

## NURBS based Ship Form Design Using Adaptive Genetic Algorithm

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### ABSTRACT .

It is studied to design the ship waterline with as few NURBS (Non-Uniform Rational B-Spline) control points as possible, based on the geometric properties of the waterplane. The appropriate multi-objective constrained optimization model is set and an adaptive genetic algorithm (AGA) is applied to solve the optimization problem. The instances of the typical waterlines design for full-scale ship indicate that it is feasible and can satisfy the engineering precision to design the waterline applying this method and the data used for waterline representation can be reduced. So it is expected to design a hull surface with as few data as possible.

**KEY WORDS:** Ship form; waterline; NURBS; control point; weight factor; adaptive genetic algorithm

### INTRODUCTION

Ship form design plays an important role in the ship design. Nowadays, parent transformation method is generally used for ship form design. The designed hull surface inherits all of the virtues and defects of the parent forms and it is difficult to realize design innovation. Waterline is an indispensable element of the ship form. NURBS (Non-Uniform Rational B-Spline), as a powerful mathematic tool, is always used for fitting the waterlines with the given points on them. This method results in the redundant data, leading to overmuch constraints for waterlines tuning and fairing(Jong and Michael, 2000; Lu, Lin and Ji, 2007a). Consequently, it will influence the fairness of the hull surface. In this paper, it is studied to design the waterline with as few NURBS control points as possible, based on the analysis of the geometric properties of the hull waterline. Using the end points of its flat side line, tangent points of the fore and aft arc curves and the tangent vector, the start tangent control point, end tangent control point and form control point are set for the aft and fore free curve respectively. Multi-objective constrained optimization is applied to the solution of this problem. The optimization model is constructed with the weights and the coordinates of the control points as the design variables. One of the objectives is to minimize the difference between the given waterplane area and the designed one, the other is to minimize the difference between the longitudinal centroid of the given waterplane and that of the design one.

An adaptive genetic algorithm (AGA) is applied to solving this optimization problem. And then, a waterline, combined with arc curves, free curves and straight lines, is described with a single NURBS curve function. The instances of the typical waterlines design for full-scale ship indicate that it is feasible and can satisfy the engineering precision to design the waterline applying this method and the data used for waterline representation can be reduced. So it is expected to design a hull surface with as few data as possible.

### DEFINITION AND PROPERTIES OF NURBS CURVE

#### **Definition of B-Spline basis function**

Let  $U = \{u_0, \dots, u_m\}$  be a nondecreasing sequence of real numbers, i.e.,  $u_i \leq u_{i+1}, i = 0, \dots, m-1$ . The  $u_i$  are called knots, and  $U$  is the knot vector. The  $i$ th B-Spline basis function of  $p$ -degree, denoted by  $N_{i,p}(u)$ , is defined as (Piegl and Tiller, 1997)

$$\begin{cases} N_{i,0}(u) = \begin{cases} 1 & \text{if } u_i \leq u \leq u_{i+1} \\ 0 & \text{otherwise} \end{cases} \\ N_{i,p}(u) = \frac{u - u_i}{u_{i+p} - u_i} N_{i,p-1}(u) + \frac{u_{i+p+1} - u}{u_{i+p+1} - u_{i+1}} N_{i+1,p-1}(u) \\ /0 = 0 \end{cases} \quad (1)$$

#### **Definition of NURBS curve**

A  $p$ th-degree NURBS curve is defined by (Piegl and Tiller, 1997)

$$C(u) = \frac{\sum_{i=0}^n N_{i,p}(u) \omega_i P_i}{\sum_{i=0}^n N_{i,p}(u) \omega_i} \quad 0 \leq u \leq 1 \quad (2)$$

Where the  $\{P_i\}$  are control points (forming a control polygon), the  $\{\omega_i\}$  are the weights, and the  $\{N_{i,p}(u)\}$  are the  $p$ th-degree B-Spline basis functions defined on the non-periodic (and non-uniform) knot vector  $\{\underbrace{0, \dots, 0}_{p+1}, u_{p+1}, \dots, u_n, \underbrace{1, \dots, 1}_{p+1}\}$