# 3D Part Retrieval in Product Data Management System

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## ABSTRACT

This investigation presents an effective algorithm of searching parts with similar shape and manufacturing features from a CAD files, identifying parts with similar shapes and features, in order to share their design and manufacturing data in product data management (PDM) systems. Polar Fourier Transform (PFT) analysis is applied to the shadings image of a part to obtain its Generic Fourier Descriptor (GFD) indexes, while feature recognition is employed to obtain the manufacturing features of a part. The similarity of two parts can be defined using GFD index and feature information. This proposed approach can be applied to PDM systems in web-based environment to search parts with a particular shape and manufacturing feature, and to process the automatic version control by analyzing the differences in shape and manufacturing feature of different version parts.

**Keywords:** Polar Fourier transform, part search, Web-page, product data management

## 1. INTRODUCTION

Computer-aided design is an essential element in the modern design and manufacturing fields. Large–scale enterprises have utilized CAD system more than 30 years. Solid modeling system is a representation of a geometric model on the CAD system. Boundary representation (B-rep) is the main stream of a solid modeling system, where the representation of topologic and geometric entities is un-ambiguous and provides the detail descriptions of the design and manufacturing information.

A product may be mobile phone, portable computer, car, or even an airplane, and may range in quantity from several dozens to several millions. Because products change frequently and also the number of drawing files increases so quickly, the management and searching of the drawing file has become a significant task since enterprises adopted the CAD systems.

A well developed classification schema need to be established in order to manage the large number of drawing files. Group technology (GT) is an effective schema for capturing the design and manufacturing attributes of a part in an alphanumeric string, called a GT code. However, the GT code representation has some limitations, especially when the shape of the part is very complex, meaning that the manufacturing attributes cannot be easily retrieved.

As an increasing number of CAD models become available on the enterprise, designers can re-use existing drawing files, and extract design patterns from the web-based environment to modify as new parts in order to shorten the design cycle time and increase the competition of their products on the market. A designed part with a set of characteristics is generally given, and considered as a goal part. All parts are searched to retrieve similar designs from a drawing database and compare their similarity.

## 2. LITERATURE REVIEW

Elison [1] presented some relationships between attribute and application, and also indicated that some desirable properties such as function, shape, tolerance, material and manufacturing methods can measure the similarities in a different application area.

Typically the designer determines the appearances and sizes of the parts directly through the CAD system, and also determines the function attributes, and the manufacturing process. Therefore, the shape is the most representative information on the CAD model. If two parts have a high similarity, then the manufacturing processes, finite element analysis, and durability can be shared between them.

The shape of a CAD model is divided into two aspects, namely the mathematical representation of point, curve and surface, and the topological relationships among the geometric entities. Although the information of material and tolerance may be included on the CAD model, most CAD system mainly record the solid model information.

Iyer[2] et al. surveyed the three-dimensional shape search, and categorized 3D shape searching techniques according to shape representations into the following classes: global-feature, manufacturing feature recognition, graph, histogram, product information, and 3D object recognition.

Some researchers have focused on the descriptions of shape descriptors [3][4][5][6][7][8]. These descriptors are broadly classified into two groups: namely contour-based and region-based shape descriptors. Contour-based shape descriptors include Fourier descriptor (FD). Because contour-based shape descriptors only employ boundary information, they cannot capture the interior content of a shape. Region-based techniques derive shape descriptors from all the pixel information within a shape region. The continuous and discrete 2-D Fourier transform of a shape image $f(x,y)\,(0 \le x < M, 0 \le y < N)$ are given by Eqs. (1) and (2), respectively.

$$F(u,v) = \int_x \int_y f(x,y) \times \exp[-j2\pi(ux+vy)]\,dxdy \tag{1}$$

$$F(u,v) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y) \times \exp[-j2\pi(ux/M + vy/N)] \tag{2}$$

The $u$ and $v$ in Eq. (2) denote the $u$th and $v$th spatial frequency in the horizontal and vertical directions, respectively.

