International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 10, October-2022

Case Representation and Retrieval of Disk Workpieces based on UML

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***Abstract*—In order to solve the problem that the representation of disk workpieces is difficult in the case reasoning method, this paper proposes a method of case representation and retrieval of disk workpieces based on UML. This method uses the unified modeling language to decompose the disk workpiece case into functional attributes, material attributes, geometric attributes and processing attribute, and strengthens the logical relationship between each attribute. Disk workpieces are different from other geometric workpieces and have the characteristic of cyclotron symmetry. According to this characteristic of disk workpiece, the distribution attribute and topological relationship of disk workpiece are introduced to describe the geometric feature and spatial distribution of disk workpiece, and the geometric attribute description and similarity calculation of disk parts are realized.**

Keywords—Case representation; Topological relationship component; UML;

I. INTRODUCTION

With the development of manufacturing industry and computer technology, rotor parts manufacturing represented by disk parts is developing towards intelligent and systematic direction. In the background of intelligent manufacturing, the realization of disk type workpiece representation is the key to improve the industrial upgrading of disk type workpiece processing. Therefore, the study of case representation and retrieval of disk workpieces is an effective way to solve the problems of unsystematic representation of disk workpieces and lack of retrieval algorithms, which has great practical significance.

In order to improve the efficiency of workpiece retrieval and ensure the accuracy of retrieval, a large number of researches are devoted to the study of matching algorithm, but ignore the accurate representation of the workpiece itself [1-4]. Case-based Reasoning (CBR) [5-7] refers to historical cases, which compares historical cases with new cases, and reuse or modify them. This method is suitable for the manufacturing process of disk type workpiece and meets the dependence of experience. As the core part of CBR, case retrieval mechanism includes case representation and case similarity calculation, which meet the dual requirements of representation and retrieval in manufacturing process to a certain extent.

Fan[8] etc adopted Extensible Markup language (XML) to implement the Internet-based CBR system under the client-server architecture in the case representation method of fixture design. L.[9] etc considered the relationship between geometric shape and topology in fixture design and retrieval, evaluated the similarity of geometric parts through the maximum similarity connected subgraph in graph theory, and realized the effective retrieval of geometric features. Yu[10] et proposed LPM-CBR-K algorithm by taking pseudo-metric as the calculation metric of case similarity. In this method, BP neural network is used to fit the measurement relationship between cases to classify the case base and construct a new matching pool. J.[11] et proposed a method of fusion of case-based reasoning and hybrid swarm intelligence. Under the framework of particle swarm optimization algorithm, the crossover mutation operator of genetic algorithm was fused, and the case-based reasoning method was introduced to improve the convergence of the algorithm.

Throughout the above research on case retrieval and representation, there are few applications in product manufacturing, too few representation methods for workpiece manufacturing cases, and lack of effective retrieval methods. This is obviously not conducive to the dynamic balance correction and other secondary machining correction processes in workpiece manufacturing. A few scholars combined the processing parameter representation method to represent workpiece cases, ignoring the diversity of workpiece processing methods in actual production.

In this paper, the UML based disk workpieces modeling, the construction of disk workpieces case structure model, using object-oriented method, the case is expressed in modular way, using case similarity calculation for retrieval. This method is widely applicable to many application scenarios such as fault diagnosis and machining parameter prediction. UML is different from other representation methods in that it can not only reflect the attributes and knowledge structure of artifacts clearly, but also satisfy the calculation of attribute similarity in case retrieval. Finally, it is verified by application experiment.

II. CASE REPRESENTATION OF A DISK WORKPIECES

According to the characteristics of disk workpiece, the attribute characteristics of disk workpiece can be divided into four aspects: functional attribute, material attribute and geometric attribute. Its case represents the modeling structure, as shown in Fig 1.

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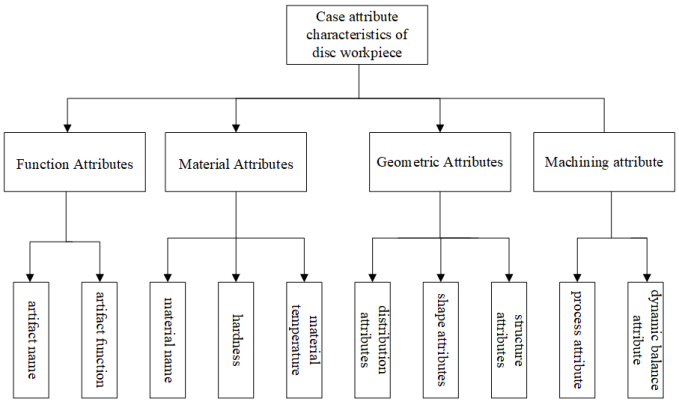

Fig. 1. Modeling structure diagram for case representation of disk workpieces

Unified Modeling Language (UML) is a standard Language for describing, visualizing, and documenting the products of object-oriented systems. As a modeling tool for object-oriented design, UML is independent of any specific programming language.[14-15]The case representation method based on UML is adopted, which can realize the modularity of case representation and describe the relationship between various attributes of disk workpieces more intuitively.

