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

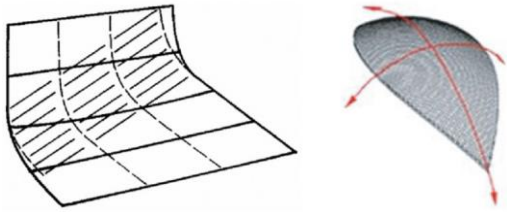郑玉健　　伯彭波

哈尔滨工业大学(威海)

GDC 2017　2017.8.13

Outline

- Research Background
- System Overview
- Algorithm
- Result
- Contribution and Limitation

Outline

- **Research Background**
  - 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]
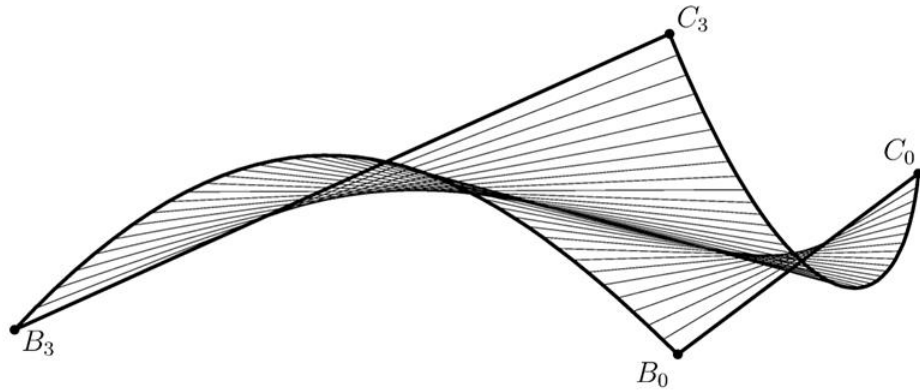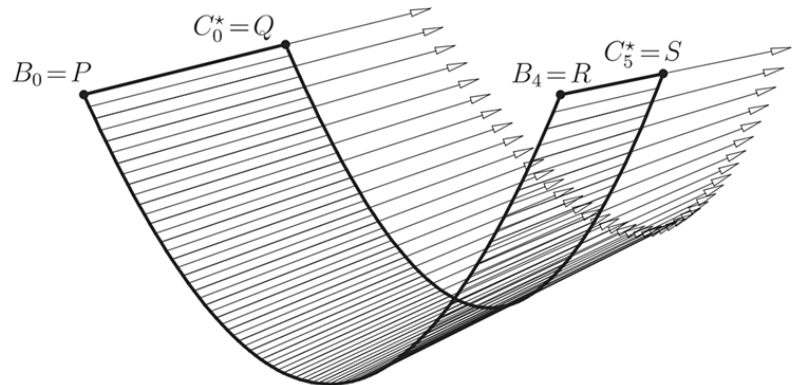

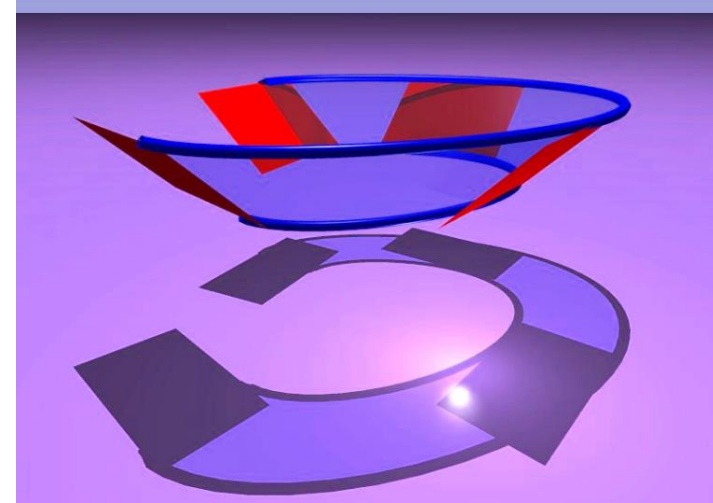Walt Disney Concert Hall
[Jerry's Motel]

[Chen and Tang. 2010]

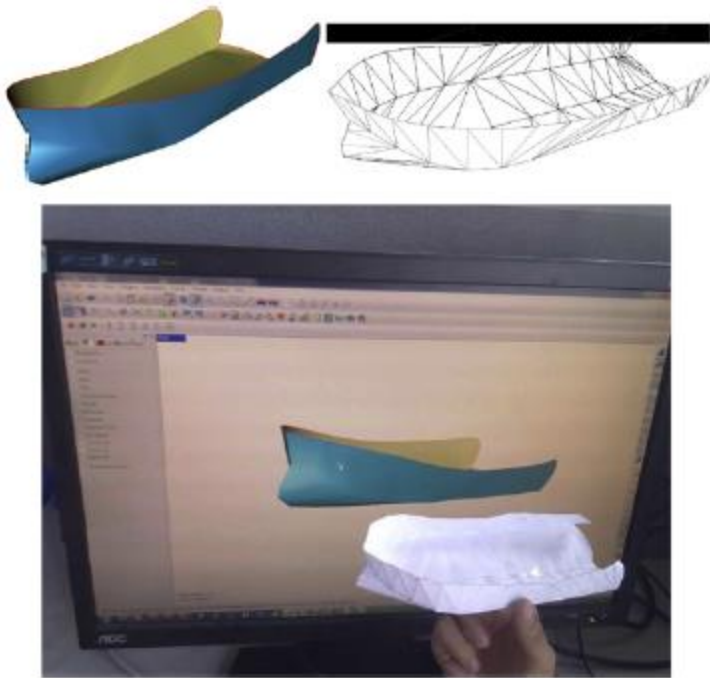# Developable Surface Construction

[Aumann G. 1991]

[Pottmann and Wallner. 1999]