The FD should not be calculated directly from the image because of the variant problem of the translation and rotation. Usually, the original shape image in the polar space is first computed, and then transferred onto the rectangular polar image on the Cartesian space. Hence, the 2D FT is applied on this rectangular image, and the polar FT has a similar form to the normal 2D discrete FT in Cartesian space.

Cardone et al. [9] presented an algorithm to identify machined parts in a part database. They adopted reduced feature vectors to access shape similarity defining a distance function between two sets of reduced feature vectors to distinguish two similar parts.

The Google search engine has become the standard text-based search engine. Funkhouser et al. [10] presented a Web-based search engine system that supports queries based on 3D sketches, 2D sketches, 3D models and text keywords. For the shape-based queries, they developed a matching algorithm that adopts spherical harmonics to calculate discriminating similarity measures.

Recently some engineering shape benchmark are proposed by Doug et al. [11] and Jayanti et al.[12] and similarity comparison are proposed by Hong et al. [13].

This investigation develops a web-based architecture for processing 3D machined parts through an Internet and communicates with PDM systems in order to preserve the automatic version control of the parts.

## 3. PROPOSED APPROACH

### 3.1 Shape Representation and Similarity Criteria

Various shape representation and similarity criteria have their benefits and limitations. To handle real applications, similarity criteria should fulfill the following requirements:

a. The shape representation should be unique.
b. Shape representation should be twisted invariant.
c. The relationship between the shape representation and similarity evaluation should be highly linear.
d. The result of similar assessment should be symmetrical.
e. The computational time of similarity evaluation should not be proportional to the number of the candidate parts.

### 3.2 Searching Target

The proposed searching algorithm should be able to retrieve the STEP (STandard Exchange of Product data model) file format from various CAD systems. As well as the STEP AP 203 file format, the proposed method also support the triangular mesh and native file (.prt) of the SpringSolid system. SpringSolid system was developed by the Solid Model Lab. at National Taiwan University.

Since STEP AP 203 only knows the information of manifold_solid_brep entity, which is the external shape of the part, feature recognition is first parsed and analyzed. Some information of manufacturing features can be obtained for further analysis.

### 3.3 Shape Representation

The main representation task can be divided into two parts, namely feature and shape. Figure 1 illustrates the analytic approach.

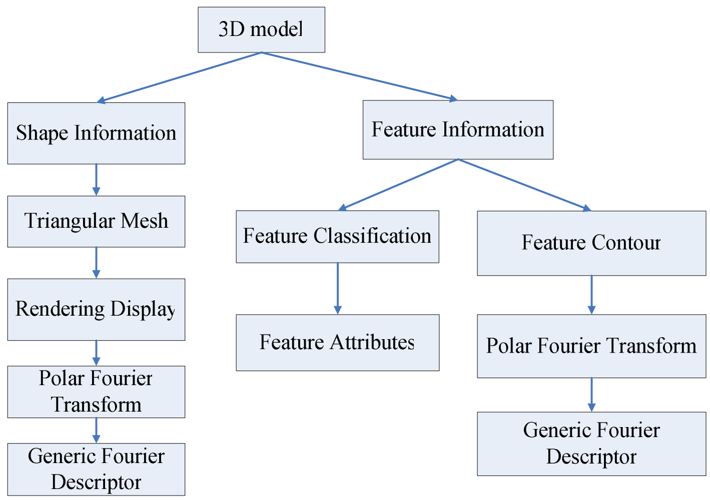


Fig. 1: Analytic approach.

This approach employs 2-D Polar Fourier Transform (PFT). The amplitude of PFT frequency is applied to evaluate the Generic Fourier Descriptor (GFD). The GFD index from the PFT algorithm can be adopted to describe the image contour.