Common UML relationships in the description of disk workpieces include Generalization, Aggregation, Composition, and Dependency.

A generalization relation is an inheritance relation representing general and special relations that specifies how a subclass can specialize all characteristics and behaviors of its parent class. In the representation of disk type workpiece, the relationship between the commonness of disk type workpiece and the specific disk type workpiece is embodied. The aggregate relation is the relation between the whole and the part, and the part can exist separately from the whole. The combinatorial relation is the relation between the whole and the parts, but the parts cannot exist alone without the whole. For example, in the disk workpiece attribute, the shape attribute of geometric dimension information and the disk geometric attribute. A dependency is a relationship of use in which the implementation of one class requires the assistance of another class. It is embodied in the relationship between the shape attribute and the shape attribute in the disk type workpiece.

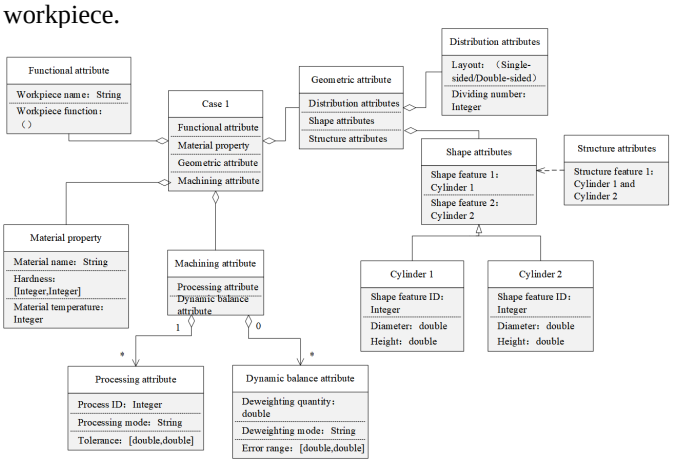

Fig. 2. UML representation of disk workpieces

III. CASE RETRIEVAL OF DISK WORKPIECES

In CBR, case retrieval is mainly to calculate the similarity measure between new cases and historical cases. In case retrieval, the Local Similarity is calculated according to each corresponding feature attribute of the cases of both sides. According to the different influence degree of different feature attributes on the overall features of the case, the feature weight value is added based on the Local Similarity, as shown in (1). The Global Similarity is obtained.

$$S_G = W_1 \cdot S_1 + W_2 \cdot S_2 + ... + W_n \cdot S_n = \sum_{i=1}^{n} W_i \cdot S_i \qquad (1)$$

S_G represents the global similarity, W_i represents the feature weight value, and S_i represents the local similarity.

A. *Feature weight value*

For the selection of feature weight value, it is mainly divided into subjective weighting method, objective weighting method and combined weighting method. Subjective weighting method mainly relies on artificial subjective judgment to assign values, and the judgment criteria are the importance degree of attributes and the capacity of attribute information, including expert direct weighting method and binary contrast method. The selection of numerical value of objective weighting method mainly depends on mathematical method and does not depend on subjective judgment. This method usually includes principal component analysis method, multi-objective programming method and entropy weighting method. The combined assignment method combines the two methods, which avoids the subjective arbitrariness and ensures the objective and scientific nature of the assignment. [16]

B. *Similarity of geometric attributes*

According to the particularity of disk workpiece geometry and considering the need of similarity calculation, the attributes of disk workpiece geometry can be reintegrated into three parts: the geometric information of disk workpiece, the dividing number information of disk workpiece, and the processing information of single and double surfaces of disk workpiece.

Geometric information can be described by voxel representation based on scanning. The method is as follows: the 2D graphics are scanned to construct the base plane in the 3D space coordinate system to form the basic geometric feature units, and the geometric feature units are combined into a complete geometry through the topological relationship description of the geometric feature units. As a geometric attribute, it is composed of multiple geometric feature units $E(X)$, and a single geometric feature unit can be expressed as: $E(X)=\{Sha,Sca,Top\}$, where Sha represents the 2D graphic feature of the scanning starting point, Sca represents the scanning feature, and Top represents the topological relationship feature of the feature unit.

