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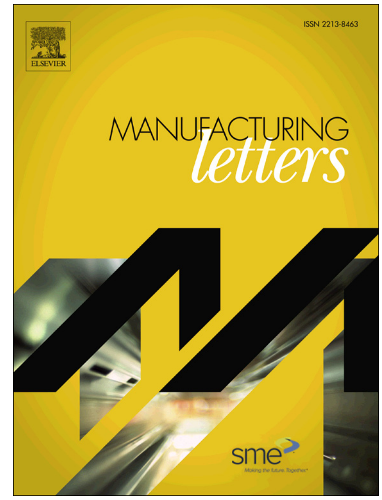

Letters

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Model-Free Subtractive Manufacturing from Computed Tomography Data

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Abstract

Great effort has been put into simplifying model reconstruction and tool path planning for machining in traditional reverse engineering with laser scanning. This paper proposes an alternative to reverse engineering using computed tomography (CT) scanning and voxel models. The new approach eliminates common issues faced in traditional reverse engineering, such as the need for parametric surface reconstruction in order to create toolpaths for a computer numerical control (CNC) machine tool. Successful duplication of a machined part with this new method demonstrates great potential for voxel models generated from CT data in reverse engineering applications.

Keywords: computed tomography, reverse engineering, voxel, machining, CNC

1. Introduction and Background

Reverse engineering has become a widely used practice in manufacturing, as it allows for duplication of parts without original design data in terms of computer-aided design (CAD) and product manufacturing information (PMI) [1,2]. Reverse engineering is composed of three general steps: sampling objects for digitization; reconstruction of geometry of objects with computation; and fabrication of the physical objects with additive or subtractive manufacturing processes [3]. Traditional reverse engineering often uses point cloud data, which can be processed to reconstruct triangulated surfaces that can then be parameterized with curve fitting algorithms [4]. Despite significant progress achieved in this domain, the approach has a number of drawbacks such as surface approximation errors, sparse point cloud sampling, and the expert-level manual interaction with the processing software to achieve acceptable results [4,5].

The present work explores a processing concept based on model-free manufacturing (MFM) wherein a part can be manufactured without a reconstructed CAD model. The elimination of an analytical geometry based CAD model removes the need for feature approximation or excess manual input. To facilitate this MFM concept, a voxel-based discretized data structure, referred to as a hybrid dynamic tree (HDT), is proposed as an alternative geometric representation. Voxels are the three-dimensional equivalent of pixels that represent discretized volumes [6]. Voxel models are advantageous over analytical volumetric representations as the unit-level voxels are capable of representing geometry of any complexity [7]. Furthermore, voxel model reconstruction does not require calculated regressions to fit parametric curves. An HDT structure employs dense grids at the root and the leaves with traditional octrees in between [8]. The root and leaf grids in HDT are tunable variables that offers the ability to control effective resolution of the voxel representation without trading off memory storage sparsity [9].