Beyond Similarity Comparison: Intelligent Data Retrieval for CAD/CAM Designs

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ABSTRACT

The profitable prospective of optimizing a new product design with re-using technical knowledge of already manufactured products has exceedingly attracted interests of manufacturers as well as designers. Re-using accumulated know-how has the potential to improve product quality, shorten the design lead-time and reduce costs. One of the key factors for the reliable accessibility of reusing the accumulated knowledge refers to classification of the entire CAD/CAM product data in a repository. In addition, to present various products, a standard data format is required. Among the main methods for classification and standardization of geometrical and topological information of a 3D model, Group Technology is one of the most important methods which contain additional information beside the geometry of a product. Based on Opitz code one of the Group Technology's approaches, this paper proposes a novel method for design decisions using a classified database. Moreover the state-of-the-art of classification methods for 3D shapes aimed for similarity comparison is reviewed.

Keywords: similarity comparison, Opitz code, CAD/CAM.
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1 INTRODUCTION

In a competitive market, development of any new product requires a shorter design lead-time and an optimal life-cycle performance. According to Ullman [32], product design decisions made at concept stage account for a 70% of the cost. To optimize design decisions, and as a substitute for a conventional and sequential design, an innovative method is proposed in this paper which integrates design as well as manufacturing considerations in geometrical design phase. In this methodology, all required design factors are evaluated jointly in the first phase of the design or in the geometrical design with Computer-Aided Design (CAD) software systems. These design considerations include manufacturability, environmental effects, functional effects and side effects, production costs and so on. Contemporary highly potential CAD software systems are able to calculate multiple physical functions and aspects of a geometrical design. However, such comprehensive calculation softwares may not be as accurate as professional softwares which calculate only a single physical design aspect such as heat, noise, pressure, etc. For those companies who ought to calculate a design with different softwares, the design process is a time consuming phase which ends with not necessarily an optimal outcome. Often a designer has to modify the design over and over again to assure all geometrical and functional requirements are optimized.

A quantitative and comprehensive similarity comparison approach aims to solve these challenges with a clustered repository which includes the know-how of already designed and manufactured products. Based on the previous knowledge of similar product designs, it is possible to estimate the characteristics of a new designed product and make better design decisions. Some of the current research works which intend to reduce the design lead-time include: case-based reasoning, concurrent engineering [33] and semantic models [22].

The proposed new approach in this paper aims to solve the described design problem with a comprehensive similarity comparison toolbox. This toolbox consists of a database and a quantitative similarity algorithm. Group Technology (GT) technique is applied for data standardization.

This paper is structured as follows: Section 2 reviews the conventional design methodology and existing methods on shape signature. In section 3 the history and an introduction to Group Technology is illustrated; followed by section 4 Opitz coding system as the chosen method for the current research. The next sections 5, 6 and 7 will enlighten the essential concept of the proposed methodology for similarity searching, including the algorithm of similarity searching, structure of its database, implementation and results. Section 8 contains the conclusion.

2 RELATED WORKS

In a conventional design method, the design process starts when a designer receives new requirements for a new product design. In the primary step, the first draft of the product is designed and in the next step; the designed model is optimized, as seen in Fig. 1. Considering that the optimization is an iterative process, one of the methods which can decrease the number of iterations is to create an optimum first draft for design. In such a design model, initiation of an optimum first draft of design essentially depends on the experience of the designer. Considering that in the next 15 years 85% of employees in industry will be below 40, there is an imperative necessity in transferring the valuable know-how to the new and less experienced designers.

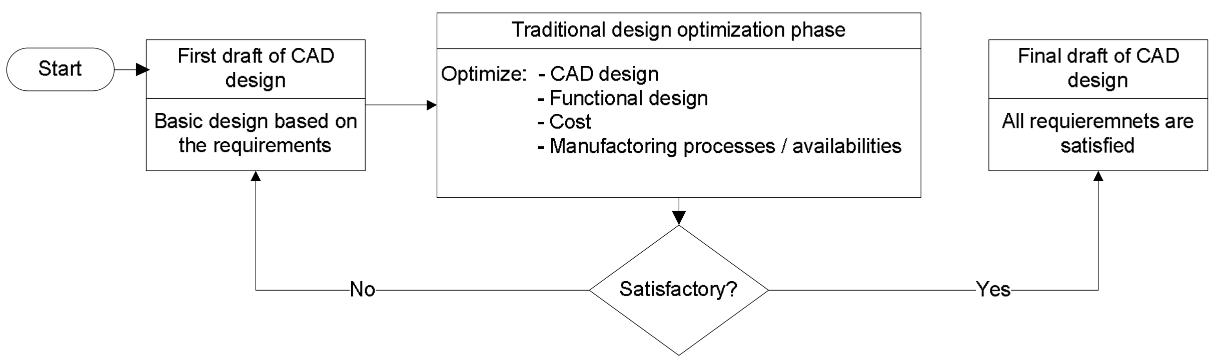

Fig. 1: Conventional design procedure.