According to the above theory, a geometric attribute similarity calculation model is constructed, as shown in (2).

$$sim(A,B) = W_E S_E + W_D S_D + W_F S_F \qquad (2)$$

S_E S_D S_F is the similarity of the corresponding geometric information, dividing number information, and single and double surface information. W_E W_D W_F represents the corresponding weight coefficient. As shown in (3), geometric

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information similarity can be specifically expressed as the weighted sum of shape similarity, scan similarity and topological relation similarity.

$$S_E = W_{Sha} \cdot sim_{Sha} + W_{Sca} \cdot sim_{Sca} + W_{Top} \cdot sim_{Top} \quad (3)$$

sim_{Sha} sim_{Sca} sim_{Top} is the corresponding shape similarity, scanning similarity, and topological relation similarity. Represents the corresponding weight coefficient.

1) Shape similarity

According to the voxel construction method[17], the geometric feature units of the workpiece can be regarded as being formed by scanning two-dimensional graphics in space. The geometric similarity of feature is to calculate the similarity of 2D graphics at the beginning and end of geometric feature element scanning.

For radians, the parameters are radii and radians. The calculation of the feature geometric similarity of the fourth geometric feature unit is shown in (4):

$$sim_{Sha\ i}(A,B) = 1 - \sqrt{\sum_{k=1}^{h} \left(\frac{A_{ik} - B_{ik}}{A_{ik} + B_{ik}}\right)^2} \quad (4)$$

The shape similarity between workpiece A and workpiece B is calculated as shown in (5).

$$sim_{Sha}(A,B) = \sum_{i=1}^{n} w_i \cdot sim_{Sha\ i}(A,B) \quad (5)$$

w_i is the geometric similarity weight of each geometric feature element, which is related to the proportion of the geometric feature element to the workpiece.

2) Scan Similarity

The description of scan path can be generally divided into two ways: straight line segment and arc segment. If only one scan mode is included, other parameters are set to 0. The similarity calculation between workpiece and workpiece scanning is shown in (6):

$$sim_{Sca}(A,B) = 1 - \sum_{i=1}^{\max(m,n)} \left(w_i \sqrt{\sum_{j=1}^{19} \left(\frac{A_{ij} - B_{ij}}{A_{ij} + B_{ij}}\right)^2}\right) \quad (6)$$

3) Similarity of the topology Relationship

Topological relationship refers to the spatial connection and adjacency relationship between geometric feature units in the same geometry, which does not need to consider the specific location. In the topological relations, the accessory (slave) genus relation, the adjacency relation and the exact relation are represented by 0.25, 0.5 and 0.75 respectively. If there is no topological relationship between two geometric feature units, it is denoted by 0, and the same geometric feature unit is denoted by 1. The geometric feature units in the workpiece geometry constitute the topological relation matrix, and the similarity calculation of the topological relation between the workpiece A and the workpiece B is shown in (7):

$$sim_{Top}(A,B) = 1 - \frac{\left[\sum_{i,j=1}^{\max(m,n)} (A_{ij} - B_{ij})^2\right]^{1/2}}{2(m+n)} \quad (7)$$

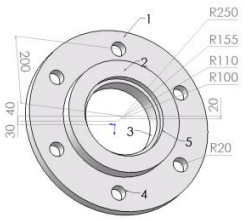


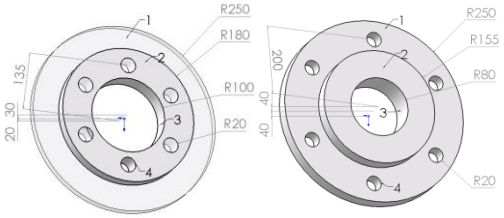
Fig. 3. Sample disk parts G1

TABLE I. G1 TOPOLOGICAL RELATION MATRIX

	1	2	3	4	5
1	1	0.5	0.25	0.25	0
2		1	0.25	0	0.25
3			1	0	0.25
4				1	0
5					1

IV. CASE ANALYSIS

As shown in Fig.4, G2 and G3 are disk part models different from G1. When the similarity of each attribute of disk parts is determined, the geometric similarity of disk parts is analyzed experimentally.



(a) Disk parts G2 (b) Disk parts G3

Fig. 4. G2 and G3 models of disk parts

Of the two parts, feature 1 is disk stretching; Feature 2 is the disk stretch adjacent to feature 1. Characteristic 3 is negative tension; Feature 4 is the hole feature.