Multiple views can be utilized to overcome problems resulting from the rotation effect of an object. Light field cameras are placed on 20 vertices of a regular dodecahedron. Twenty different views are obtained, distributed uniformly over a 3D model. The 20 views can roughly represent the shape of a 3D model as shown on Fig. 2. Two extra projection images from the negative Y axis $(0,-1,0)$ and the negative X axis $(-1,0,0)$ are provided to suit the behavior of CAD modeling. The ability to run the rendering shading is the essential capability of the CAD system, where Java3D is adopted for the graphic user interface.

The proposed approach focuses on the representative items of the manufacturing feature, including the feature type, feature quantity, approach direction, datum position and growing direction.

The feature profile and growing direction can be compared for the same type feature. Since the feature profile is 2D domain, it can use GFD rule to analyze the feature profile. Figure 4 depicts a flow chart of manufacturing feature comparison.

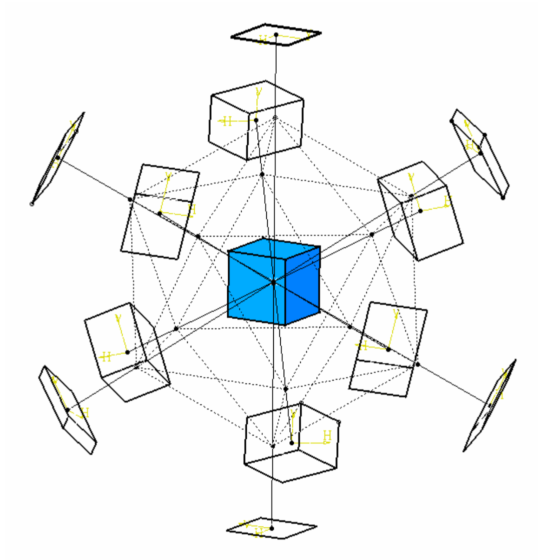

Fig. 2: Light field cameras on 20 vertices of a regular dodecahedron.

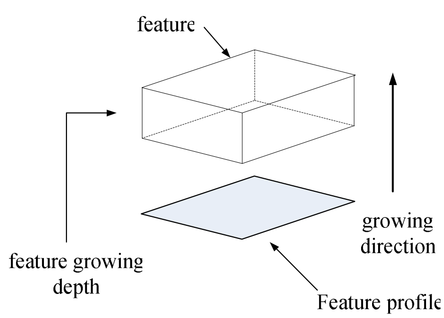


Fig. 3: Feature profile.

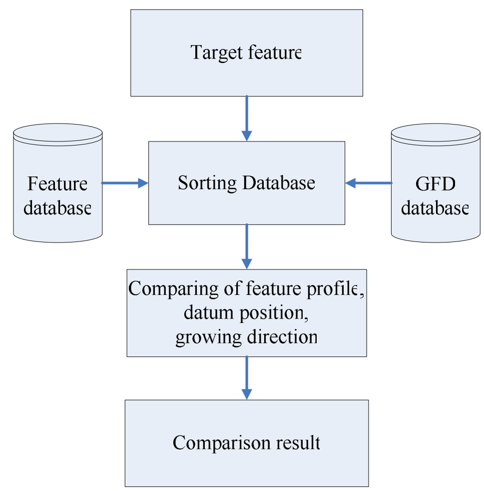


Fig. 4: Feature comparison.

### 3.4 Similarity Evaluation

The similarity comparison between two parts can be performed after completing the calculation of GFD and feature analysis,

The GFD descriptor is the frequency spectrum distribution of the discrete elements. A low frequency item can influence entire shape of the body, while a high frequency item can affect the detail of the contour.

To describe the shape, the acquired Fourier coefficients must normalize, so that their rotation, scaling and start points are independent of shape descriptors. The similarity between the query shape Q and a target shape T is derived from the Euclidean distance *d* between their GFDs:

$$d = \left( \sum_{i=1}^{N/2} \left| GFD_i^Q - GFD_i^T \right|^2 \right)^{1/2} \tag{3}$$

where N denotes the number of discrete points.