In the other words, the objective is to reduce the time, cost and energy expended for the conventional design process while preserving the high quality. Essentially, there are two types of solutions for this problem. The first attempt is to speed up the iteration time and the second is to reduce the number of the iterations. The first solution refers to the investigation in the hardware equipments. Aiming for the second solution; the only factor which influences the reduction of the number of iteration is a proper initiation of the first draft of design which is based on a tested and proved model. Consequently, a structured database containing design information, similarity comparison algorithms and a retrieval system are the major requirements.

Comparing the geometrical 3D CAD models is a complicated task. To perform this, an injective (one-to-one) function or principle is required to transform a 3D shape to a computable model so called shape signature. A shape signature is defined as capsulated information of a solid model including all the major geometrical and topological features of an object. In addition, the shape signature is supposed to have an understandable and computable format for automatic computation and comparison by computer, like image, graph, vector or an ordered string of numbers or alphabet. Thus, the outcome of similarity assessment between two 3D shapes is based on the comparison of their shape signatures. Hence, similarity assessment between two 3D shapes includes two main steps: First to compute a shape signature and second to compare the shape signatures by a suitable distance function. Cardone et al. 2003 [4], Gao et al. 2006 [10], Liverani and Ceruti 2010 [21] use almost the same classification for shape signature methods while the classification of Iyer et al. 2006 [15] is slightly different. Both categorization models are basically the same; a minor difference refers to including the multi-resolutional method into the first categorization model. In addition, the feature-based category has been properly divided into global and manufacturing features in the first categorization.

In the following list, a comprehensive combination of both major categorizations is briefly described. The methods in parentheses belong to Iyer et al. classification and they refer to the identical characteristic of object.

- **GLOBAL FEATURE-BASED METHODS (INVARIANT-BASED METHODS AND HARMONIC-BASED).** Using invariants of a 3D shape such as volume, surface area, higher order moments, geometry ratios, distances, etc. [8],[6],[19].
- **MANUFACTURING FEATURE-BASED METHODS**. In this method, the manufacturing features are recognized from a CAD model. Belonging to this category, MDG (Model Dependency Graph) approach for a 3D CAD model is used to compare machining parts [4].
- **HISTOGRAM-BASED (STATISTICS/PROBABILITY-BASED) METHODS**. Using shape functions to create a shape distribution of random sampling of points [13],[26].
- **GRAPH-BASED METHODS**. A graph-based method develops a graph based on the encoded shape, geometry or feature of a 3D model [17]. In some methods, the sub-graph isomorphism is used in order to match B-Rep graphs, or to match eigenvalues of a model signature graph which is constructed from the B-Rep graph [7].
- **3D OBJECT RECOGNITION BASED METHODS.** Ruiz-Correa et al. [28] introduced spin images as a signature and Lamdan et al. [20] established a method based on geometric hashing as a shape descriptor.
- **MULTI RESOLUTION DESCRIPTOR- BASED.** This method has been investigated by Gao et al. [10] with a Dilation based Multi-Resolutional Skeleton (DBMS) method for retrieving similar parts. Their method for shape signature generation consists of several consequent stages including: B-rep building of component, voxelization, DBMS graph generation. The direct result of having several phases to get the signature is dramatically escalating the cost of time and computation.
- **PRODUCT INFORMATION-BASED METHODS: (GROUP TECHNOLOGY-BASED METHODS).** Hendeson et al. [12] used GT for similarity detection in concept of Agile Manufacturing. Iyer and Nagi [16] developed a new Group Technology (GT) method to compare the similarity between parts. A Type Abstraction Hierarchy (TAH) is considered as an alternative for GT [30].

All mentioned methods do have advantages and disadvantages. The application and the feature type of a 3D shape are two major factors to determine which method has the highest efficiency for the appointed purposes.

3 GROUP TECHNOLOGY (GT), SELECTED SHAPE SIGNATURE

This paper is based on applying GT method for producing the shape signature, because of the following two main reasons:

1. *Interactive design rather than isolated design*: it is essential to consider the design process as a first step in the product development chain which is ended by manufacturing. The best geometrical design which can not be manufactured is useless. Design is not an independent effort; but an interactive procedure. An ideal design is the one which is manufactured at low price while keeping a high level of quality. Appling GT as a manufacturing-based grouping methodology for producing design signature can fulfill the gap between Computer-Aided Design and Computer-Aided Manufacturing, refer to Fig. 2. In addition entering GT at the early stage of the geometrical design gives the designer an improved overview on the steps that a design goes through until production.
2. *Product signature instead of shape signature:* the second factor for choosing GT refers to the flexible nature of GT. The format of GT as an alphanumerical string has the capability to be extended with extra digits to contain additional product data. This characteristic promises to advance one step beyond having merely shape information.