TABLE II. SIMILARITY BETWEEN G1 AND G2, G3

Similarity	*G1 and G2*	*G1 and G3*
Shape similarity	0.7022	0.6949
Scan Similarity	0.4947	0.5823
Similarity of the topology Relationship	0.9259	0.9804

By calculating the geometric similarity and scanning of disk type workpiece, and assigning weights, the similarity of G1 and G2 geometric attributes is 0.8523, and that of G1 and G3 is 0.8722. G3 has higher similarity than G2, which meets the requirements in the process of design and manufacturing. It can be used as a reference for the similarity of geometric attributes of disk parts.

V. CONCLUSION

In this paper, UML is used to represent the case representation and retrieval method of disk parts in the manufacturing process, and a case model of disk parts manufacturing is constructed. The case model retrieval similarity calculation is divided into four attribute features, which also meets the general design requirements and rules. The case similarity of disk parts in machining process is obtained by weighting the last four attributes. It is conducive to the retrieval of disk parts.

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The geometric properties of disk parts are analyzed by voxel construction method. This method has a small amount of data and can simply describe the geometric properties of disk parts. This method can only be applied to the series of disk parts to realize the manufacturing process optimization in the same manufacturing process. Later, the case study of disk parts will be oriented to complex geometric structure and surface features.

REFERENCES

[1] H. shaohua,L. ling,"Some problems in case Retrieval and case Base Construction", Information Science, 2003(6): 629-631.

[2] Zh. Jinwu,L.tao,H.jianhua,"Development and Application of TBM selection adaptability Evaluation system based on case-based reasoning", Journal of Railway Science and Engineering, 2020, 17(6): 1562-1570.

[3] K.qingyu,H.jie,W.yong, "Research on Fault diagnosis system based on Fuzzy case-based reasoning", Changjiang Information & Communications, 2018 (11):157-159

[4] L.zhongliang,W.keyun,K.renke, "Study on a Case Retrieval Algorithm in Case-based Reasoning System" [J]. Computer Engineering and Applications, 2005(25): 230-232.

[5] Z.L. Cao, H. Zhu, G.J. Lin, Q.M. Hu. Design method of composite component based on case-based reasoning. Materials Express, 2020,10(12):2149-2153

[6] G.L. Wang, X.Q. Zhou, J. Liu, P.H. Zhu, H.B. Zhou. Polishing process planning based on fuzzy theory and case-based reasoning. The International Journal of Advanced Manufacturing Technology , 2017, 90:907–915.

[7] H.yumei,X.chengyuan, "A Summary of Research on case-based reasoning", Journal of Yanshan University(Philosophy and Social Science), 2011, 12(4): 102-108.

[8] FAN L,KUMAR A S. XML-based representation in a CBR system for fixture design[J]. Computer-Aided Design Application,2005, 2(1-4):339-348.

[9] L.chen,W.xin,S.chun, "Case Representation and Retrieval under a Case-based Reasoning System for Fixture Design", Journal of Mechanical Engineering, 2015, 51(7): 136-143.

[10] Y.xiaosheng,S.jin,R.mingxia, "Improved Case Reasoning Algorithm Based on Pseudo-Metric" Computer Technology and Development, 2020, 30(10): 69-74.

[11] J.tianlun,W.yan, "Energy Efficiency Optimization Method for Discrete Manufacturing Systems Based on Fusion Case Reasoning and Hybrid Group Intelligence" Information and Control, 2020, 49(3): 323-334, 342.

[12] C.shuqiong, "Typical structure modeling and application facing to the 3D model retrieval" Machinery Design & Manufacture , 2008(11) : 204-205

[13] X.dan,Z.huaiyu,Z.zhinong, "Mixed Geometric Features and Their Topological Relations" Ordnance Industry Automation, 2008(7): 26-28, 31

[14] S.weizhong,M.zhong, " Review of the unified modeling language " Journal of Computer Research and Development,1999(4):385-394

[15] C.juan, "Object-oriented system analyze and design based on UML". WUHAN UNIVERSITY OF TECHINOLOGY,2005

[16] J.zhansi,C.liping,L.nianmeng, "Similarity analysis in nearest-neighbor case retrieval". Computer Integrated Manufacturing Systems, 2007, 110(6): 1165-1168.

[17] X. Jing-wei, CHEN Yan-hui, " Evaluation of Part Similarity Based on Part Feature Unit", Modular Machine Tool & Automatic Manufacturing Technique,2021(8):165-168

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