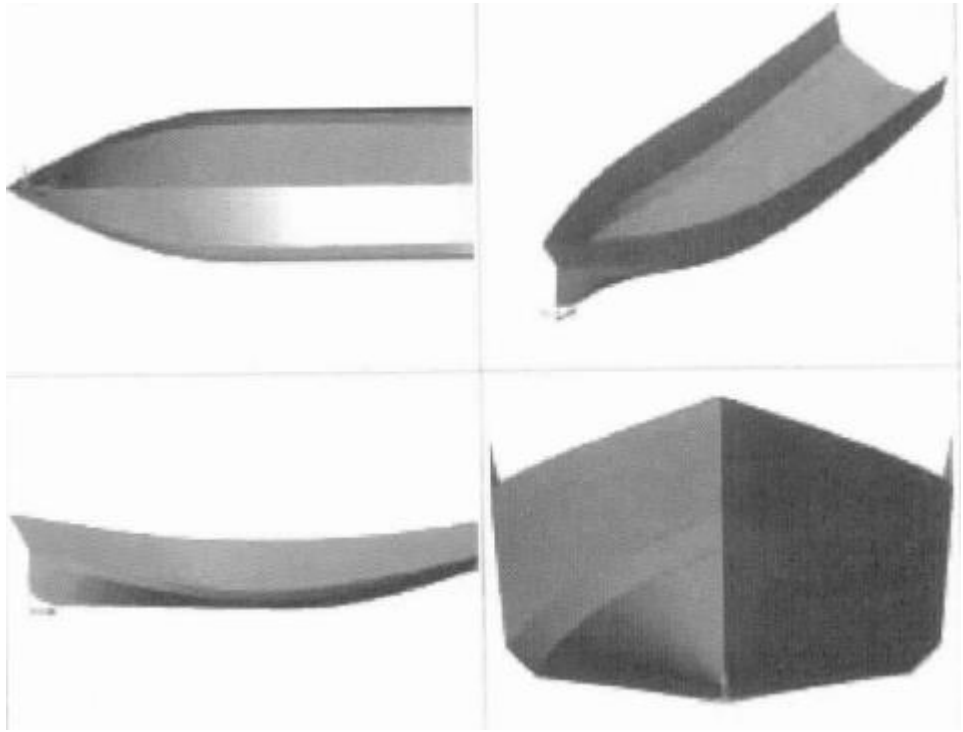


[Wang and Tang. 2005]

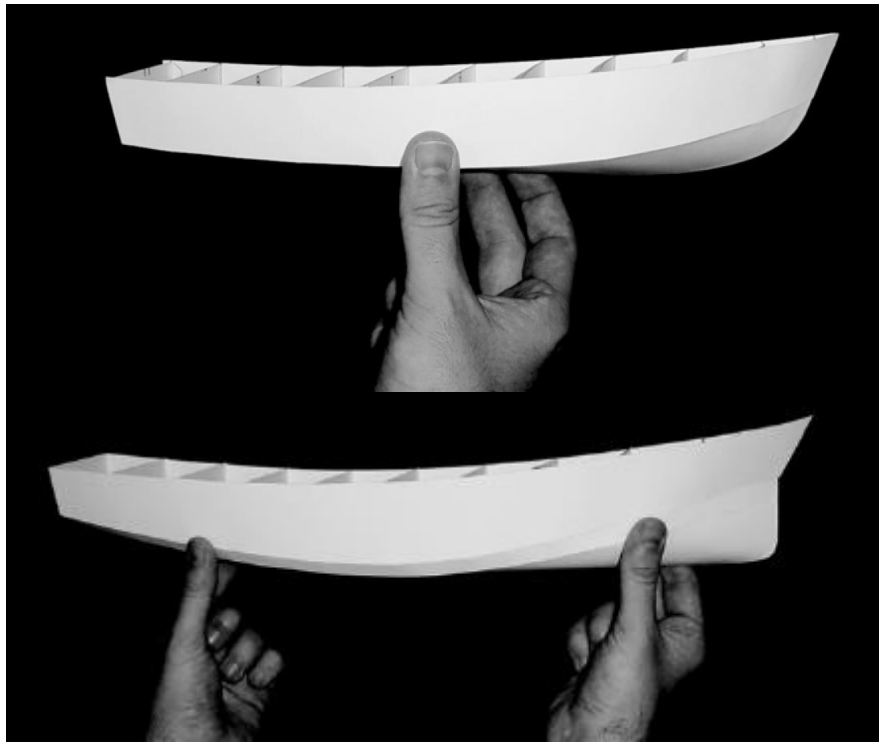


[Chen and Tang. 2013]

Developable Surface in Ship Hull Design



[Konesky B. 2005]

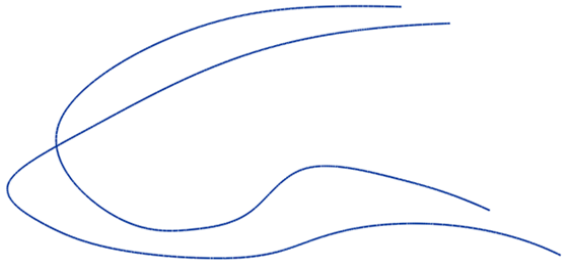


[Pérez and Suárez. 2007]

Outline

- Research Background
- **System Overview**
  - Key Idea
- Algorithm
- Result
- Contribution and Limitation