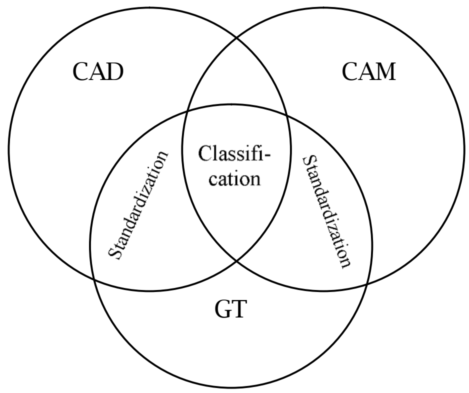

Fig. 2: Classification as a key association between CAD and CAM.

Despite the main application of GT in manufacturing, GT has highly affected the design process as well. The major benefit of using GT for design is standardization. Estimates show with using GT, design and consequently manufacturing are improved through enhancing quality, productivity throughput and overall profitability [31]. GT generates an alphanumeric string based on the individual attributes of a part such as geometrical shape, dimensional accuracy, material and production quality [29]. Using GT concept in design, through the predetermined collection of characteristics, the designer has a number of alternatives and choices to initiate the new design. In this way, he might be inspired for an innovative new design or he decides to pursue the existing successful designs. Thus the retrieval of earlier successful design knowledge becomes an uncomplicated assignment.

The concept of Group Technology first was introduced by S.P. Mitrofanov in U.S.S.R who began his work in 1950s. He published a book entitled Scientific Principles of Group Technology translated in English in 1966; however, it was published in original language much earlier. Mitrofanov won the Lenin prize for his outstanding achievement in GT [27]. He identified 3 major problems to be solved by GT: First; eliminating any unwanted variations in active technological process. Second, improving process to a level where they would be applicable to large batch and mass production techniques and third, introducing high-speed, easily adjusted equipment [29]. Mitrofanov's work was followed up by A. P. Sokolovskiy subsequently.

A second major researcher was Herwart Opitz at late 1950s and beginning of 1960s, who came up with the conclusion that although the designs and functions of the parts might be different, there were many similarities in the parts being manufactured (based on his research on the entire German machine tool industry). His work successfully resulted with the creation of the Opitz classification and coding system widely used in German industry [9].

Third research: was started from the standardization at Serck Audco Valves, a valves manufacturing company in 1959. They developed an eight-digit coding for a unique identification for each element in the production process as a GT system. The result was 20% reduction in work pieces and purchased parts as the effect of part standardization [29].

Another attempt in England was followed by E.G. Brisch, who developed a concept for code classification. His work later was employed in E.G. Brisch and Partnes Ltd. Furthermore Forges et Alteliers de Construction Electrique de Jeument of France in 1959 followed Brisch's coding and standardization successfully [11],[14].

In the recent decade, different applications for GT have been implemented and investigated. Some of the important researches are briefly described in the following sentences. Kaperthi and Suresh used a neural network to identify features from bit-mapped 2D drawing to feed a part in Opitz code [18]. Nadir et al. [23] and Ames [2] developed a system which generates codes from 3D data source. Barton and Love [3] developed a system which automatically encodes an engineering drawing to GT.

As mentioned before, one of the main objectives of Group Technology is design standardization. Group Technology applies predetermined selection of characteristics of products including design engineering and functional characteristics as well as physical characteristic. As a result of the standardization, searching and retrieval systems can be improved and optimized. The significant impacts of using GT are related into its application in design and manufacturing. In industry, GT is relevant to agile manufacturing, variant process planning, manufacturing cell layout and manufacturing technology systems design and manufacturability evaluation [1],[29].

There are different methodologies to generate GT code, the most important ones include: Opitz classification system (University of Aachen in Germany), Brisch System (Brisch-Birn Inc.), CODE (Manufacturing Data System, Inc.), CUTPLAN (Metcut Associates), DCLASS (Brigham Young University), MultiClass (OIR: Organization for Industrial Research), hierarchical or decision-tree coding structure, and Part Analog System (Lovelace, Lawrence & Co., Inc.) [1],[33].

In each of the mentioned approaches, the basic idea is to capture critical design and manufacturing attributes of a part and place them in an alphanumeric string, or the GT code that is assigned to that part.

One of the most successful and worldwide used coding system based on GT concept is the Opitz coding system. In the next sections, a new approach developed for design optimizing based on Opitz coding system is described.

4 OPITZ CODING SYSTEM

The Opitz coding system was introduced by Herwart Opitz, professor of machine tools and production engineering from Technical University of Aachen in Germany [24]. The Opitz classification system has been widely used in manufacturing since then. Opitz code is composed of thirteen primary digits to convey the design and manufacturing information of a part and the digits are divided to three sections. The first five digits called 'form code' which presents the design attributes. The second four digits or the 'supplementary codes' are reserved to indicate some of the manufacturing attributes. Third section or 'secondary code' is an extra four digits to be used optionally as flexile digits for defining particular requirements or presenting the operation sequences [1]. Since the focus in this paper regards to the geometrical aspect of Opitz code, for the rest of this paper only the first five digits or the 'form code' will be considered as Opitz code.

