

Localization for Automated Inspection of Curved Surfaces

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ABSTRACT

This paper deals with localization of curved surfaces, meaning the optimum positioning of a target surface obtained by some manufacturing process with respect to an ideal design surface. The localization problem is formulated as an optimum parameter estimation problem involving rigid body translations and rotations obtained through unconstrained minimization of a distance norm. An iterative localization algorithm has been developed that terminates when the magnitudes of rigid body translations and rotations become smaller than preset threshold values. To reduce the cost of localization for large amounts of data arising in high-precision applications involving free-form surfaces, methods to improve the efficiency of the process based on coherence considerations of the input data are investigated. An example based on actual measured data from a manufactured sculptured surface illustrates our technique.

NOMENCLATURE

$B_{i,M}, B_{i,N}$: B-spline basis functions
 $[C]$: Euclidian transformation matrix
 d : manufacturing tolerance
 $d(P_1, P_2)$: Euclidian distance between two points
 d_{pR} : minimum distance from point R to a parametric surface $p(u, v)$
 $d(p, q)$: maximum distance between two parametric surfaces $p(u, c), q(u, v)$
 e_x, e_y, e_z : unit vectors of an orthonormal Cartesian system
 h_{ij} : weights of the rational B-spline design surface
 m, n : number of control polyhedron vertices of design surface
 M, N : parametric orders of design surface
 p, q : number of control polyhedron vertices of target surface
 P, Q : parametric orders of target surface
 P_{ij} : control polyhedron vertices of design surface
 Q_{ij} : control polyhedron vertices of target surface
 $p_{M,N}(u, v)$: scaled design surface
 $q_{P,Q}(s, t)$: scaled target surface
 $P_{M,N}(u, v)$: design surface
 $Q_{P,Q}(s, t)$: target surface
 r_{ij} : sampled points on target surface after transformation
 R_{ij} : lattice of sampled points on target surface
 s, t : parameters

t : translation vector
 t_x, t_y, t_z : components of translation vector
 u, v : parameters
 U, V : knot vectors
 w_{ij} : weights of target surface
 θ : angle of rotation of target surface with respect to y axis
 ϕ : angle of rotation of target surface with respect to z axis
 ψ : angle of rotation of target surface with respect to x axis

INTRODUCTION

Localization is the process of verification of shape conformance of a manufactured part with a toleranced geometric description of an object. For objects with very high precision requirements, the need exists for accurate localization methods, due to the inaccuracies of physical manufacturing processes. The specific problem addressed is localization of a *target surface* with respect to an ideal *design surface*. The target surface may be represented by either a parametric surface predicted from numerical simulation of a manufacturing process, or by directly measured data from a manufactured surface. The design surface is a rational B-spline surface patch. Applications similar to these arise frequently in marine, aerospace and mechanical engineering problems.

For solution of the problem with high precision addressed in this paper, knowledge of the manufactured surface using parametric equations, or a dense set of measured data points, is needed. In Wierzbicki (1990), methods are suggested to simulate the shape of a thin plate subjected to die-less forming operations using analytic and numerical techniques. In addition, methods for surface reconstruction using a number of data points based on the B-spline representation of surfaces are well-known (Gordon, 1974; Tiller,

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