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New feature extraction and processing methods for the advanced knowledge based process planning of forming operations

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Abstract

A new method for the automated extraction, recognition and interpretation of forming features is presented. The motivation is to apply knowledge based engineering (KBE) methods more intensively on process planning procedures for forging, tube hydroforming and sheet metal forming. With a new thinning method three-dimensional (3D) CAD data is reduced to a 1D skeleton graph. By curvature based segmentation of the surface and the neighborhood relations further information are provided. Depending on the gained classification, analyzing algorithms can be performed again with an adapted level of detail. Herewith the process planning can be supported on a much higher level than before.

Keywords: Feature extraction; Knowledge based engineering; Process planning; Forming operations; Forging; Tube hydroforming; Sheet metal forming

1. Introduction

To be competitive within a global market, all processes in a product life cycle should be economically optimized. Besides the production and distribution of physical goods, the product development as a knowledge working aspect has an important impact on the costs. Experience shows us that approximately 80 % of the whole product costs are defined in the early stages of design and engineering [1], making this phase of product life cycle to one with the largest optimization potential.

Even if resource efficiency today is more important than ever, a rational way of engineering has always played a role. Therefore parts and their geometries have been classified by special characteristic lists to be able to systematically re-use the already done knowledge work and the multiple gained experiences [2-3]. After decades of using such fixed classification systems the computerization of the work was a further step leading to the age of computer integrated manufacturing (CIM). Today the usage of modern computer aided design (CAD) systems, finite element analysis (FEA) tools and other software is an essential part of research and development processes.

Knowledge based engineering (KBE) is the latest development in that field which uses features to support the daily engineering work. Three ways of feature usage are known, design by features, feature mapping by user interaction and feature recognition [4] - the most sophisticated approach. Compared to automated engineering processes for machined parts which focus mainly on the removal of stock, the automatic extraction of forming features is much more ambitious.

The following sections of this paper aim at the explanation of the different geometry processing methods for bulk and sheet metal parts and shall demonstrate their potential in future manufacturing process planning.

2. New methods and algorithms for feature recognition

The main driver for developing new methods and algorithms for feature recognition is to use features more

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intensively for several purposes in the field of process planning of forming operations such as bulk and sheet metal forming. Therefore it was necessary to find a way to automatically extract and recognize their geometric characteristics. An analysis of the state of the art resulted in a comparison of the digital way of geometric computation and the human way of interpreting the geometry of objects. One finding is that the visual intelligence of humans compares objects by reducing them to some kind of a skeleton. A second finding is that recognition is done with an increasing level of detail from a rough to a fine resolution. This top down strategy will be used in the presented approach too.

2.1. Extracting a skeleton by thinning

There are several methods known that extract skeletons. A common method is the medial axis transformation (MAT), whose drawback is the sensitivity to small changes on the geometry as it is shown in Fig. 1.

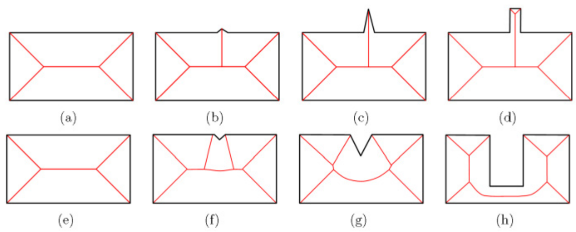

Fig. 1. Medial axis transformation and the sensitivity to small changes on geometry resulting in different graphs

The MAT of a three-dimensional (3D) object produces (except for cylindrical parts) 2D medial surfaces. Due to their complex shape and interconnectivity, it is difficult to interpret the original object on this basis.

Compelling reasons for the usage of the here proposed alternative thinning method “divergence based parallel thinning” are:

- reducing 3D-modells to an 1D skeleton and
- robustness to small geometrical changes.

We implemented a parallel thinning approach, which is directed by a divergence scalar value (per voxel). This divergence is computed by using the gradient vector flow (of distance values) and allows to extract 1D skeletons from geometries where other approaches fail [5]. Fig. 2 shows different voxel resolutions of a CAD model to demonstrate their different looks, depending on the available computing speed. By choosing the right orientation and other parameters the resulting skeleton can be influenced. After determining the first voxel based skeleton, several post processing steps have to be done (a-f) to get a proper skeleton (Fig.3).

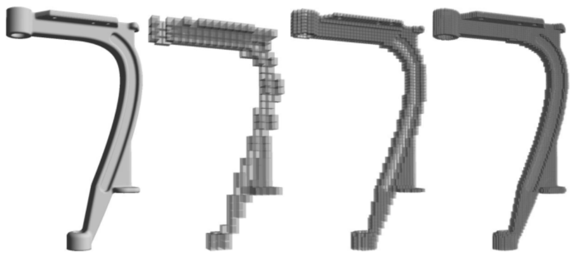

Fig. 2. CAD-model and different resolution of voxel discretization (300, 3.000 and 30.000 voxel)

a. Compute Voxel skeleton by thinning
b. Convert to graph-based skeleton
c. Recognize and split junctions
d. Prune remaining skeleton branches to increase stability
e. Recognize and correct straight branches
f. Smooth branches to remove discretization artifacts

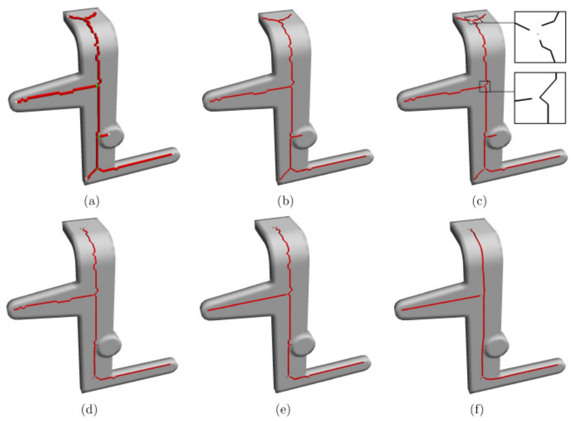

Fig. 3. Steps for extracting and post processing of skeletons

2.2. Curvature and histogram based segmentation of surfaces

On geometries without volume, such as sheet metal forming parts, the proposed method for extracting a skeleton is not applicable nor would a skeleton be significant for the desired analysis. Thus, we propose a novel segmentation approach which will be presented in detail in a separate publication. The main idea is to utilize a histogram of the principal curvature values to identify and segment characteristic parts of the geometry.

Fig. 4 shows a T-shaped “hat” geometry that is common for automobile parts and its 2D histogram of the curvature values. The clusters identified in the histogram describe the highlighted chamfers. We found that reducing the mesh by these segments and re-estimating the curvature significantly improves the analysis of the remaining mesh. This segmentation step