System Overview



Boundary Curves

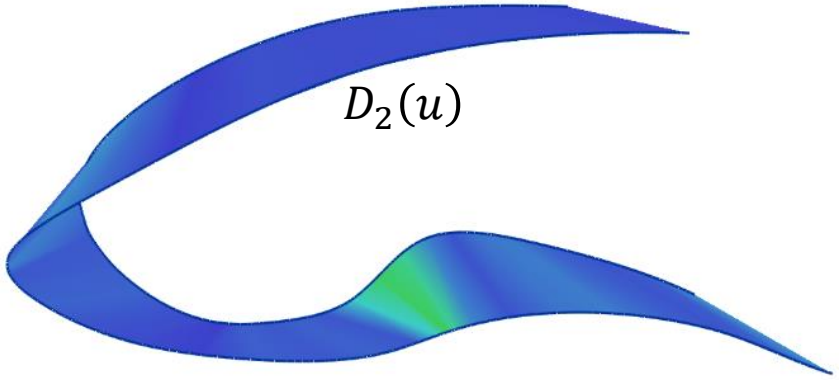
OR

Type Points

Input

$D_1(u)$

$D_2(u)$



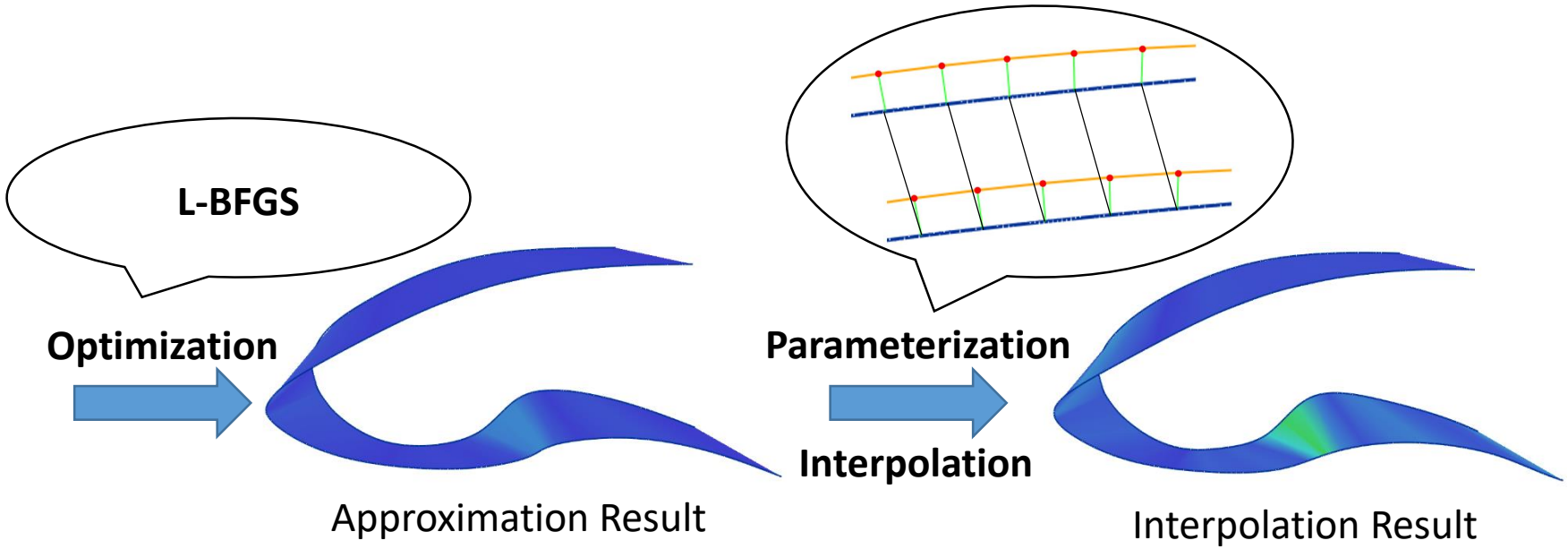
$$S(u,v) = D_1(u)(1-v) + D_2(u)v$$

Interpolation Result

Output

Key Idea

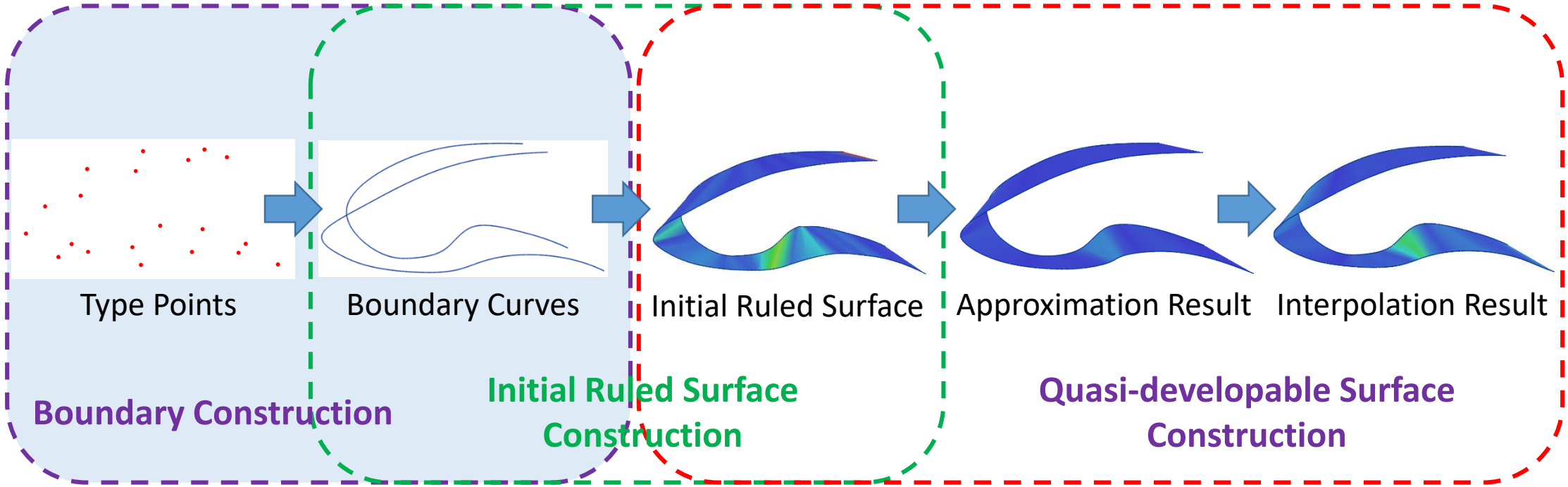
How to get good **Parameterization**?