The first digit of Opitz code refers to 'part class' and has two main categorizations: rotational parts and non-rotational parts. Rotational parts are classified by length-to-diameter proportion while the non-rotational parts are identified by length, width and thickness. The non-rotational parts are divided into three major categories of long part, cubic parts and flat parts. Each of the two mentioned classifications has its own classification however; all of them have 5 digits to be fulfilled with 10 possibilities indicated with numbers from 0 to 9 based on the distinguished feature of a part. Tab. 1 presents the details of Opitz code digits (1-5) assigned for the rotational parts in cubic form while each digit details and describes a feature. The first five digits of non-rotational parts are dedicated to part class, main shape, rotational machining and auxiliary holes and gear teeth respectively. Each digit may have a grouping in itself, i.e., digit 5 in Tab. 1 which has three extra grouping as well. Or it might be without any inter grouping like digit 3, Tab. 1.

DIGIT 1 Part class			DIGIT 2 Main shape				DIGIT 3 Main boring / rotational surfaces machining		DIGIT 4 Plane surfaces machining		DIGIT 5 Auxiliary holes and gear teeth			
0	Rotational parts		0	Block-like parts		Cuboid	0	No features	0	Without machined surface	0	Without features		
1			1			Right angle parts	1	One smooth boring	1	Chamfers	1	Without Shaped / without gearing		One boring direction
2			2			Composite cuboid	2	One main boring once/ multiple ascending	2	One flat surface	2			Several boring directions
3			3			Parts with clamped surfaces and main boring	3	One main boring with form element	3	Flat stepped surfaces	3		With drilling template	One boring direction
4			4			Parts with clamped surfaces and main boring with jointing plane	4	Two main parallels bores	4	Flat stepped surfaces vertically inclined and/or opposite	4			Several boring direction s
5			5			All others	5	Many main boring in parallels	5	Groove and/or slot	5	Shaped without gearing		Shaped without drilling
6	Non-rotational parts		6	Case-like parts	Not split	Approx-imate or composite cuboid	6	Many main boring perpendicular	6	Groove and/or slot and 4	6			Shaped with boring
7			7			Any shapes	7	Ring surfaces / Ring groove machining	7	Curved surfaces	7	Gearing		
8		Cubic part A/B<=3, A/C<4	8		Split	Approx-imate or composite cuboid	8	7 + main boring	8	Guided surfaces	8	Gearing with boring		
			9			Any shapes	9	All others	9	All others	9	All others		

Tab. 1: Opitz key table for codes and classification of non-rotational shapes which are cubic [24].

5 ADVANCED DATA RETRIEVAL BASED ON SIMILARITY ANALYSIS

The presented approach in this paper includes three phases: (i) standardizing design product information using Opitz code (ii) using comprehensive similarity comparison toolbox and (iii) two searching algorithms to retrieve similar models.

This methodology supports the designer in the design decisions in the following ways: first, it suggests the designer similar CAD models as well as retrieving all information about them. Second, by retrieving the similar models; various information are given to the designer regarding the manufacturability, costs, quality and some other attributes of a product. Third, it facilitates the innovation by comparing similar products with different applications. Fig. 3 presents the procedure of the approach using the similarity comparison toolbox [25].

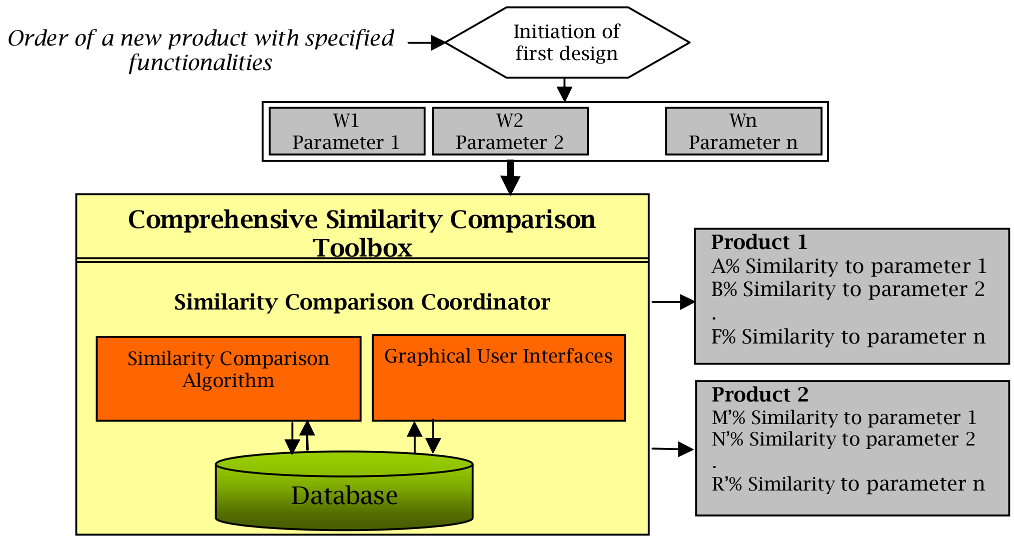

Fig. 3: Design procedure using similarity comparison toolbox.

