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A developed algorithm for simulation of blades to reduce the measurement points and time on coordinate measuring machine (CMM)

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ABSTRACT

A 3D Coordinate Measurement Machine Facility (CMM) of the latest technology enables both researchers and industrial manufacturers to evaluate the precision of the different manufacturing techniques that are usually applied for the production of the mechanical component. Especially when the examined component is a blade, due to the geometrical complexity, larger errors can occur during the manufacturing procedure. These errors have a strong impact on the final performance. The high precision measurement with a CMM requires scanning with small steps, which means measuring several points that need long-time measurement.

The aim of this paper is to develop a method for simulating objects by three-dimensional scanning, with a small number of points, while achieving the goal of a certain allowable deviation. The curves used are of a 3rd degree polynomial form.

1. Introduction

Various mathematical models have been presented to represent free surfaces. Most existing algorithms were developed mainly for close approximation of the individual surfaces and then to connect smoothly with the help of NURBS (Non-Uniform Rational B-splines). Also genetic algorithms were developed to optimize the measuring path in Coordinate Measuring Machines (CMM).

The reverse design, although conceptually simple, in practice comprises a plurality of tasks that eventually proved difficult to implement. The Coordinate Measuring Machines (CMM) do not provide clear information on the measured surfaces and the sheer volume of data points from the obtained results is quite time-consuming to process.

Many researchers have directed their effort to solve these problems by trying to determine the number of points to control the path and the movements of the probe on the measured surfaces.

Lin et al. [1] proposed an automated setup sequence of points to be measured, categorizing the verifying data using distances and angles. Then, using a NUBS (cubic non-uniform B-spline) mathematical model fitted to smooth surfaces. In addition to the benchmarks, the parameters of NUBS curves and surfaces, fail to indicate points – nodes that can turn unevenly measured points in smooth curves and surfaces, while maintaining function in the form of local control. Sarkar and Menq [2] developed automated process control measurement points of the surfaces, using the method of least squares [3] for fitting satisfactory points on NURBS surfaces and solid models. In another approach, Gibson and Wang [4] described for the complex surfaces of bone prostheses, after having built the NURBS surfaces from clouds of corresponding points, that the three-dimensional problem is transformed into

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two-dimensional, slicing three-dimensional models and approaches through NURBS levels. In this process equiangular auxiliary levels are placed over the alleged surface of the prosthesis in order to extract two-dimensional features of the surface of the bone. The characteristic curves are further analyzed to find checkpoints describing these curves better. To optimize the measurement path on machine CMM, genetic algorithms are used evenly [5]. Here the problem of optimizing the path of the measuring machine probe is to find the shortest path with the help of genetic algorithms. Additionally, analyzing the choice of parameters, the functional behavior and the problem of early convergence is also of high importance. The basic parameters of a genetic algorithm are the population size or the number of chromosomes, the maximum number of generations and the criteria for adaptation. Another method [6] combines genetic algorithms, a climbing method (Quasi-Newton) and a method for controlling the limits of the variables (Constraints Handling Method) for the automatic joining of two or more point clouds and the acquisition and improvement of electronic geometry of objects a small number of measured points. The combination of these methods aimed partly to exploit the advantages and secondly to avoid their drawbacks. Advantage of genetic algorithms is that they are looking for solutions to the full range of possible solutions and thus not trapped in a local minimum. Even prove efficient when the number of variables is limited and when this number or the total search space of solutions grows shown signs of weakness. The method "climbing" is advantageous to identify local minima even for a large number of variables but directly dependent on the initial assessment of these vectors. The testing method of the variables limits was applied to reduce the space in which to search the solution and thus to speed up the whole process. Lyche and Morken [7] applied a method that reduces the number of nodes of a given B-spline curve, taking into account the allowable tolerance. Ming-Chih and Tai [8] presented a method for preprocessing data points for curve fitting in reverse engineering. This method has been developed to process the measured data points before fitting into a B-spline form. Zachos et al. [9,10] also examined the camber line deformation effect on the performance of the 2-stage experimental axial steam turbine blade based on a high fidelity CMM inspection of the actual geometry.

2. The proposed method

The aim of this paper is to develop a method for simulating objects by three-dimensional scanning, with as small number of points, while achieving the goal of a certain allowable deviation. The curves used are 3rd degree polynomial form, which have four free variables. As data is received the maximum acceptable deviation, is received on *Y* axis, of this curve from the new 3rd degree curve to be created.

The approach with the 3rd degree curves becomes feasible by using the program Matlab. The program takes as input the coordinates (x, y) of n points forming the curve. These coordinates can be drawn having the CAD drawing of the object (Fig. 1a).

The process of approximation n points with coordinates (x_n, y_n) belonging to a level, with the help of 3rd degree polynomials, requires the use of a number of characteristic points of which will pass the polynomial curves. The initial curve is divided into smaller parts that can be accessed satisfactorily by curves of 3rd grade (Fig. 1b).

Initially the first four points are approached by a polynomial curve using the method of least squares (Fig. 1c).

The polynomial equation is of the form:

$$Y(i) = Ax^3(i) + Bx^2(i) + Cx(i) + D \tag{1}$$

A full determination of polynomials, requires the calculation of the four unknown coefficients (A, B, C, D). Since the least squares method minimizes the sum of squared deviations (S), the coefficients are determined differentiating this sum to each parameter and equaling it to zero.

$$S = \sum_{i=1}^{n}\left(y(i) - \left(Ax^3(i) + Bx^2(i) + Cx(i) + D\right)\right)^2 \tag{2}$$

$$\frac{\partial S}{\partial A} = -2\sum_{i=1}^{n}x^3(i)\left(y(i) - \left(Ax^3(i) + Bx^2(i) + Cx(i) + D\right)\right)^2 = 0 \tag{3}$$

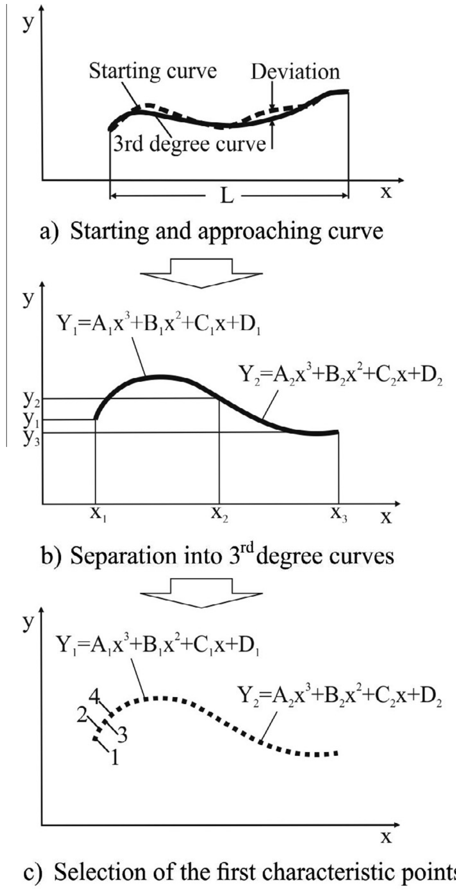

Fig. 1. 3rd Degree curves.