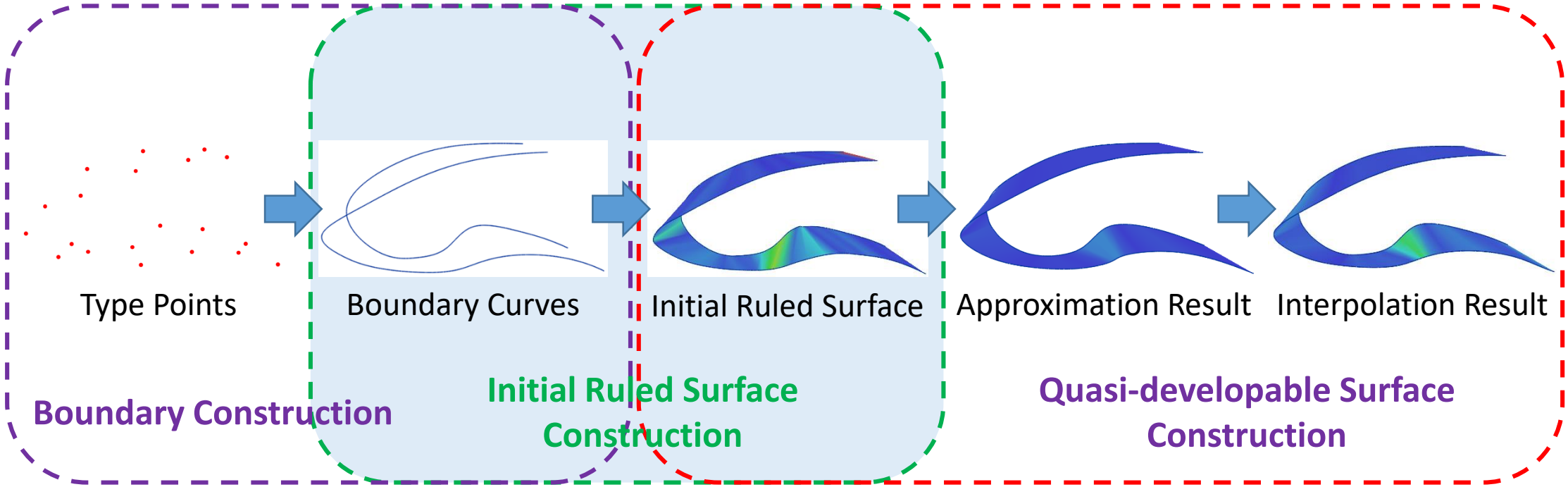
Outline

- Research Background
- System Overview
- **Algorithm**
  - 1 Boundary Construction
  - 2 Initial Ruled Surface Construction
  - 3 Quasi-developable Surface Construction
- Result
- Contribution and Limitation

