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Cost estimation for sheet metal parts using multiple regression and artificial neural networks: A case study

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Abstract

Increasing competition in sheet metal operations has urged those companies to search for tools that generate accurate cost estimates within a short time period. The requirement for on-line generation implies that the underlying cost estimate needs to be generated without extensive process planning first. Analysis has been conducted on developing a less-detailed method, based on a brief analysis of the CAD-file. Cost formulas are composed by applying regression techniques and neural networks. A case study is used to compare both methods. The results obtained indicate that neural networks give better results but are still mainly considered black boxes.

Keywords: Cost estimation; Sheet metal; Regression analysis; Neural networks

1. Introduction

Cost estimation is a field which over the years has received much attention from manufacturing engineers. In an ideal situation all necessary cost information is present, allowing to calculate the costs accurately. For sheet metal parts, this information comes from the process plan, typically comprising the geometrical details of the part, the different production steps, the processes to use, the process' parameters, the tolerances and other relevant data. Generating such process plan requires a substantial amount of time. However, the customer expects a price quotation almost instantaneously so it cannot be justified to generate a process plan for every possible order. Since process-planning-based methods are too time consuming, other fast yet accurate methods are required.

This paper discusses the results of a case study conducted in two sheet metal companies to verify whether accurate estimates can be generated without process planning and within an acceptable time span. The cost estimate is generated by mainly considering geometrical aspects: all necessary data comes from the CAD-file of the part or from a simple sketch. The paper has 6 sections and is divided as follows. Section 2 discusses the importance of cost estimation in manufacturing environments and elaborates on the main cost estimation approaches. Section 3 addresses the techniques most commonly applied: multiple regression and artificial neural networks (ANNs). Design issues, advantages and disadvantages are mentioned. Section 4

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discusses the case study conducted and Section 5 summarizes the results obtained. The Section 6 concludes this paper.

2. The importance of cost calculation and cost estimation

Sheet metal companies take, due to the competitive nature of the market, different measures to distinguish themselves from their competitors. Offering customized, high quality, products at the lowest price possible is the ultimate target in order to survive. In order to set the price as competitive as possible, the cost needs to be known. After manufacturing a product, detailed information can be collected and used to determine the cost of the end product by means of after-calculation. However, quite often an estimate of the production cost is required, prior to the actual production of that part. The cost thus needs to be estimated within a specified accuracy range, although all necessary detailed information is not present yet. To overcome this lack of detailed information, cost-estimation techniques are used to approximate the cost within a certain accuracy range. In literature, different cost estimation techniques can be found, resulting in three main approaches (Wierda, 1990).

- *Variant-based cost estimation*: the cost estimate for a product is based on the actual cost of similar products manufactured before. Deciding upon the degree of similarity is not that straightforward and rather subjective, hence sensitive to mistakes. Part coding is the main approach for converting the parts' features into numerical properties to be used for the clustering procedure. Throughout past decades, many classification systems have been developed. Most of those systems are intended for general application, but some have been developed for specific operations such as forging, casting etc. Although many different codes exist, it is generally assumed that no universal method exists for classifying and coding parts (Gallagher and Knight, 1986).
- *Generative cost estimation*: the cost is estimated in an analytical way based on a detailed analysis of the different production processes. For each distinct process the direct and indirect cost is assigned. The disaggregation of the total cost in its components requires a specific method. One approach is to assign the cost to design features (Wierda, 1990), (Geiger and Dilts, 1996), (Staub-French et al, 2003). A design feature is a group of faces of a product that together have an engineering meaning. Production times and hence cost can then be assigned to those design features. This method requires detailed information and will mainly be based on process planning details.
- *Hybrid cost estimation*: if a product requires different parts, it can occur that those parts are at a different stage of the product development cycle. This implies that some of the parts will have detailed information available while others are still at the earliest stages with insufficient data. For parts with the required data available, generative methods can be used. For those parts still at the earliest stages, variant based methods will be used.

The accuracy increases as cost engineers pass from variant-based techniques to generative cost estimation and the generation time will increase accordingly. Although different techniques are available for generating cost estimates (H'Mida et al., 2006), the research in this paper focuses on regression techniques and ANNs.

3. Regression analysis and neural networks for cost estimation

3.1. Regression analysis

Since the 1970s regression techniques have been used for cost estimation due to their well-defined mathematical background. Ever since, this technique has been applied to support cost engineers in different fields (Zang et al., 1996), (Shtub and Versano, 1999), (Chen and Chang, 2002), (Kim et al., 2004).

For cost estimating purposes, regression techniques are used to examine the contribution of different variables to the cost. One starts with a list of variables possibly influencing the cost. Based on statistical tests, significant variables are selected from the list and combined into cost-estimation relationships (CERs). The best property of regression techniques is the ability to interpret the relationships between the cost and the variables considered. Although applied frequently, some drawbacks of regression techniques should be taken into account. Firstly, there is no general approach to help the cost engineer in choosing the model that