[Aumann G. 2004]
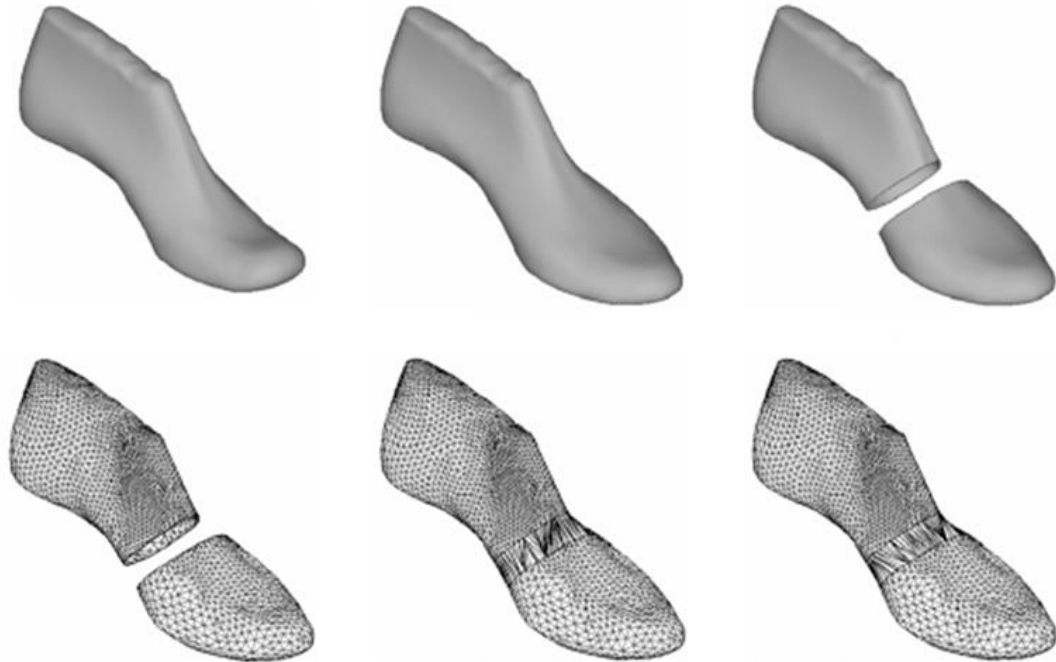

[Tang et al. 2016]

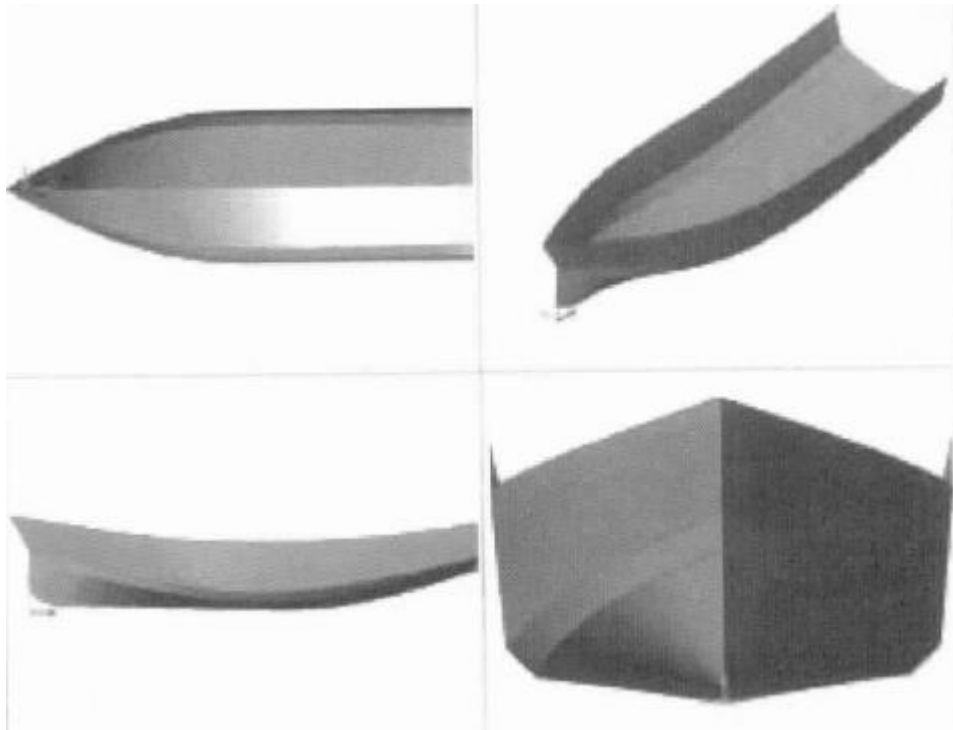# Developable Surface Construction
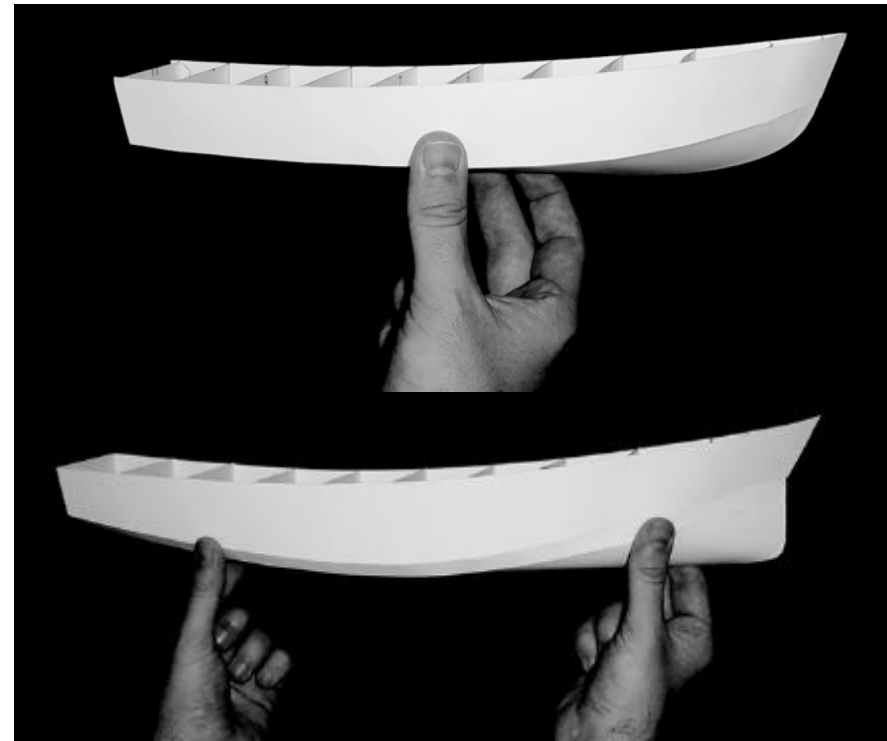

