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Development of a dual-projected-based automated interference matrix algorithm for Industry 4.0

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Abstract

In order to complete the intelligent assembly operation, the cooperation between assembly robotic arm and assembly sequence planning (ASP) is necessary. This is a matter of great importance, as traditional product assembly incurs considerable manpower and time, generally accounting for 20–70% of the total manufacturing workload. In this paper, we develop a dual-projected-based automated interference matrix (DPIM) algorithm that analyzes the relations between the components of a given product. In order to reduce the number of times that collide detection is performed in comparison with the method only do collision detection, the DPIM algorithm relies on static interference detection and dual-projected detection to generate a contact matrix, a direction contact matrix, and an interference matrix. By reducing the number of times collide detection is performed, DPIM can reduce the workload of assembly, thereby reducing the total manufacturing load overall and the manufacturing time likewise.

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Keywords: assembly sequence planning, automation, collide detection, interference matrix

1. Introduction

Increasingly, traditional manufacturing model has been difficult to satisfy customer's rapidly changing demands. Therefore, industry 4.0 is currently the world's tendency of automation technology and generate a new type of manufacturing model. In order to achieve Industry 4.0 standards, companies should not only automatic all manufacturing process but also make it more intelligent. According to the changes of product, intelligent

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manufacturing provides more flexibility and automatically to adjust the manufacturing parameters rapidly. In the whole manufacturing process, the assembly operation has great relationship with the manufacturing cost and time. In general, product assembly accounts for more than 40% of the total cost incurred in a manufacturing process [1], and product assembly accounts for 20–70% of the total manufacturing workload. Without exception, intelligent assembly operation is an important key in intelligent manufacturing. In order to complete the intelligent assembly operation, the cooperation between assembly robotic arm and assembly sequence planning (ASP) is necessary. A robotic arm is one of tools that usually used in intelligent manufacturing because of it's flexibility and programmable control. Thus, the robotic arm is very suitable for using in assembly operation if assembly operations belong to the complicated work. On the other hand, ASP plays an important role in product development, production system design, and production scheduling [2]. Traditional ASP incurs both considerable manpower and considerable time. Given the high cost of these resources, refinements to traditional ASP—or even a reconceptualization—should be considered [3]. Specifically, if the product assembly sequence can be automated, the gains would be multiple and extensive in regard to reducing the time and cost of manufacturing and in regard to enabling companies to respond immediately to rapidly changing consumer demand.

In this paper, we develop a DPIM algorithm capable of automatically generating an interference matrix from a CAD file through three matrices: the contact matrix, the direction contact matrix, and the projection matrix. The rest of this paper is organized as follows: Section 2 reviews the literature focused on generating an assembly sequence by using an interference matrix. Section 3 describes the DPIM algorithm. Section 4 offers an account of the DPIM algorithm's verification. Section 5 presents the results of this research and describes directions for future study.

2. Related work

The contact matrix represents the contact relationship between the components of a product. The contact matrix in the present study verified that the CM is a square matrix of a product formed by n components $\mathrm{e_s}$ (with $s = 0$ to n). The $cm_{s,t}$ shows that the component e_s has contact with component e_t. Contact matrix represent the contact relationship between the components. This paper's contact matrix verified that the contact matrix CM is a square matrix of a product formed by n components $\mathrm{e_s}$ (with s=0 to n). The $CM_{\mathrm{s,t}}$ represent the component e_s have contact with component e_t. The CM defined as Fig. 1 (a). Interference analysis calculates the directions in which it is possible to assemble a component without causing interference [4]. The interference matrix describes the collision interference relationships between the moving component and the other components as the former moves from the original assembly position a potentially infinite distance along the axes of the Cartesian coordinates (±x, ±y, ±z) [5]. The interference matrix in the present study verified that the interference matrix IM_{k} is a square matrix of a product formed by n components $\mathrm{e_s}$ (with $s = 0$ to n). IM_k is defined as Fig. 1 (b) where $IM_{kst} = 1$ if component e_s interferes with component e_t while moving along direction k. If component e_s does not interfere with component e_t, the value of the interference matrix is revised to zero. Because the component does not interfere with itself, IM_{kss} is always equal to zero.

(a)

$$CM = \begin{matrix} & e_0 & e_1 & \cdots & e_n \\ e_0 \\ e_1 \\ \vdots \\ e_n \end{matrix} \begin{bmatrix} cm_{0,0} & cm_{0,1} & \cdots & cm_{0,n} \\ cm_{1,0} & cm_{1,1} & & cm_{1,n} \\ \vdots & & \ddots & \vdots \\ cm_{n,0} & cm_{n,1} & \cdots & cm_{n,n} \end{bmatrix}$$

(b)

$$IM_{kst} = \begin{matrix} & e_0 & e_1 & \cdots & e_n \\ e_0 \\ e_1 \\ \vdots \\ e_n \end{matrix} \begin{bmatrix} im_{k,0,0} & im_{k,0,1} & \cdots & im_{k,0,n} \\ im_{k,1,0} & im_{k,1,1} & & im_{k,1,n} \\ \vdots & & \ddots & \vdots \\ im_{k,n,0} & im_{k,n,1} & \cdots & im_{k,n,n} \end{bmatrix}$$

Fig. 1 (a) Contact matrix and (b) interference matrix

3. The method of collision-based generate interference matrix

- Step.1. Interference detection and generating the contact matrix and extending the contact matrix

In the contact matrix (CM), if there is no contact relation between e_s and e_t, the value of CM_{st} is 0. Otherwise, i.e., when there is a contact relation between e_s and e_t, the value is 1. In the direction contact matrix