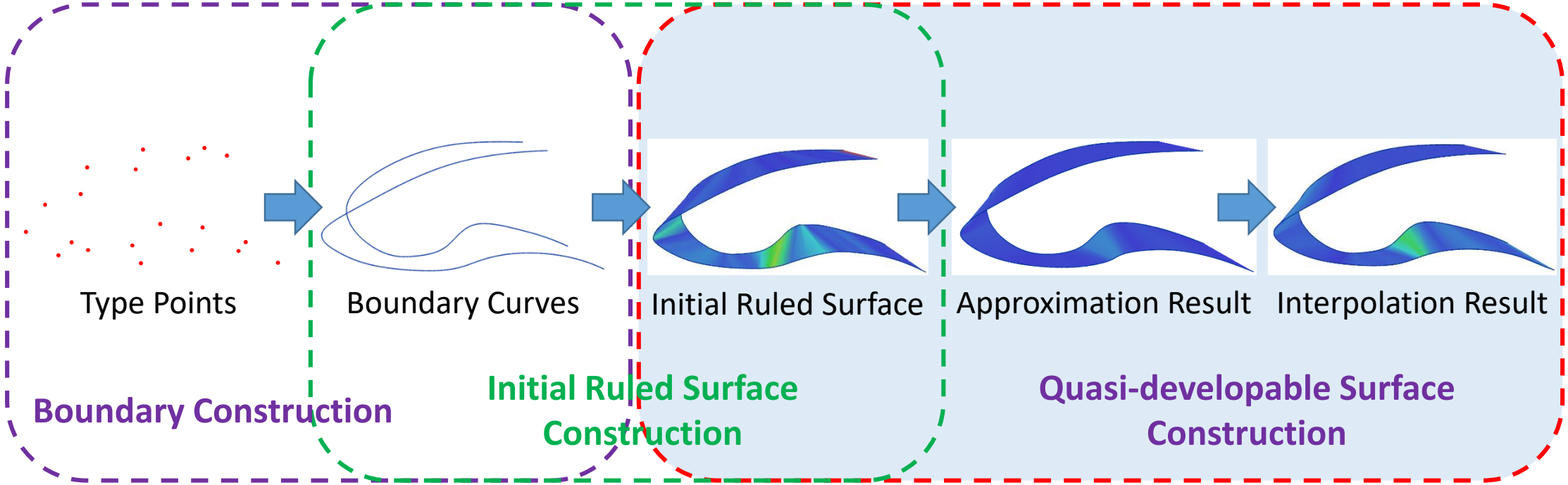
Algorithm Overview



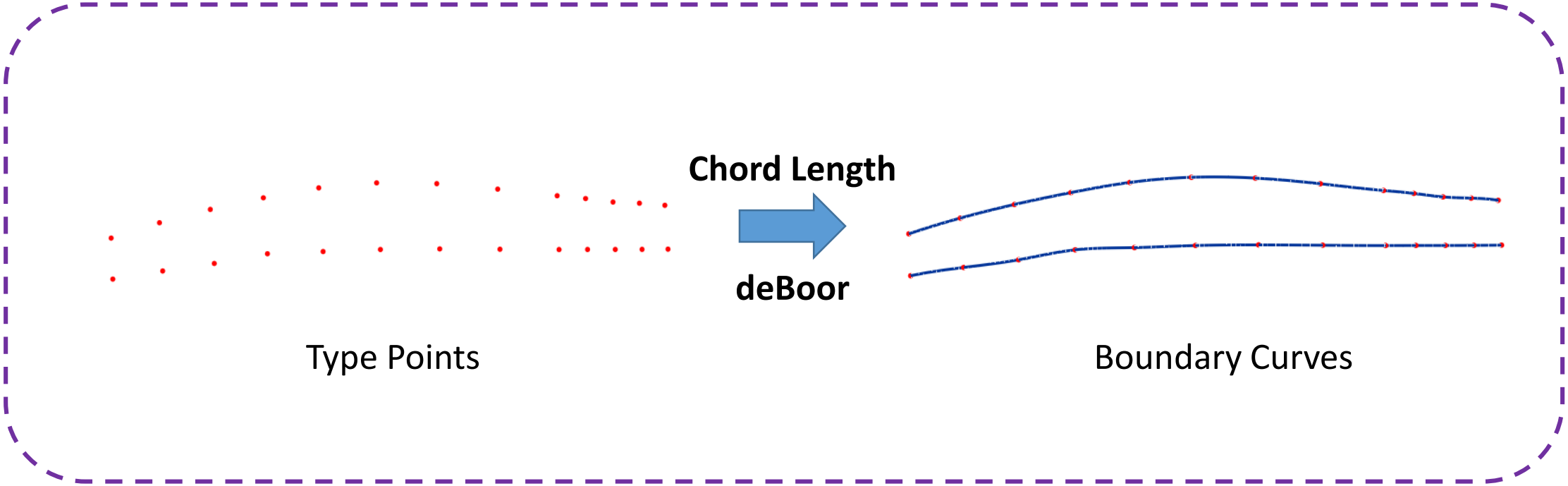
Algorithm Overview



Algorithm Overview

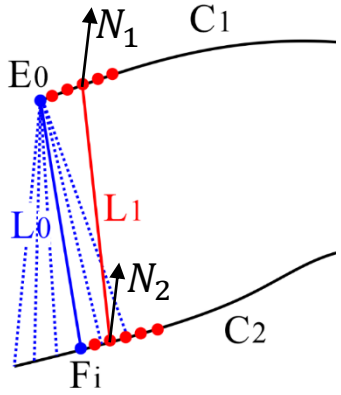


1 Boundary Construction



2 Initial Ruled Surface Construction

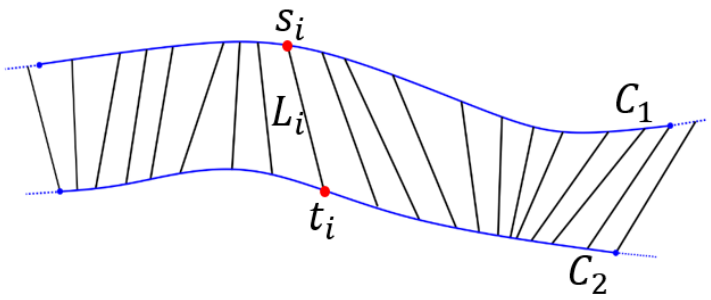
Search Ruling



$\theta(N_1, N_2)$

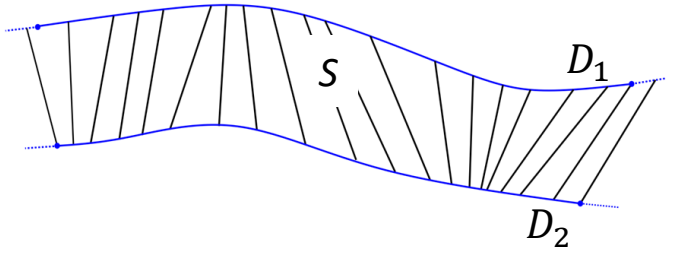
Metal $\leq 6^\circ$ [Rolf et al. 2002]

Compute Interpolation Parameter



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

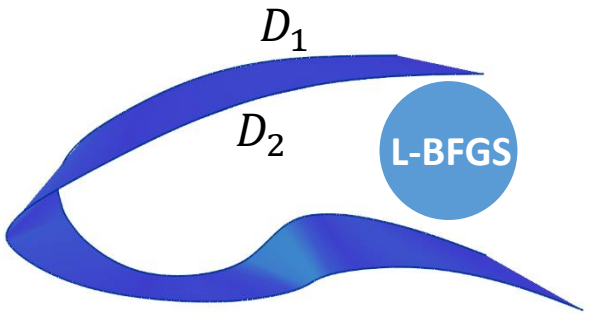
Construct Ruled Surface



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

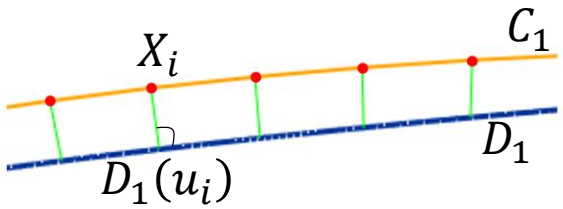
3 Quasi-developable Surface Construction