[Liu et al. 2011]

[Chen and Tang. 2013]

[Wang and Tang. 2005]

Developable Surface in Ship Hull Design
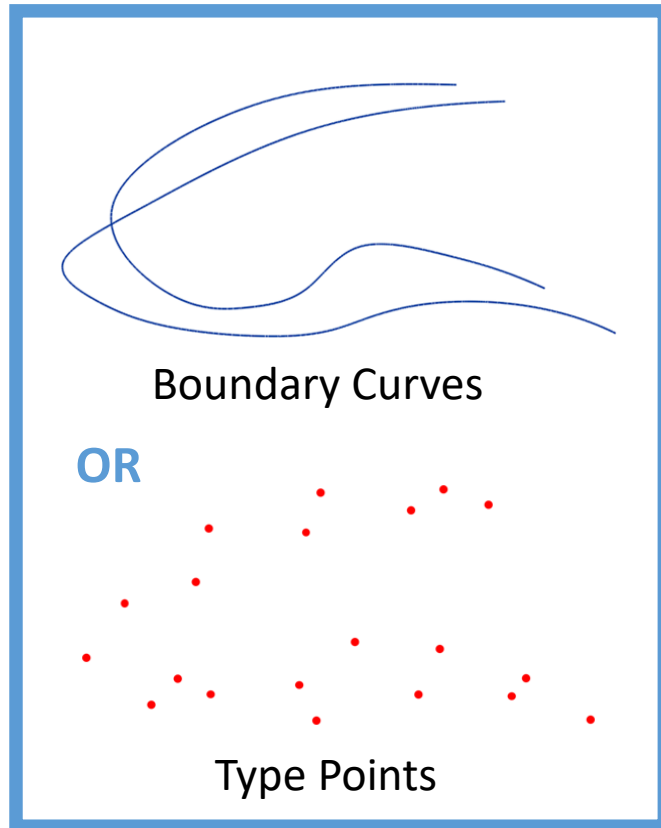

[Konesky B. 2005]

[Pérez and Suárez. 2007]

Outline

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

System Overview

Input

Boundary Curves

OR

Type Points

Output

$D_1(u)$

$D_2(u)$

Quasi-developable Surface

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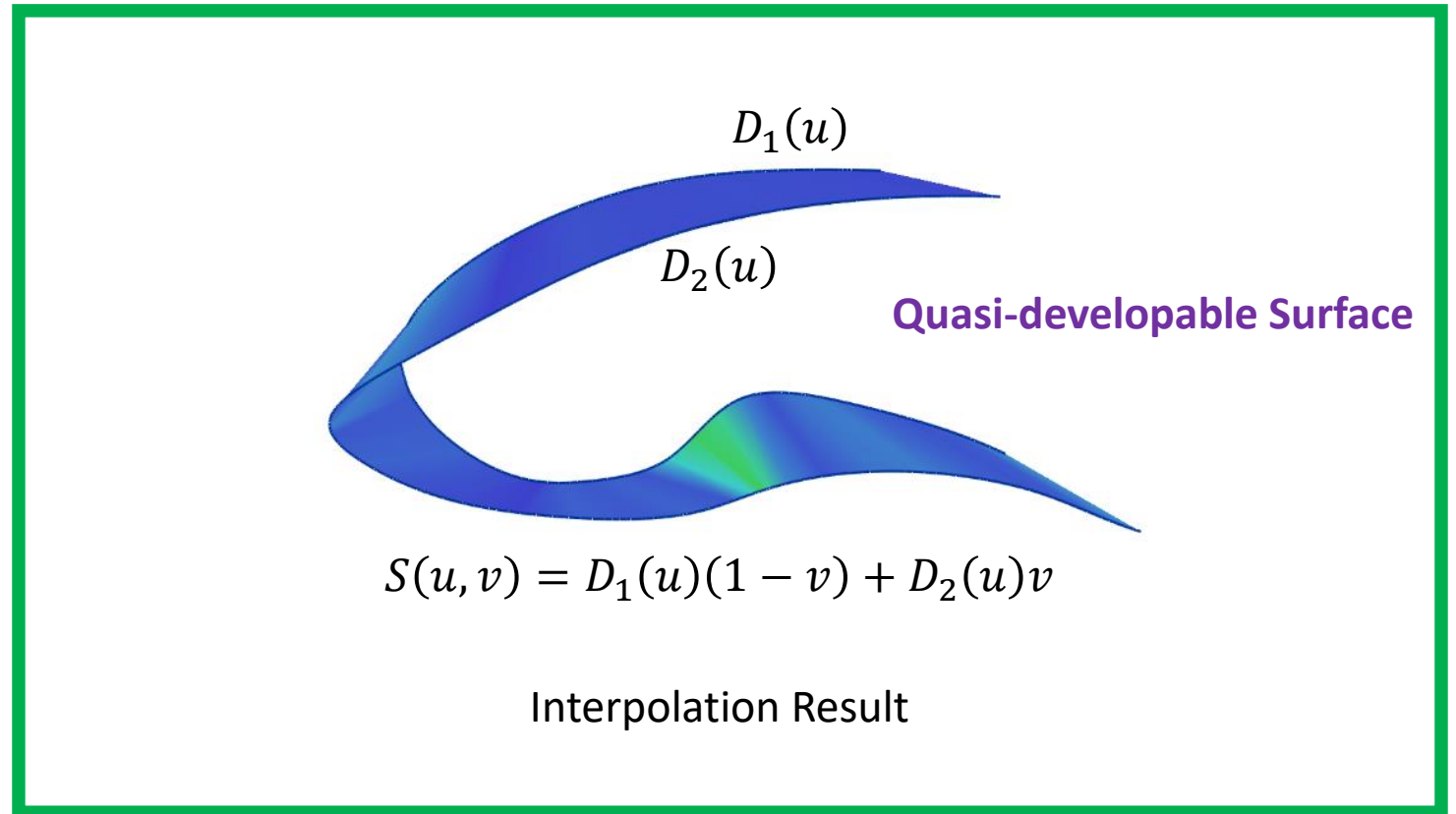
Interpolation Result

Key Idea

How to get good **Parameterization**?