The high-frequency coefficients strongly affect the contour, while the low frequency coefficients have little effects on it. The modified Euclidean distance d between their GFDs proposed in this schema is givcn by

$$d = \left( \sum_{i=1}^{N/2} \left| GFD_i^Q - GFD_i^T \right|^2 \times GFD_i^T \right)^{1/2} \quad (4)$$

Fig. 5 illustrates the flow chart of shape comparison.

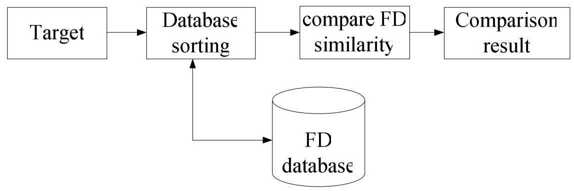


Fig. 5: Flow chart of shape comparison.

## 4. SYSTEM IMPLEMENTATION

The proposed algorithm is written in Java, with Swing for the graphic user interface, Java 3D for displaying 3D graphic shape representations and a Microsoft SQL Server database to store the necessary information.

### 4.1 System Architecture

To search the similarity part in PDM system [14], a Thick Server-Thin Client is applied for the system architecture, which is divided into three sections, web-page interface, server with computational kernel and database, as illustrated in Fig. 6.

A web-page user interface is adopted to access and retrieve the drawing files, view the 3D graphic representations and display the sorted results.

Shape and feature retrieval and evaluation to calculate the GFD index is the kernel of the proposed approach. To lower the burden of the user interface, this high heavy calculation is separated from the graphical user interface. After reading the STEP file, the proposed approach first executes the feature recognition, and reconstructs and splits the advanced face, and finally transfers the triangular mesh to a web-page interface in order to display the 3D object.

The calculation kernel has two elements, the GFD server manager and the PDM server. The GFD server manager can create the corresponding GFD computing server, which can analyze 3D models and calculate the GFD index. The tasks of the PDM server include the management of drawing, evaluation of similarity and data transfer. GFD calculation is then performed with the image of the shape and feature profile in the GFD Computing server. Hence, the value of GFD for the body shape and feature profile can be obtained and passed to the PDM server. The similarity evaluation can then be started in PDM server by comparing this GFD index with the GFD index stored on the database.

For the graphic user interface, it receives the original data file and returns back for displaying the triangular mesh and manufacturing feature information, and stores the necessary information to the database.

The database is employed to store all information on the processes, including the native file, image of shape, image of feature profile, manufacturing features, and results of GFD index. Figure 7 illustrates all data tables.