The comprehensive similarity comparison consists of a coordinator module, a similarity comparison algorithm and a database illustrated in Fig. 3. The coordinator is responsible for controlling and applying the weights or priorities to the parameters, to ask from the designer about the significant parameters (which can not be ignored in the design). In addition, the coordinator establishes the temporary database and sets and determines the tolerances.

To configure the toolbox, the first steps are the standardization of the products and setting the similarity algorithm off. For the standardization, the Opitz code has been selected as a GT code for its extensive classification of parts.

6 DATABASE DESIGN FOR INTERACTIVE SIMILARITY COMPARISON AND DATA RETRIEVAL

Two major challenges concerning the similarity searching and retrieval in a database design are explained in section 6.1. Consequently, two methods for database design are illustrated in section 6.2 to avoid any potential problems raised by the challenges.

6.1 Active Database

'Flowing behavior' of pairwise similarity comparison and 'responding environment' are two major issues to be considered in design of a database for similarity searching application.

6.1.1 Flowing behavior

Pairwise similarity searching in a database has a flowing behavior. It means in a database of similar models, the criteria for similarity detection gradually changes after a number of similarity comparisons occurs. For example, S1,2 in Fig. 4 presents the percentage of similarity between image 1 and 2, and S2,3 indicates the percentage of similarity between image 2 and 3 and so on. It is noticeably observed that S1,2 and S2,3 indicate roughly the same percentage however, S1,6 refers to very different percentage and to a far less percentage number. In the other words, if the pair similarity comparison is continued in a domain including variant objects, after a number of objects, there might be just a trivial similarity between the first object and the last object. A continuous similarity comparison may causes isolation from the correct direction of searching.

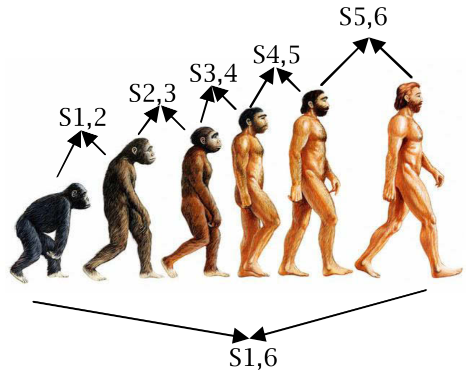

Fig. 4: Flowing behavior of pairwise similarity comparison: every side pairs have a high similarity although the first and the last images are not very similar. Fig. based on [5].

6.1.2 Responding environment

Every new successful design has to be saved in the database as well as being immediately available for the subsequent similarity searching and retrievals. Thus the searching algorithm of the database should be flexible and classified to adopt the new member in the right position in the database.

6.2 Two Proposed Methods for a Quantitative Retrieval

With applying Opitz code as the shape signature, similarity comparison between two 3D shapes is concluded to one-by-one digits comparison of two Opitz codes. Since each digit is dedicated to a specific feature of the solid model, it is possible to prioritize some features in the similarity comparison process. Therefore, two possibilities are considered for the similarity retrieval in the database. First possibility is the similarity retrieval with an equal weight/ priority for each digit and the second possibility is dedicated to the similarity retrieval with prioritized digits. These two methods are explained in details in the next sections.

6.2.1 First possibility: similarity retrieval with an equivalent priority for all digits

When all digits in Opitz code have the same priority, there is a possibility that the similarity criteria changes gradually, refer to the 'flowing behavior' of the similarity searching, as discussed before. To prevent this challenge, in our proposed method, the database is divided into clusters in which each cluster has a header, see Fig. 5. Based on some characteristics, each entity (the information package of an object) belonging to the same cluster have similar attributes. The header is selected as the most referred entity in the previous searches in its cluster. Each header is a representative of its cluster. In every similarity searching each entity gets a score if it has been referred and the one which has a higher score will be placed as the header of its cluster. In the next searching if another entity holds a higher score, it will be replaced with the current header [25].

To give the retrieval an improved focus, it is possible to have a quantitative similarity searching; it means the user can choose a similarity percentage for the retrieved results. Since a five digits Opitz code is considered here, the user can choose a number including 20%, 40%, 60%, 80% and 100% of similarity for the retrieval. In general, the value of the digits for similarity comparison is calculated by Eqn. (6.1)

$$\text{Value of each digit} = (100 / \text{number of digits}) * 100\% \qquad (6.1)$$

Furthermore, the total number of the similarity forms between two similar Opitz codes with considering the order and the number of the similar digits is calculated by *Sim(n,i)* when *n* is the number of total digits in the code and *i* is the number of similar digits, Eqn. (6.2). In the other words, two similar Opitz codes have one of the similarity forms among all the possible forms calculated by Eqn. (6.2).

$$Sim(n,i) = \sum_{i=1}^{n} \binom{n}{i} \qquad Where\ i \le n \qquad (6.2)$$

The searching process in this approach i.e., similarity retrieval with an equivalent priority for all digits is performed in two stages to achieve the possible best result for the similarity searching process. These two stages are horizontal searching and vertical searching described as following paragraph.