L-BFGS

Optimization

Approximation Result

Parameterization

Interpolation

Interpolation Result
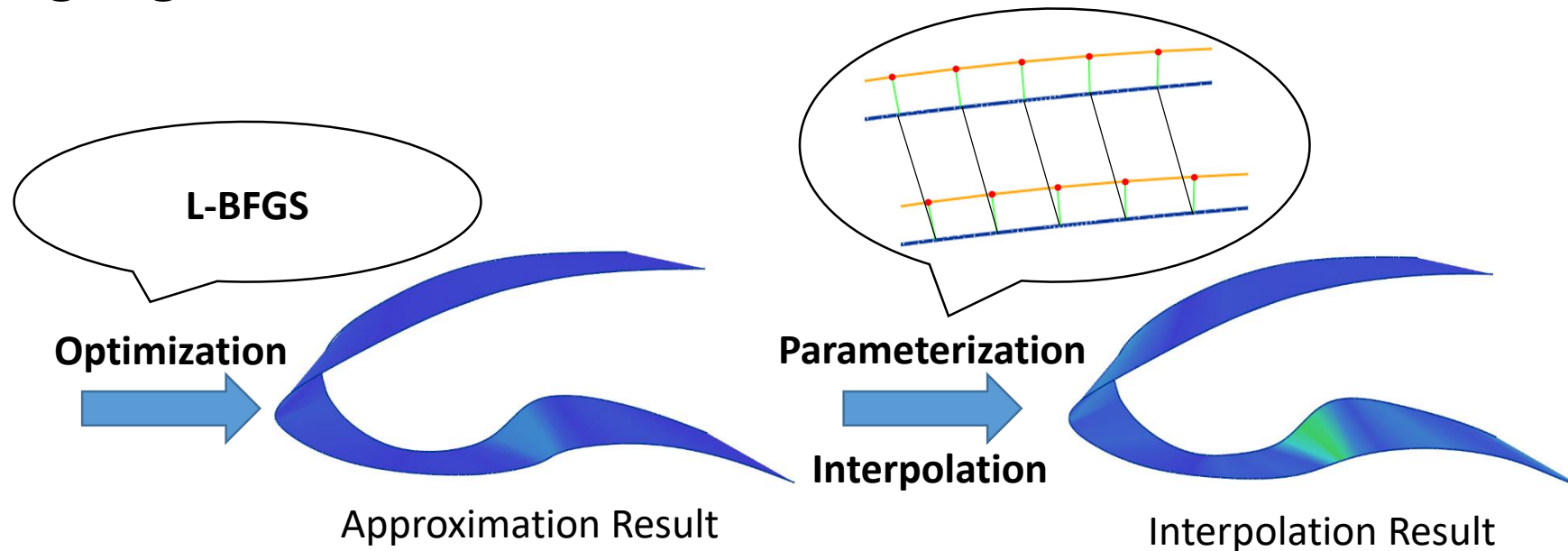
Outline

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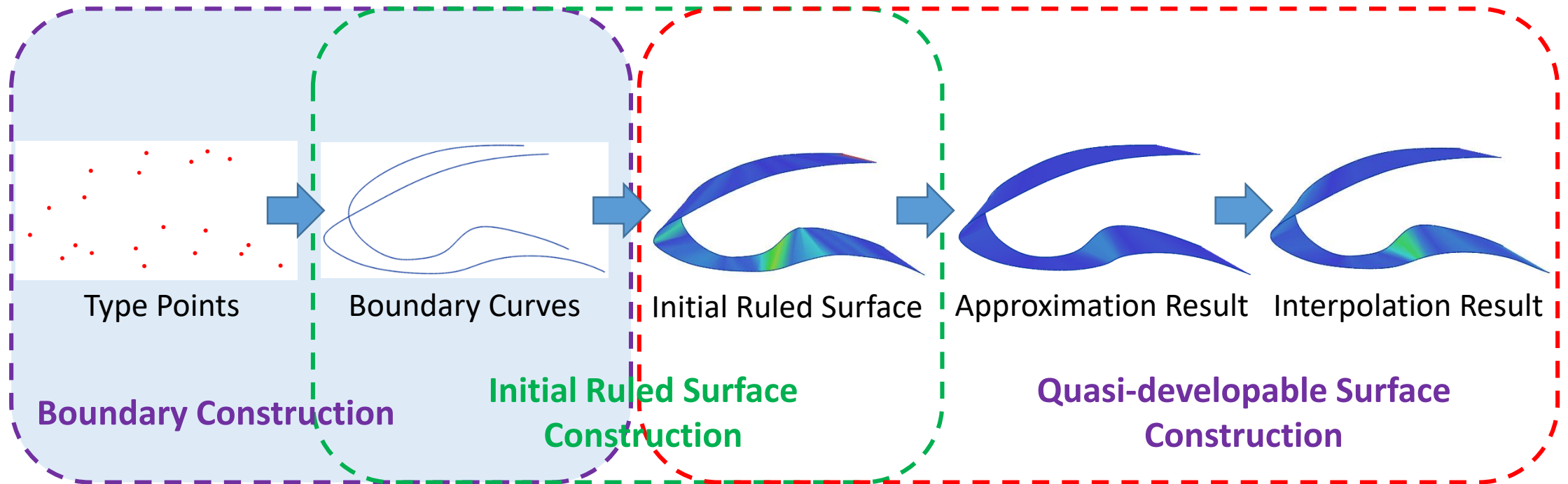- Result
- Contribution and Limitation
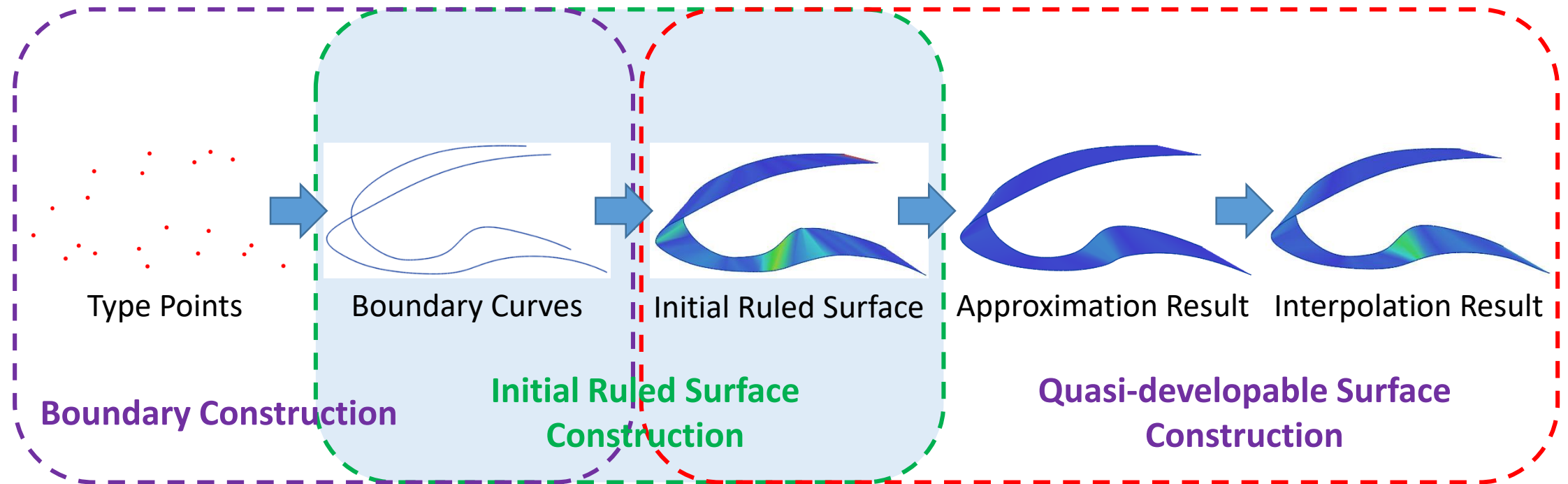
Algorithm Overview