Optimization



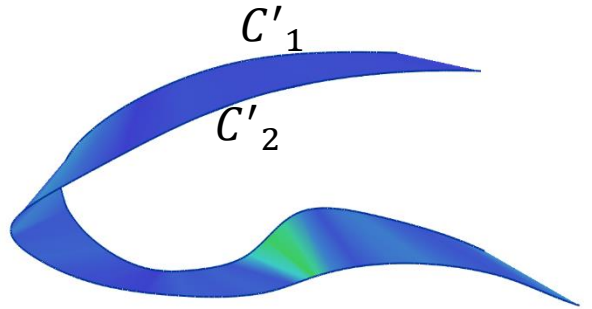
Quasi-developable and Boundary Approximating

Parameterization



u_i as the parameter of X_i

Interpolation



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

Parameterization of boundary curves driven by developability

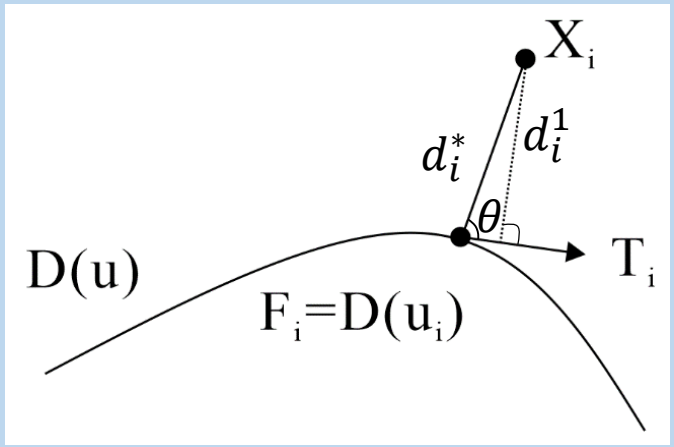
Optimization

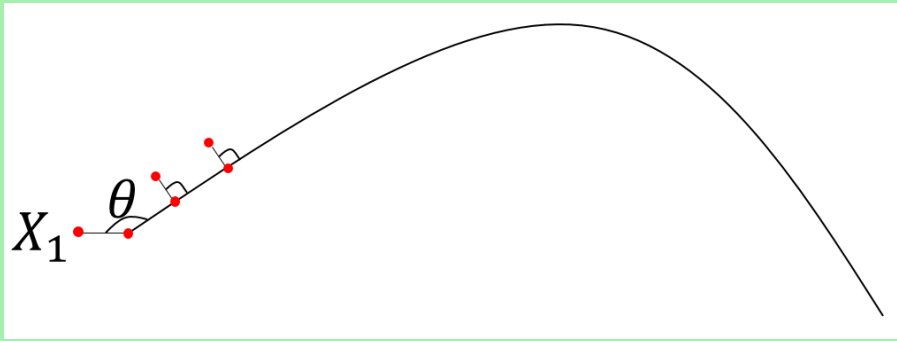
$$\min_{P,N} F_{dist} + \lambda F_{dvlp} + \beta F_{fair} + \gamma F_{regular}$$