- **HORIZONTAL SEARCHING**. This is an individual searching in the headers. If a header presents an acceptable result of similarity, the header will be selected to continue for the vertical searching. Otherwise the current header will be ignored and the next header will be examined.
- **VERTICAL SEARCHING**. Contains searching in the clusters. The second phase of similarity comparison will be accomplished in the clusters of the designated headers.

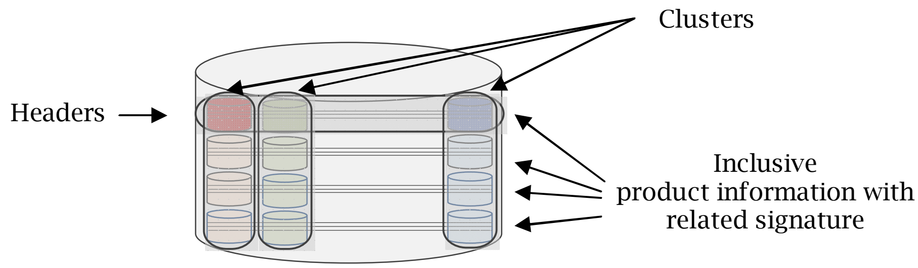

Fig. 5: Classification and layers of data in the database.

The workflow of the complete searching, including the two mentioned searching stages is presented in Fig. 6. It includes 6 steps to retrieve five similar models illustrated in the following diagram in Fig. 6.

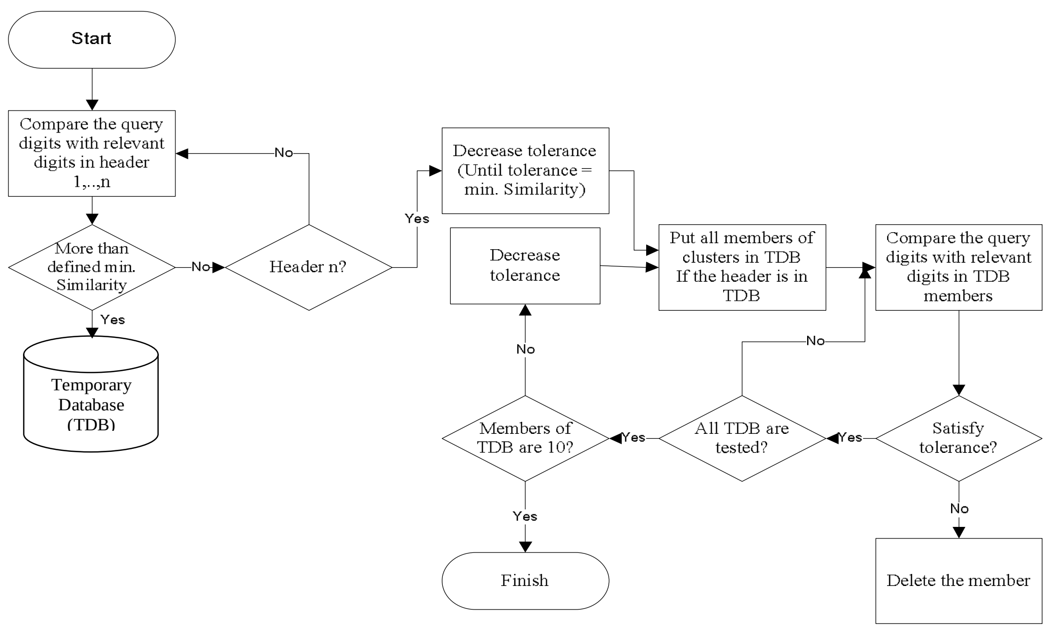

Fig. 6: Workflow of similarity algorithm.

- Step 1: Comparing the query code with the code in header 1.

- Step 2: If similarity comparison between the two codes is less than the defined minimum similarity by user, then the current header is ignored and the next header will be compared. Otherwise the current header is saved in the temporary database.
- Step 3: After all headers were checked; working on the temporary database is started. A tolerance domain (minimum similarity<tolerance<100) will be established to find the most similar models. The tolerance number is an additional value to the requested similarity percentage; see Fig. 7.
- Step 4: The process is finished when with decreasing of the tolerance; until only few designs are left in the temporary database. In presented workflow in Fig. 6, 10 designs were desired and set, however the number of retrieved designs can be defined by the designer.

6.2.2 Second possibility: similarity retrieval with prioritized digits

For such condition an interactive communication with the database has been considered. The user determines and chooses the digits with priorities. In this model, only the Opitz codes containing an identical value for the prioritized digits are retrieved and any other similarity is ignored. After the user sets the priorities, in an active system, the most similar designs are located in the headers and are retrieved. This method benefits from a flexible attitude referring to the 'responding environment' of similarity searching; as discussed before.