Type Points → Boundary Curves → Initial Ruled Surface → Approximation Result → Interpolation Result

Boundary Construction

Initial Ruled Surface Construction

Quasi-developable Surface Construction

Algorithm Overview

Type Points → Boundary Curves → Initial Ruled Surface → Approximation Result → Interpolation Result

Boundary Construction

Initial Ruled Surface Construction

Quasi-developable Surface Construction

Algorithm Overview

Type Points → Boundary Curves → Initial Ruled Surface → Approximation Result → Interpolation Result

Boundary Construction

Initial Ruled Surface Construction

Quasi-developable Surface Construction

1 Boundary Construction

Type Points → Chord Length / deBoor → Boundary Curves (Cubic B Spline Curve)

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

D_1

D_2

L-BFGS

Quasi-developable and
Boundary Approximating

Parameterization

X_i

C_1

$D_1(u_i)$

D_1

u_i as the parameter of X_i

Interpolation

C'_1

C'_2

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

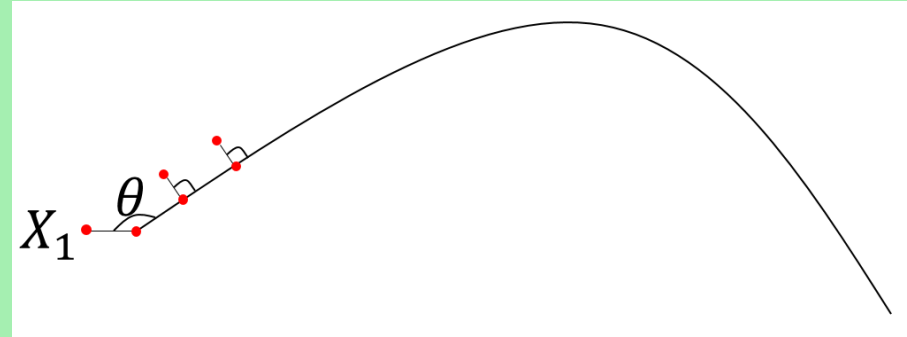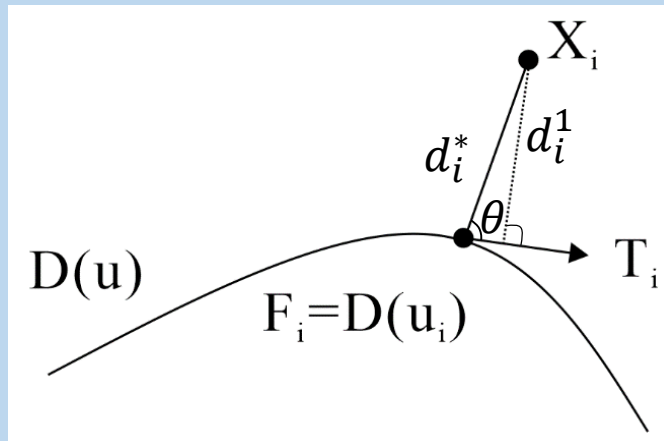**Parameterization of boundary curves driven by developability**

Optimization

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

L-BFGS

Optimization-Boundary Distance

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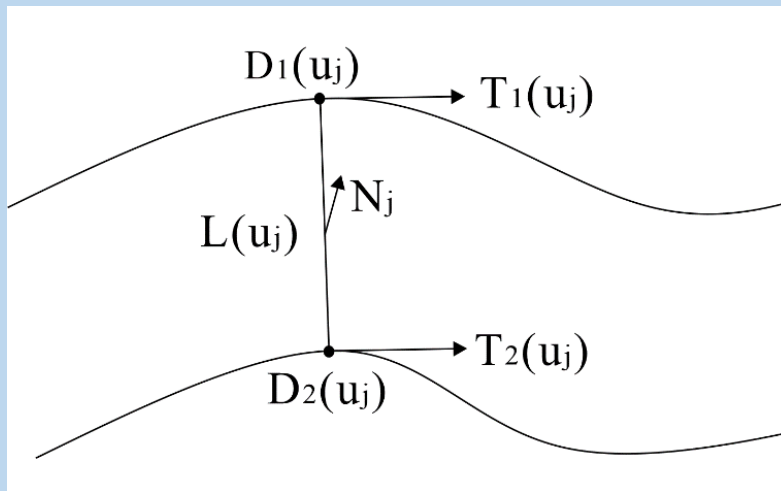