L-BFGS

Optimization-Boundary Distance

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



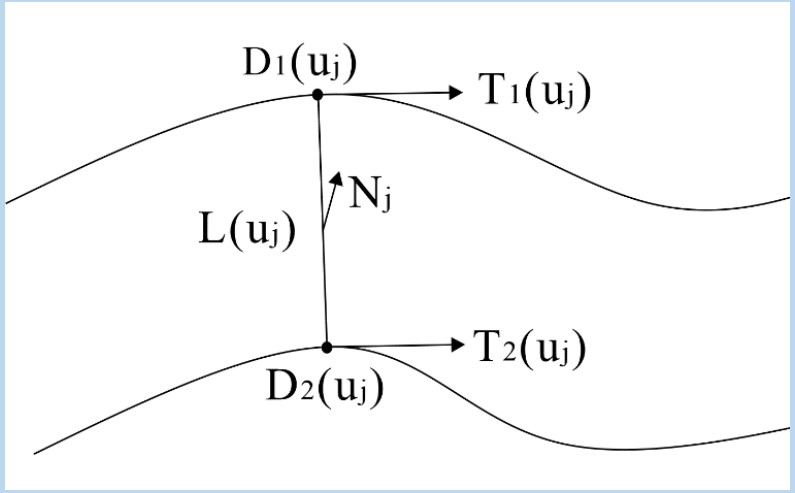


$$\alpha_i = \cos\theta$$

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

Optimization-Developability Constraint

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



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

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

Single complex Constraint

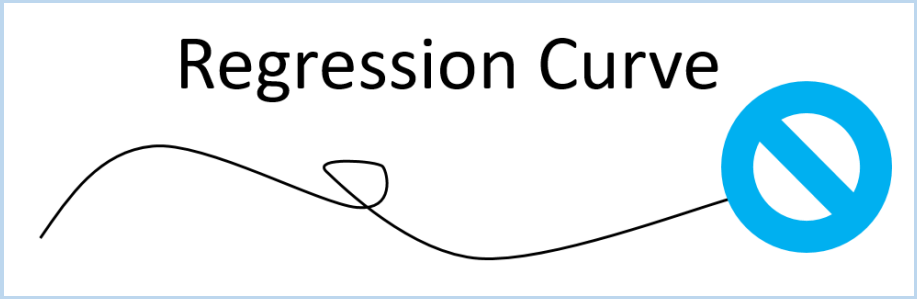
N as variable

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

Multiple simple Constraint

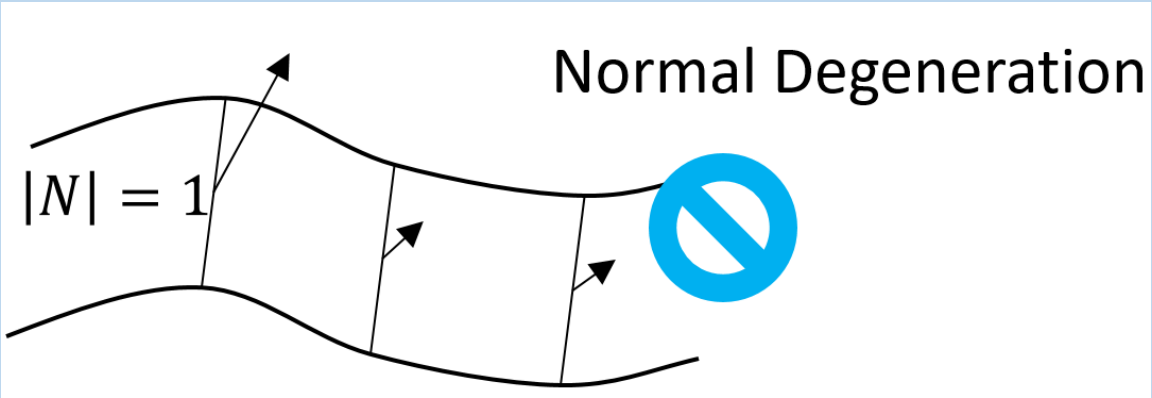
Optimization-Smoothness

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



Optimization-Normal Regular

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



Outline

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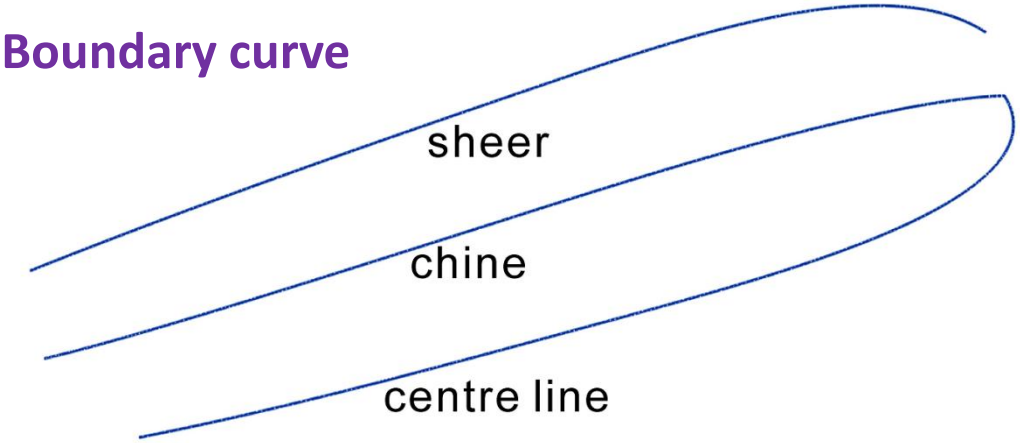
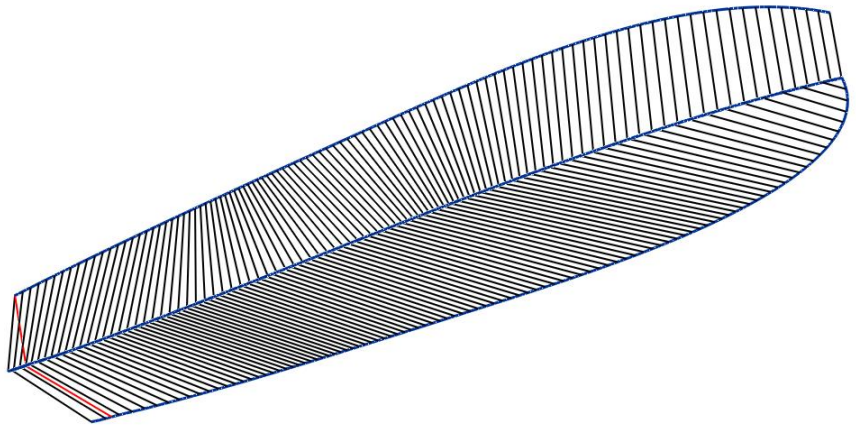
- **Result**
  - Hard Chine
  - UBC Fishing Vessel
- Contribution and Limitation