As mentioned earlier, two similar Opitz codes with equivalent priorities for digits may have one of the singular forms of similarity, calculated by Eqn. (6.1). This equation is changed to Eqn. (6.3), when the digits have priorities. In this equation, n is the number of total digits in the Opitz code and x is the number of prioritized digits.

$$Sim(n-x,i)=\sum_{i=1}^{n-x}\binom{n-x}{i} \qquad Where\ i \leq n\text{-}x \tag{6.3}$$

The number of possibilities to prioritize the digits, without considering the order of the digits, i.e. $P(n,i)$, is calculated according to the Eqn. (6.4), when n is the number of the Opitz code and i is the number of prioritized digits. If the order of the digits is considered, the number of possibilities to prioritize the digits is calculated by the Eqn. (6.2) where n is the number of Opitz code and i is the number of the prioritized digits. Clearly the number of the retrieved models or the quality of the results depends on the number of the models in the database.

$$P(n,i)=\sum_{i=1}^{n} i \tag{6.4}$$

7 IMPLEMENTATION

A software system has been developed to produce the Opitz code for each shape designed in a commercial CAD tool based on the Opitz code classification and layout. A medium to ease this transformation is the Initial Graphics Exchange Specification (IGES) file which is extracted from a CAD model. The IGES file is received by the developed system and is processed for obtaining the shape features followed by constructing the Opitz code for that particular shape. After Opitz code is generated, the similarity searching system is started using an incorporated GUI. The software system extracts Opitz code from the requirements and is able to prioritize some digits of Opitz code for emphasizing on the explicit required properties. Additional tow GUIs have been designed as well to demonstrate the CAD sketches of the retrieved models and their Opitz codes. Two types of similarity searching are considered for the system i.e., searching with equivalent value for digits as well as searching with non-equivalent digits or prioritized digits.

Searching with equivalent value for digits: when user chooses to search with equivalent weights for the query digits he will be asked to select a similarity percentage for the retrieved models. This is for limiting the number of the retrieved model. Without considering any limitation for the retrieval, it is possible to have many retrieved models which the maximum number of the retrievals is calculated with Eqn. (6.1).

Searching with non-equivalent digits or prioritized digits: if the user prefers to have a prioritized search, he is ought to select the prioritized digits in GUI, presented in Fig. 7. He can select one to five digits to be prioritized. Based on the value of each digit, Eqn (6.1), and the number of prioritized digits, the level of similarity is specified as well. The possible number of retrieved models with prioritized digits is calculated with Eqn. (6.3).

The related CAD models as well as their Opitz codes are presented by the system. The designer has the possibility to refine his search by increasing the level of similarity.

By clicking 'CAD sketch of similar models', a new window is opened which presents all CAD models within the same level of similarity.

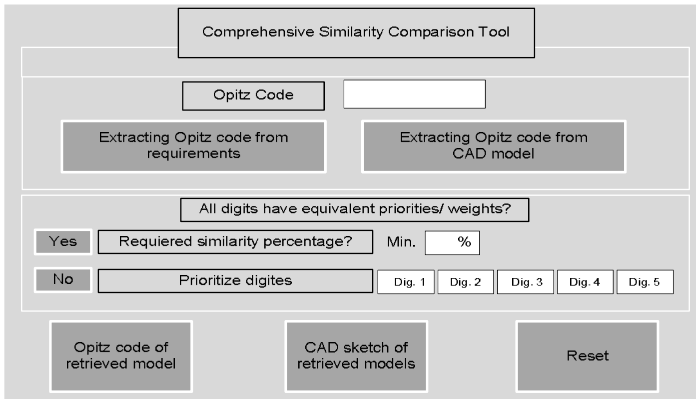

Fig. 7: Graphical User Interface for quantitatively similarity retrieval.

7.1 Results and Evaluation

In this section, an experiment to present the retrieved similar parts for a query part is demonstrated and evaluated using our developed algorithms. For this experiment a database including more than 200 non-rotational parts of very similar and very different solid models has been used. The database was developed at the Institute of Computer-aided product Development Systems, Universität Stuttgart, Germany.

For this experiment, the method of similarity retrieval with prioritized digits has been selected, while the prioritized searching is more structured and fewer results are obtained for different level of similarity in comparison with the other method which considers an equivalent priority for all the digits. Fig. 8 demonstrates the retrieved shapes in different required level of similarities based on the prioritized digits in red color.