$$\alpha_i = |\cos\theta|$$

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

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
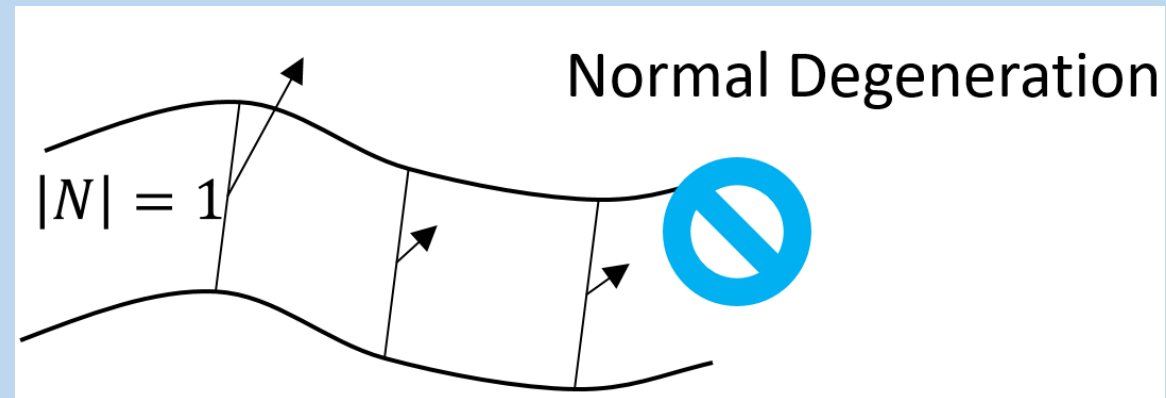
Optimization-Smoothness

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

Regression Curve

Optimization-Normal Regular

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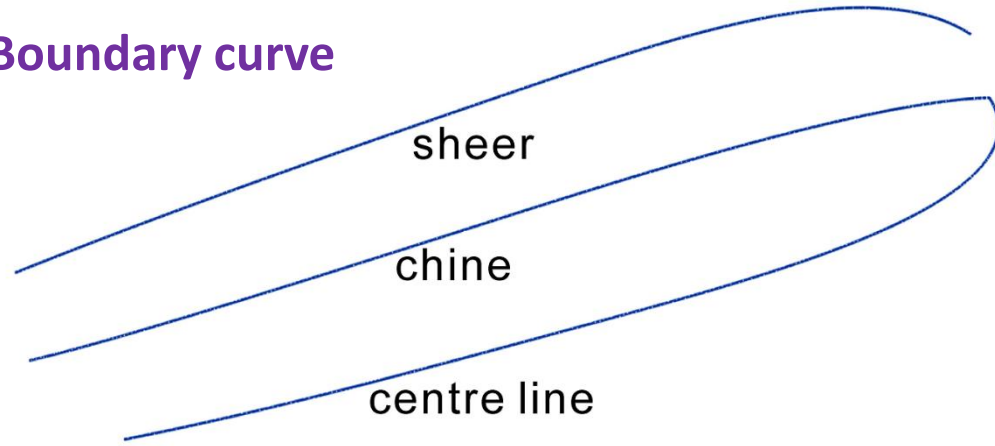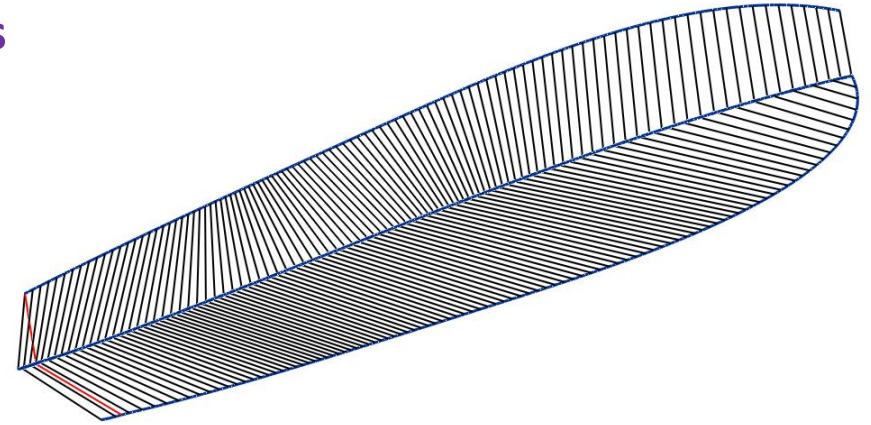
Outline

- Research Background
- System Overview
- Algorithm
- **Result**
  - Hard Chine
  - UBC Fishing Vessel
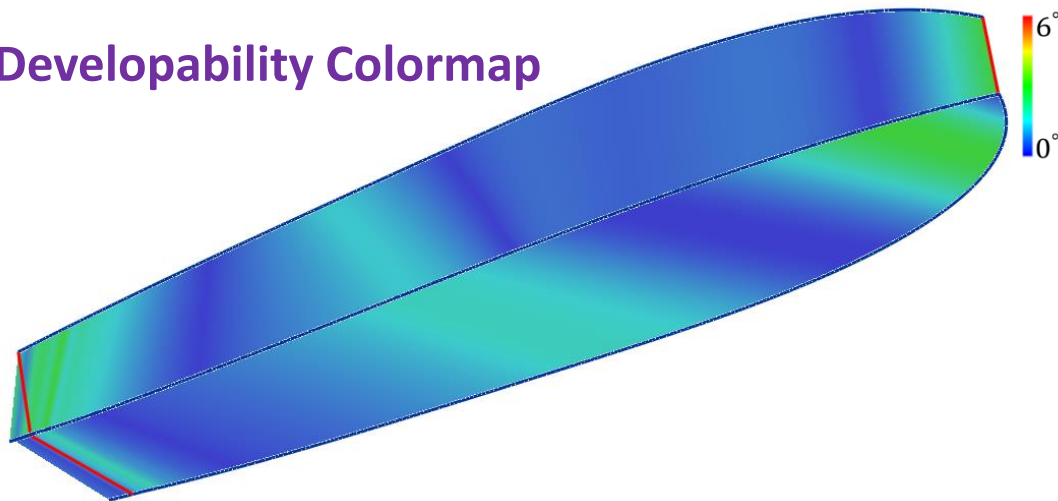- Contribution and Limitation
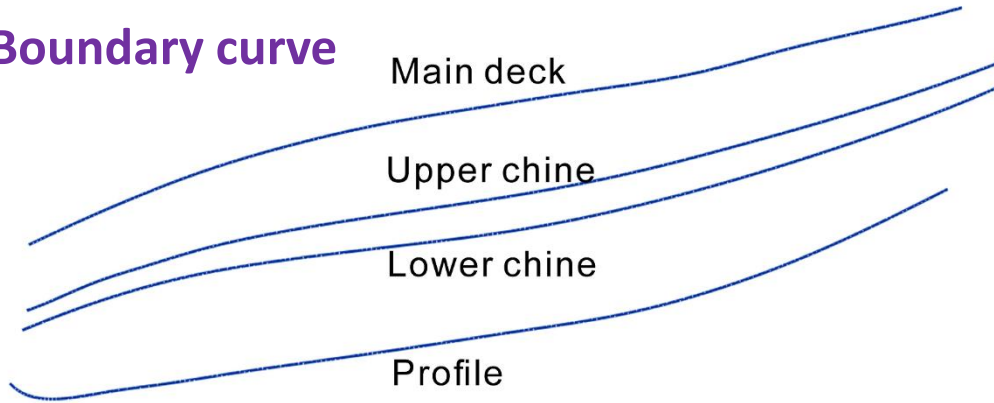
Result-Hard Chine