Result-Hard Chine

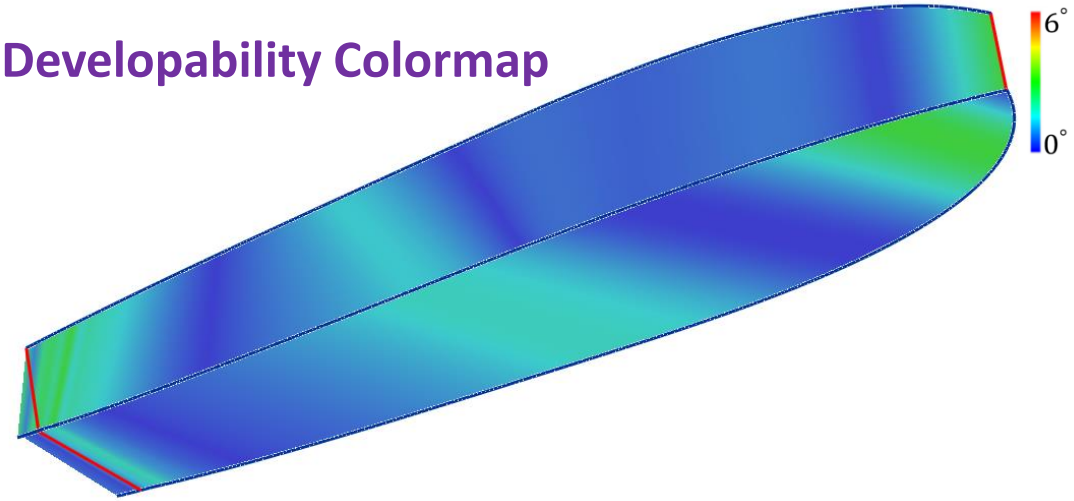
Boundary curve



Rulings



Developability Colormap

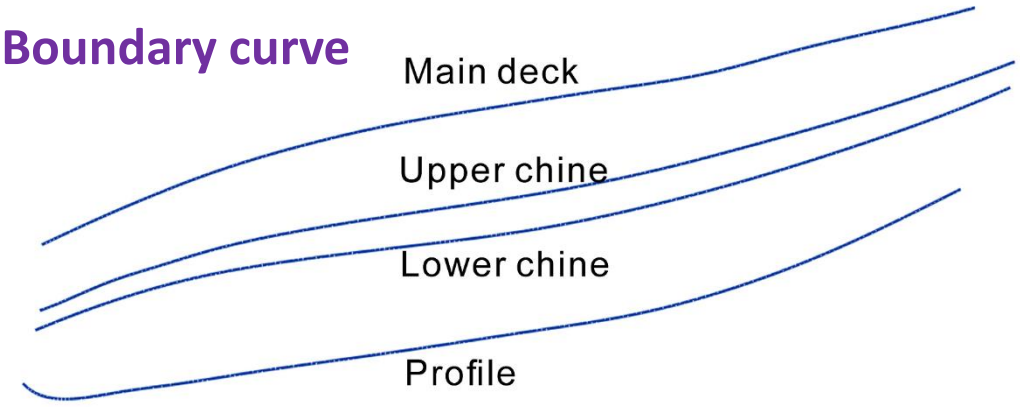


Error

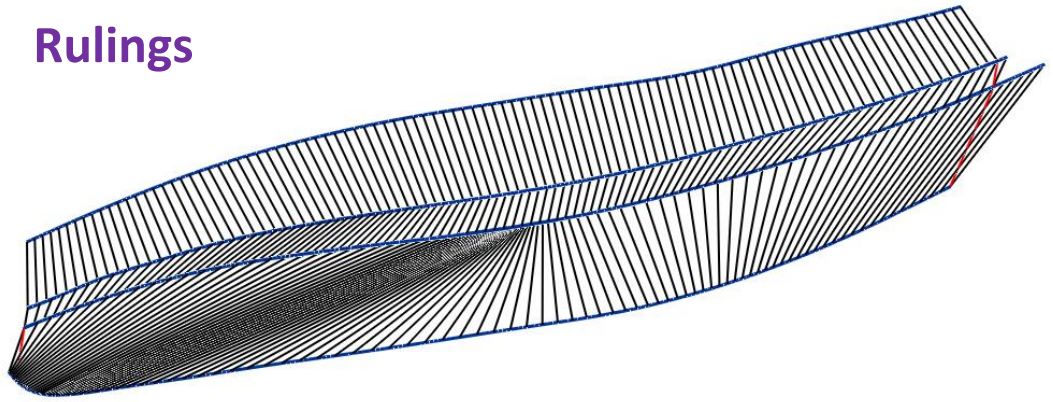
Ave_error	Max_error	Modif_dist
0.45°	3.08°	0.00%