There are three retrievals presented in this experiment, Fig. 8. In the first retrieval, two digits in the positions of 2 and 4 have priorities. The total number of retrieved shapes is 41 which only some of them are presented in Fig. 8. Considering that the applied Opitz code has five digits, thus the value of each digit is 20% calculated based on the Eqn. (6.1). Consequently, the minimum similarity percentage between the retrieved shapes and the query model is 40%. The second retrieval with three prioritized digits and minimum similarity of 60% has resulted to a smaller group of shapes with the total number of 22. Furthermore, the last experiment with four prioritized digits aimed for 80% of similarity, has resulted to 100% similarity of retrieved Opitz codes. In Fig. 8, Opitz codes of the retrieved model have been presented as well in which the interpretation of each digit refer to Tab. 1.

In the presented example of the searching and retrieval, it is seen that in the retrieval #3 there are 4 prioritized digits resulted to 80% of similarity; however the retrieved codes are identical referring to 100% similarity. The result of the retrieval demonstrates the retrieval of two solid models looking different having identical Opitz codes. The retrieval of these two equal codes emphasizes on the potential drawback of Opitz code as shape signature. Since the feature definition of Opitz code for each digit is based on the manufacturing attributes, it is possible that two shapes with the same Opitz codes have different geometries and shapes. This problem is solved when the current Opitz code includes extra digits i.e., supplementary codes and secondary codes or even additional digits based on the specific product characteristics.

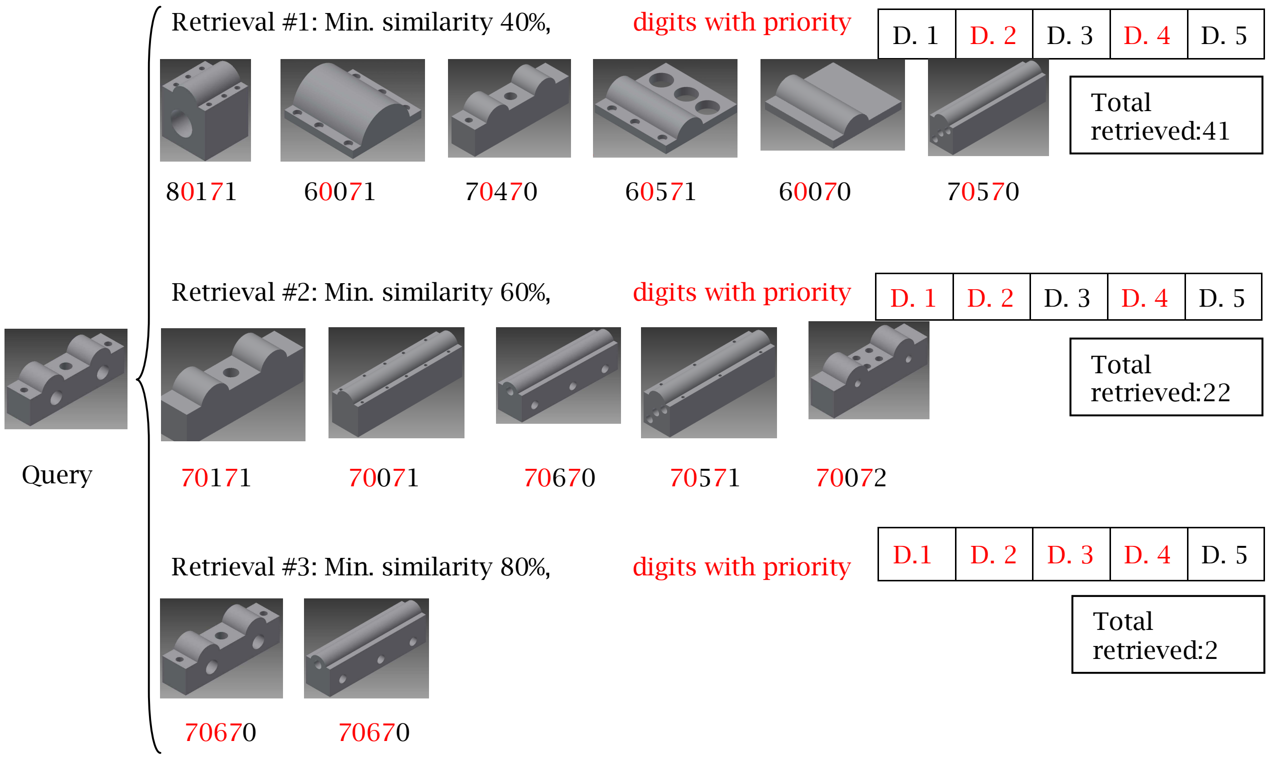

Fig. 8: Data retrieval with different similarity percentages.

8 CONCLUSIONS

In this research, an Opitz coding based shape signature and two different techniques for data retrieval for a comprehensive similarity comparison toolbox has been developed. The Opitz code structure has been selected as a Group Technology to classify and standardize the geometrical information of a CAD model. One of the main challenges in this work is related to the precise and exact extraction of GT code from the requirements. Another challenge refers to the quality of the generated Opitz code. However, the quality of the Opitz code can be improved with initiating a manual coding structure for a particular product. As a future work the Opitz code has to be extended with the additional digits dedicated to some exclusive features of a part to improve the accuracy of the similarity retrieval.

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