Adaptive Grasping and Adjusting Method of Virtual Hand Gestures with Semantics Information for Virtual Assembly

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Abstract—To improve the grasping efficiency and posture fidelity of virtual hands in virtual assembly processes, a novel adaptive grasping and adjusting method is presented. The attributes and information of assembly parts and assembly gesture of virtual hands are described completely with semantic description models in advance. Basic gestures model base and gestures knowledge base are established to facilitate the generation of hand gestures. According to the spatial relationship between a part and a virtual hand and the semantic description model of the part, the transitions from initial gesture to basic gesture can be calculated. Grasping rules are defined and used to adaptively obtain the final gesture and grasping position of virtual hand. Based on the constraints dynamic-solving algorithm and reasoning of semantic information, the virtual hand is adjusted to the appropriate grasping posture automatically. The validity of this method is verified by the virtual assembly of a reducer.

Keywords - virtual assembly, virtual hand, semantic description model, adaptive grasping

I. INTRODUCTION

In virtual assembly, a user completes operations of grasping and assembling of parts through a virtual hand. The fidelity of simulation process is very important, as it affects the interaction experience of a user directly[1-3]. In current virtual assembly applications, the operation efficiency of a virtual hand is not high enough[4-5], there still exists following problems:

(1) For different types of parts or the same type of parts but with different sizes, the grasping gesture and position cannot be determined quickly and efficiently.

(2) Grasping gestures cannot be changed automatically according to different assembly processes. The same part in different assembly processes may have different grasping gestures. If the user always interrupts the assembly operation from time to time to redefine the gesture when the gesture needs to be altered, it will cost a lot of time and increase the operation workload.

To solve the problems mentioned above, this paper studies the semantic description model of parts and virtual hand, then establishes basic gestures model base and gestures knowledge base. Matching and reasoning of user's intention is executed in real time to realize the adaptive grasping and adjusting method for virtual hands.

The remainder of this paper arranges as follows: Section 2 defines the research concepts and links between them. The semantic description model of parts and virtual hand are described in Section 3. Section 4 describes the basic gestures model base and gestures knowledge base. Section 5 introduces the adaptive grasping and adjusting method of virtual hand gestures. A case study is presented for further demonstration and justification of the method in Section 6. Conclusion and future research are outlined in Section 7.

II. OVERALL IDEA OF VIRTUAL ASSEMBLY BASED ON VIRTUAL HAND

A virtual hand is one of the important elements of virtual assembly and its main job is to simulate the process of grasping and assembling[6]. The realization of virtual assembly requires matching and reasoning in real time based on semantic description model of parts and virtual hand, basic gestures model base and gestures knowledge base. The process of assembly simulation includes different concepts and their interactions are shown as in Figure 1.

III. THE SEMANTIC DESCRIPTION MODEL OF PARTS AND VIRTUAL HAND

A. Semantic description model of parts

The semantic description models of parts are established through extraction and reconstruction of the precise geometric information of parts. The structure of semantic description model is shown in Figure 2. The model includes basic information, physics information,
assembly status, and assembly hierarchies and constraints information.

![Figure 2: The Semantic description model of parts](image)

**B. Semantic description model of virtual hand**

According to the anatomic structure and motion characteristics of a hand, a 3D model of virtual hand is established with some simplified processes. The model includes one palm and five fingers; each finger has three joints as shown in Figure 3. The palm and every joint can be driven independently. The palm has three rotational degrees of freedom and three translational degrees of freedom; every joint has a rotational degree of freedom. The grasping gesture of a virtual hand is determined by its joints synthetically.

The structure of semantic description model of a virtual hand is shown in Figure 4. The model includes basic information, palm position, gesture information and grasped part.

![Figure 3: The 3D model of virtual hand](image)

![Figure 4: The Semantic description model of virtual hand](image)

**IV. BASIC GESTURES MODEL BASE AND GESTURES KNOWLEDGE BASE**

The determination of grasping gestures is a complex process [7-8]. According to the part features, mapping between gestures and features is established in reference [9] without regard to the situation that the same part may have different gestures. It is seemly that different parts may have different grasping gestures, but the same kind of parts may have different gestures also. In this paper, basic gestures model base $G = \{g_1, g_2, \cdots, g_n\}$ ( $g_1, g_2, \cdots, g_n$ represents different gestures) for each type of parts is established. For example, there are 3 types of basic gesture model defined to grasp a bearing as shown in Figure 5.

![Figure 5: Different gestures for a same part](image)

Gestures knowledge base is established based on semantic description model of parts and virtual hands. The building of gestures knowledge base includes two processes, namely initialization and dynamic expansion. The initialization process stores information of specific cases by designer. During the process of grasping a new part, gestures knowledge base is the basis of matching and reasoning for adaptive grasping and adjusting of virtual hand. After a user completes grasping and assembly operation, a new gesture case can be saved automatically to realize dynamic expansion of gestures knowledge base.

**V. ADAPTIVE GRASPING AND ADJUSTING METHOD**

**A. Adaptive Grasping and Adjusting Method based on part features**

In the process of virtual hand close to a part, the initial gesture will convert and match a basic gesture stored in the basic gestures model base when the bounding boxes of the part and the virtual hand intersect. However, which basic gesture is the most suitable one depends on the type of part and spatial relationship between the part and the virtual hand. Four steps are proposed to determine the most suitable basic gesture and the flow chart of the process is shown in Figure 6.

![Figure 6: Determine a basic gesture](image)