Result-UBC Fishing Vessel

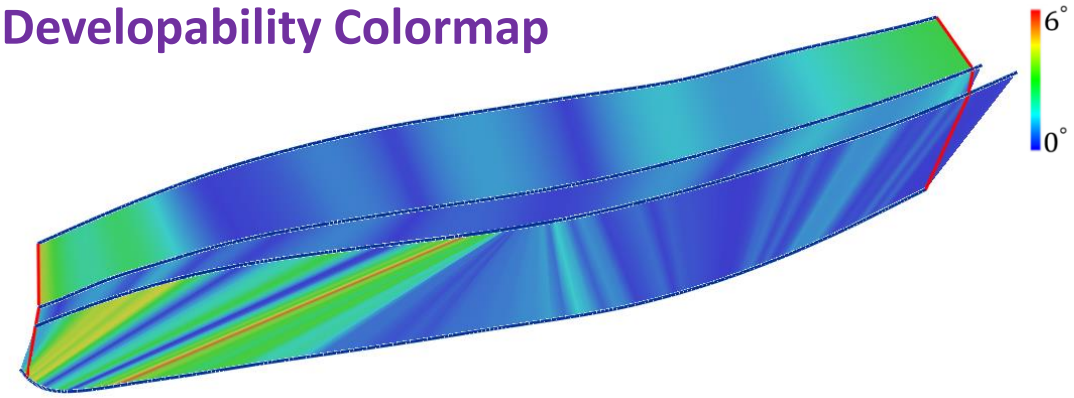
Boundary curve



Rulings



Developability Colormap

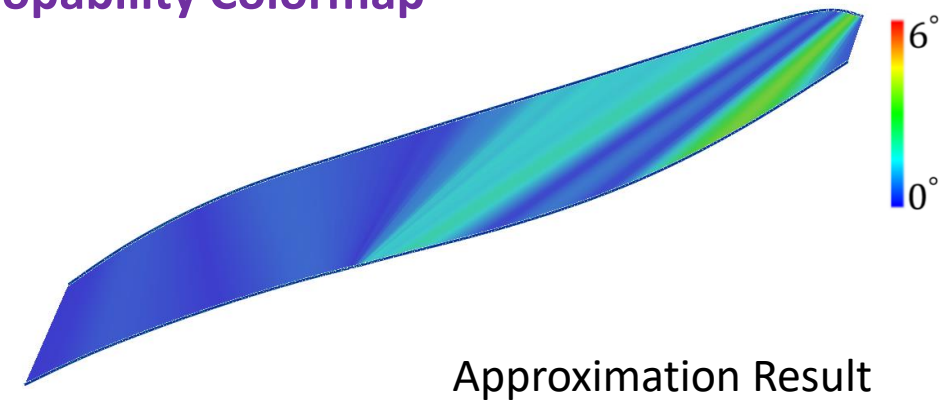


Error

Ave_error	Max_error	Modif_dist
0.52°	5.60°	0.04%

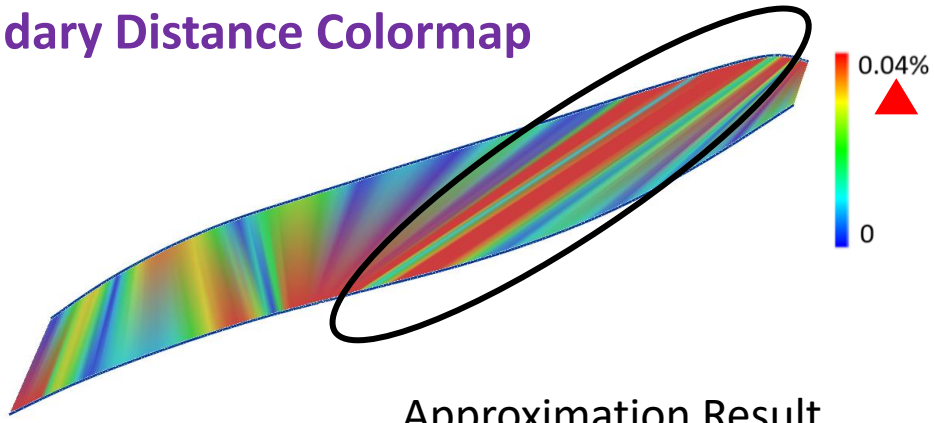
Error Controllable Data Point Modification

Developability Colormap



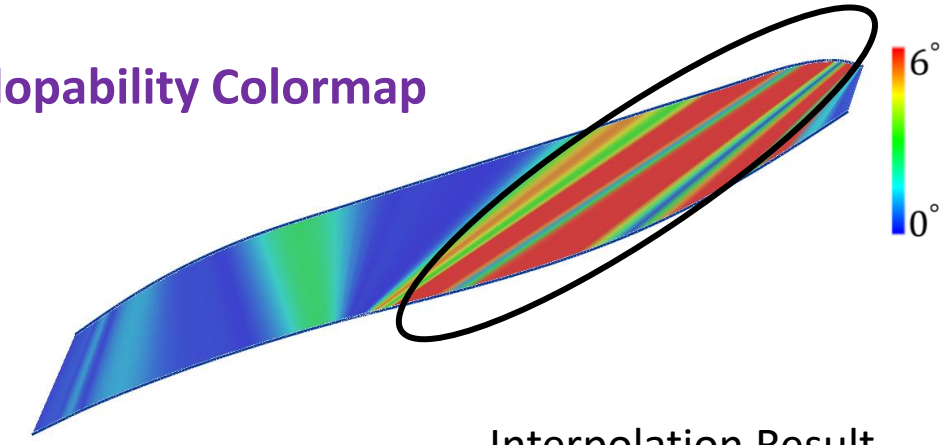
Approximation Result

Boundary Distance Colormap



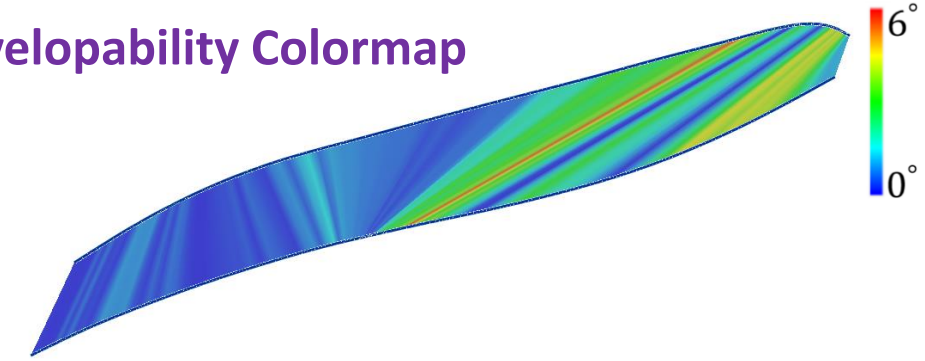
Approximation Result

Developability Colormap



Interpolation Result

Developability Colormap



Interpolation Result after Modification

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- Research Background
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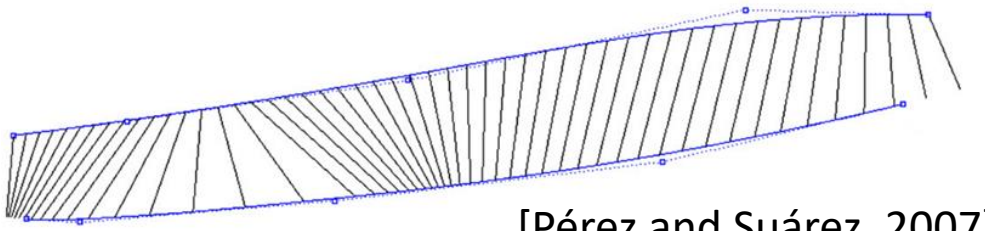
- **Contribution and Limitation**
  - Continuous Mapping
  - Limitation

Continuous Mapping

Finite Rulings

Discrete Mapping

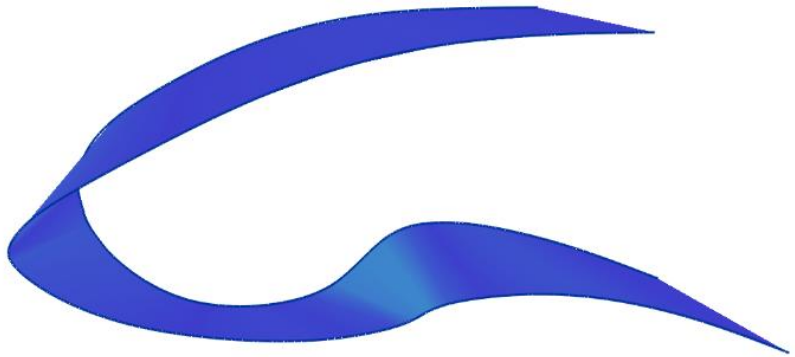


[Pérez and Suárez. 2007]

Traditional

Infinite Rulings

Continuous Mapping



Ours

Limitation

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

Efficiency

Thank you