Boundary curve

sheer

chine

centre line

Rulings

Developability Colormap

6°

0°

Error

Ave_error	Max_error	Modif_dist
0.45°	3.08°	0.00%

Result-UBC Fishing Vessel

Boundary curve

Main deck

Upper chine

Lower chine

Profile

Rulings

Developability Colormap

6°

0°
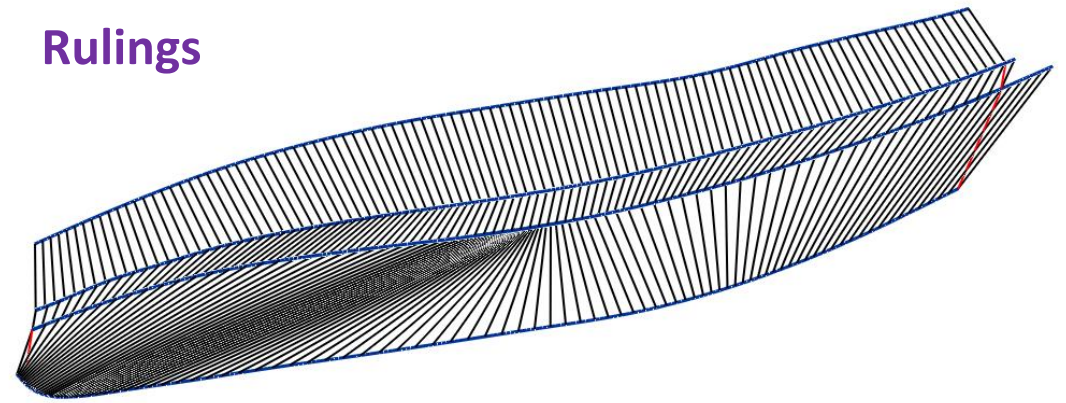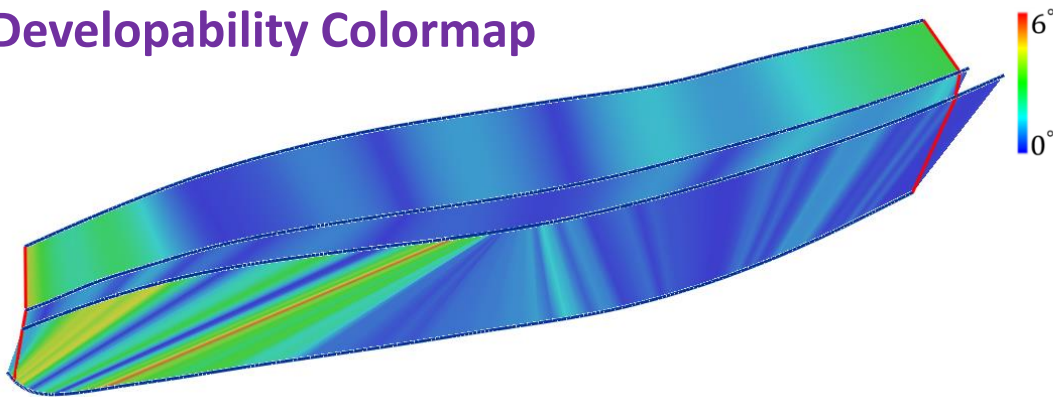
Error

