Journal of Manufacturing Systems 49 (2018) 16–24

Contents lists available at ScienceDirect

Journal of Manufacturing Systems

journal homepage: www.elsevier.com/locate/jmansys

# A machining feature definition approach by using two-times unsupervised clustering based on historical data for process knowledge reuse

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ARTICLE INFO

*Keywords:*
Process knowledge reuse
Machining feature definition
Historical data
Clustering

ABSTRACT

Machining features have been deemed as an effective way to accumulate and reuse machining process knowledge. The research gap for machining feature based method is how to define machining features, as the geometric shapes and machining processes of the same kind of machining features are only similar but not seriously unique. In order to address the issue mentioned above, a machining feature definition approach based on historical data for process knowledge reuse *via* two-times unsupervised clustering is proposed in this paper. Machining feature definition is realized based on learning machining feature patterns using unsupervised clustering by taking advantage of historical data. The feasibility of the proposed approach is validated by some aircraft structural parts, which provides an important theoretical reference for process planning and process reuse.

## 1. Introduction

Process knowledge reuse is very crucial in industrial production, especially for complex structural parts, which are widely used in aircraft and aerospace with small batches or even single-piece [1–3]. Traditionally, the process knowledge is reused directly from historical parts with the same or similar shapes, however, machining process cannot be effectively reused based on parts for the single-piece and small-batch production [4–6], as the quantity of similar parts are very limited. Under this circumstance, machining features are proposed to be used as the carrier of process knowledge [7], as research shows that although the parts of the same areas are different from each other, they can be deemed as the composition of a series of machining features which have similar shapes and machining processes. Machining feature is an effective way to accumulate and reuse machining process knowledge [8,9]. In NC (Numerical Control) machining area, it could improve NC programming efficiency and shorten the preparation cycle of NC machining [10–12].

Machining feature is defined as a set of geometric elements with certain shape and machining process. The definition of specific machining features is very important, where topology structure, geometric parameters, and machining process are defined for machining features. In other words, machining feature definition can also be understood what conditions should be satisfied and then the machining features can be classified into one kind machining feature, so they can use the same machining process, it is essential for machining features. Machining feature definition is the basis for machining feature recognition, and other machining feature based applications. Traditionally, the machining features are defined based on human experience. In practice, the geometric shapes and machining processes of the same kind of machining features are only similar but not seriously unique. Whether the definition of the same kind of machining features is too strict or too loose, the quality of process reuse based on machining features would be affected [13]. *e.g.*, the machining features shown in Fig. 1 can all be named as pocket features according to traditional feature definition, which are with similar geometric shapes, but their machining processes are always different from each other [14,15]. The topologies of the three machining features are very similar, Fig. 1(a) and (b) have the same machining process, but different from Fig. 1(c)–(f) have the same topologies, but due to the difference of the area of bottoms, their machining processes are different from each other. It is difficult to explicitly define the boundary of different topologies and continuous geometric sizes. Therefore, the definition of machining features should to be studied in depth.

In order to address the issue mentioned above, a machining feature definition approach based on historical data *via* two-times unsupervised clustering is proposed, and complex pockets with 3-axis and 5-axis machining of structural parts are mainly studied in this paper, where pockets are the main machining features of structural parts. The historical data of machined parts contain geometric models and

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https://doi.org/10.1016/j.jmsy.2018.08.003
Received 2 February 2018; Received in revised form 19 August 2018; Accepted 29 August 2018