Ave_error	Max_error	Modif_dist
0.52°	5.60°	0.04%

Error Controllable Data Point Modification

Developability Colormap

Approximation Result
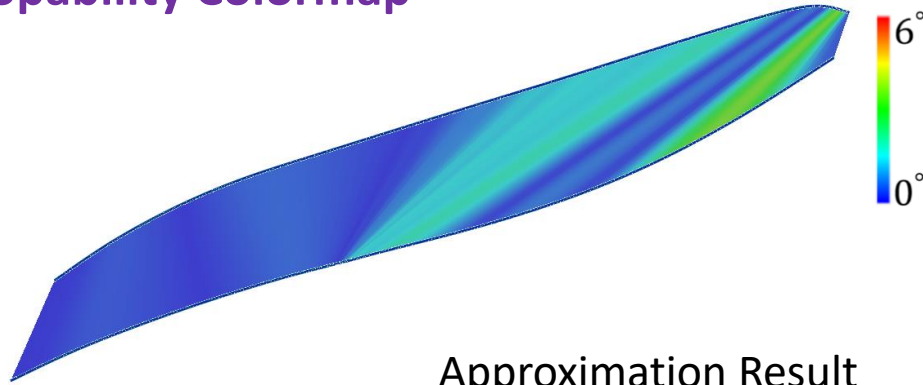
Boundary Distance Colormap
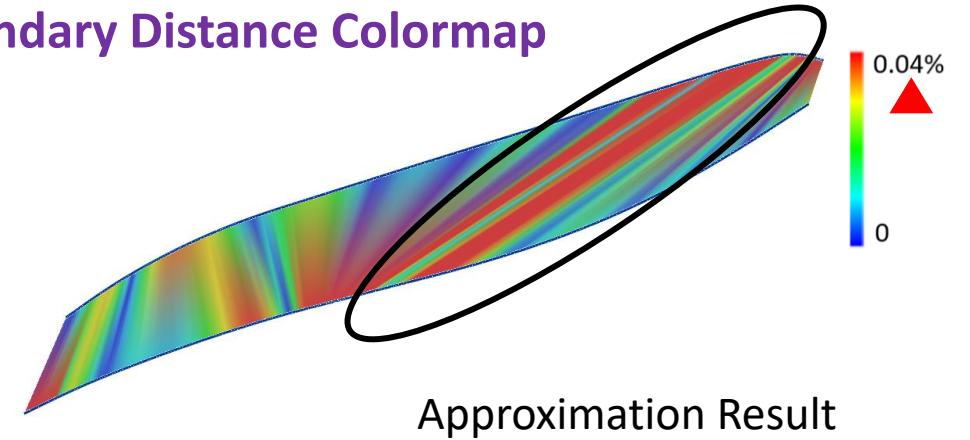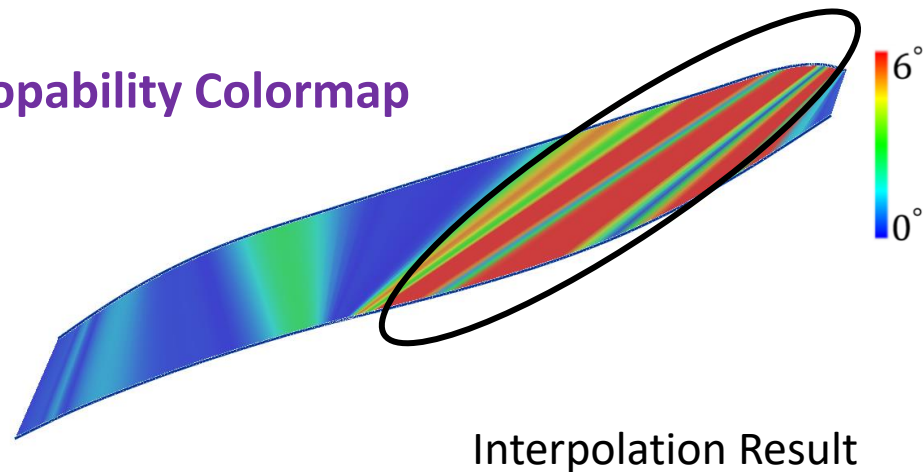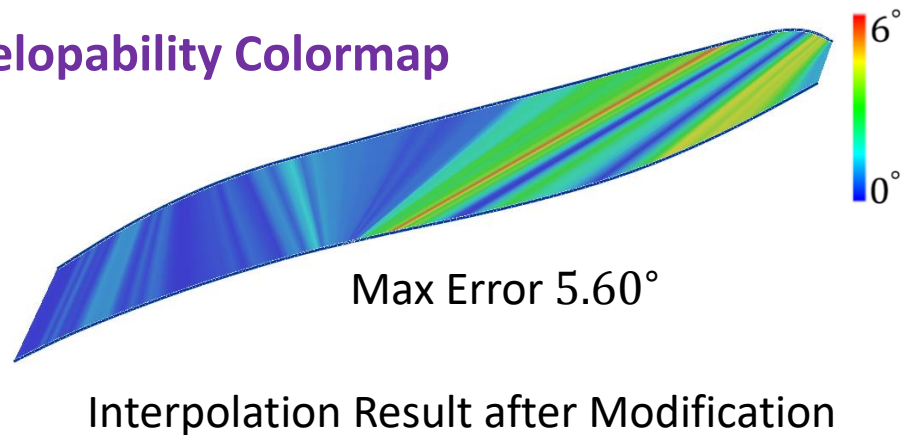
Approximation Result

Developability Colormap

Interpolation Result

Developability Colormap

Max Error 5.60°

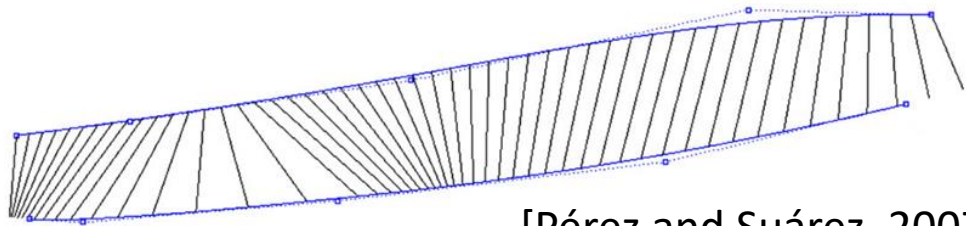Interpolation Result after Modification

Outline

- Research Background
- System Overview
- Algorithm
- Result
- **Contribution and Limitation**
  - Continuous Mapping
  - Limitation

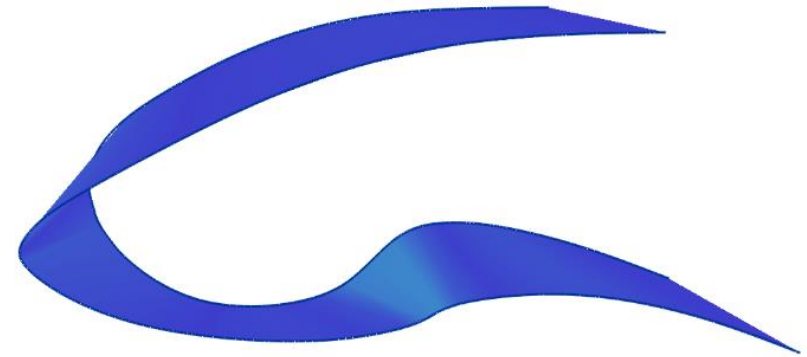# Continuous Mapping

Finite Rulings

Discrete Mapping

Infinite Rulings

Continuous Mapping

[Pérez and Suárez. 2007]

Traditional

Ours

Limitation

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

Efficiency

Thank you