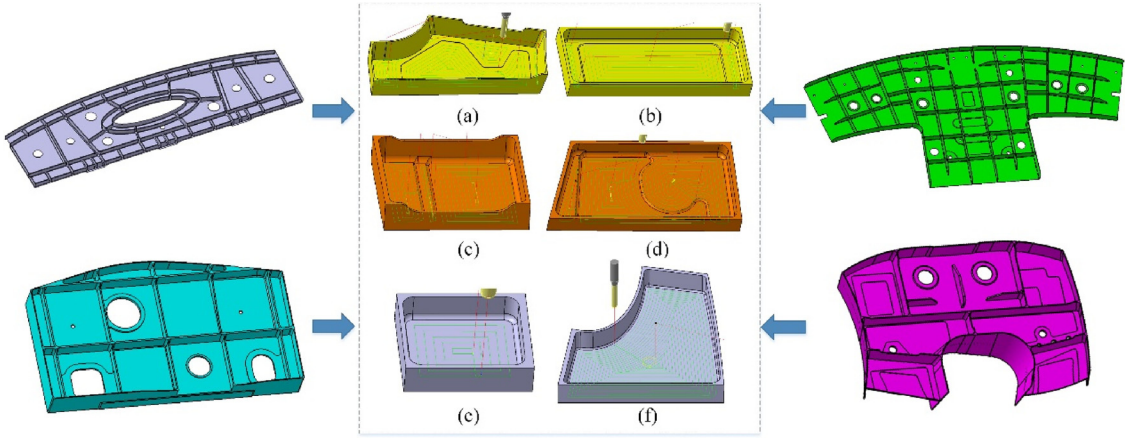


**Fig. 1.** Machining features of structural parts.

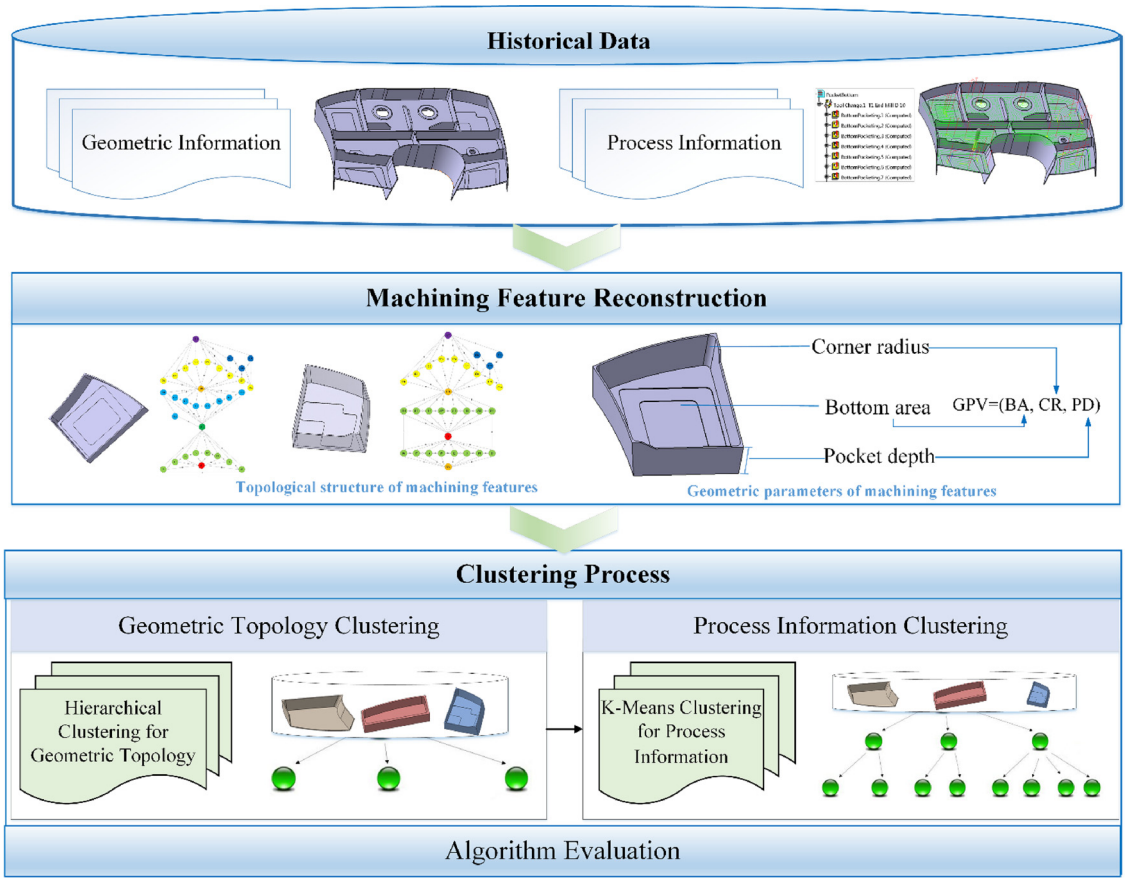


**Fig. 2.** The overall idea of the proposed approach.

corresponding process information. The historical data can provide significant basis for the reuse of machining process, as machining process experiences are contained in historical data, and can be used for the definition of machining features. Machining features are reconstructed firstly from the historical data of machined parts based on a series of geometric and process rules, and then two times of clustering processes are carried out to define the same kind of machining features by considering topologies and geometric sizes, which are associated with machining processes by learning machining feature patterns. Thereby, the definition of machining features for process reuse is realized by taking advantage of historical data. The overall idea of the proposed approach is shown in Fig. 2.

## 2. Literature review

Machining feature has been intensively focused in the last thirty decades [16,17]. ISO STEP AP224 [18] defines machining features as: a volume of material that shall be removed to obtain the final part geometry from the initial stock, where 17 types of machining features are contained. However, the definition of machining features is kind of fixed and mainly the typical machining process is included in the machining semantics, which may be not enough for complex structural parts with multi-variety and small-batch production.

In regards of machining feature definition methods, the existing methods can be divided into geometric topology based methods and machining process based methods.