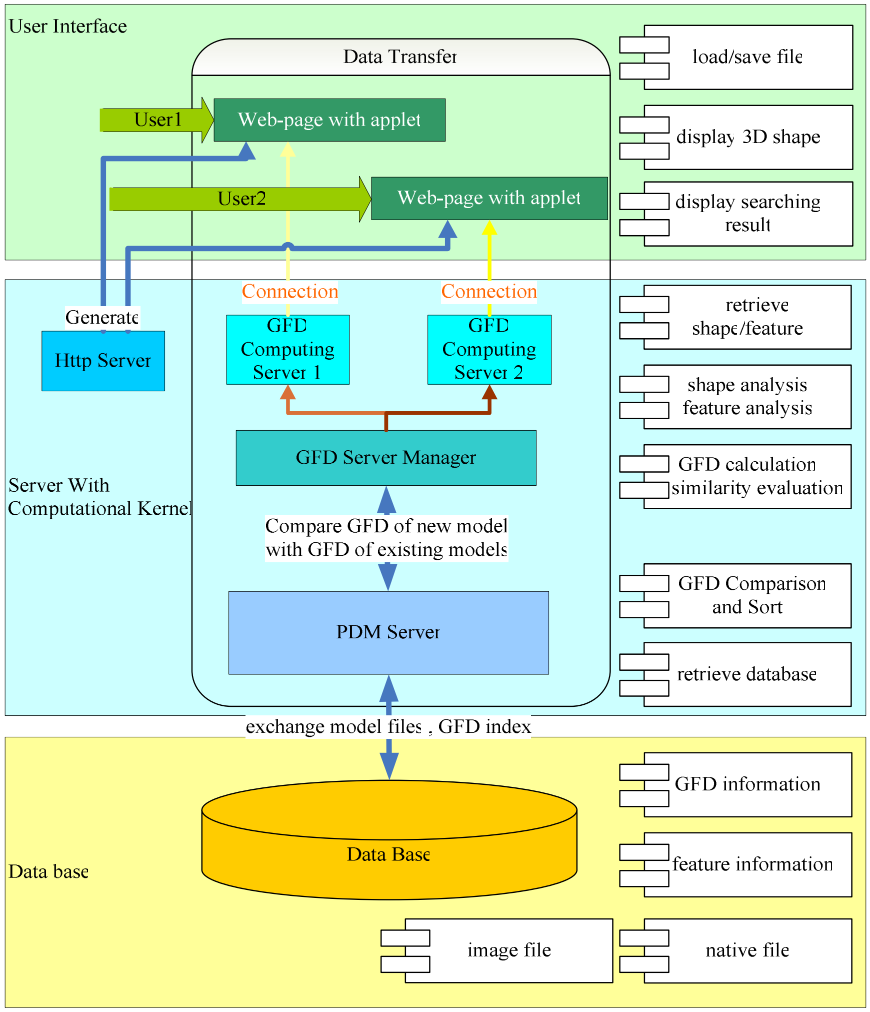


Fig. 6: System architecture of proposed algorithm.

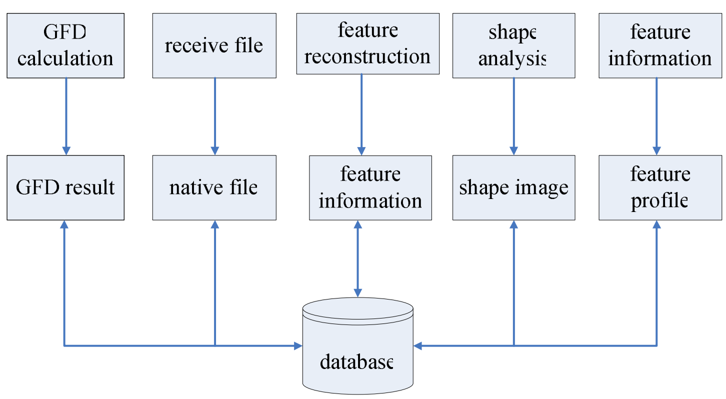


Fig. 7: Data tables.

## 4.2 Similarity Searching Program

The main window of PDM system is shown in Fig. 8. Part files and 3D drawings are managed and displayed in the PDM system. To search for a similarity part in this system, a part file must be chosen first, then pressing the part search button, and the similarity searching program for this part will be activated.

Figure 9 illustrates the graphical user interface for the part search in the PDM system. The Java 3D viewer and setting option is shown on the left, while the part information and searching result is shown on the right of the figure. The target object is also shown on the left top of the figure.

After the file is opened, the part has individual handling process. The part can be viewed and rotated through the 3D visualization. While reading the file, system can parse and recognize all the characteristic features using feature-recognition parser. The manufacturing features and native file are then transmitted to the database management system.

The shape of manufacturing feature can be chosen for comparison according to the type of file. If the shape image is chosen, then the system can automatically rotate the part, and establish the projection image at various view directions. After obtaining the projection image, the system then continues to derive the GFD index by the PFT rule, and compares the target GFD index with that on the database. Finally, the system sequentially sorts the comparing result. The user can click and select part to view or download for reference.

If a user chooses to compare a manufacturing feature, for example general-boss, then the system can compare the feature profile of the general-boss, and sort the comparing results. If the target parts have multiple features, then the system can compare the feature sequentially. Target part has three manufacturing features, and the searching result is also illustrated in Fig. 10.

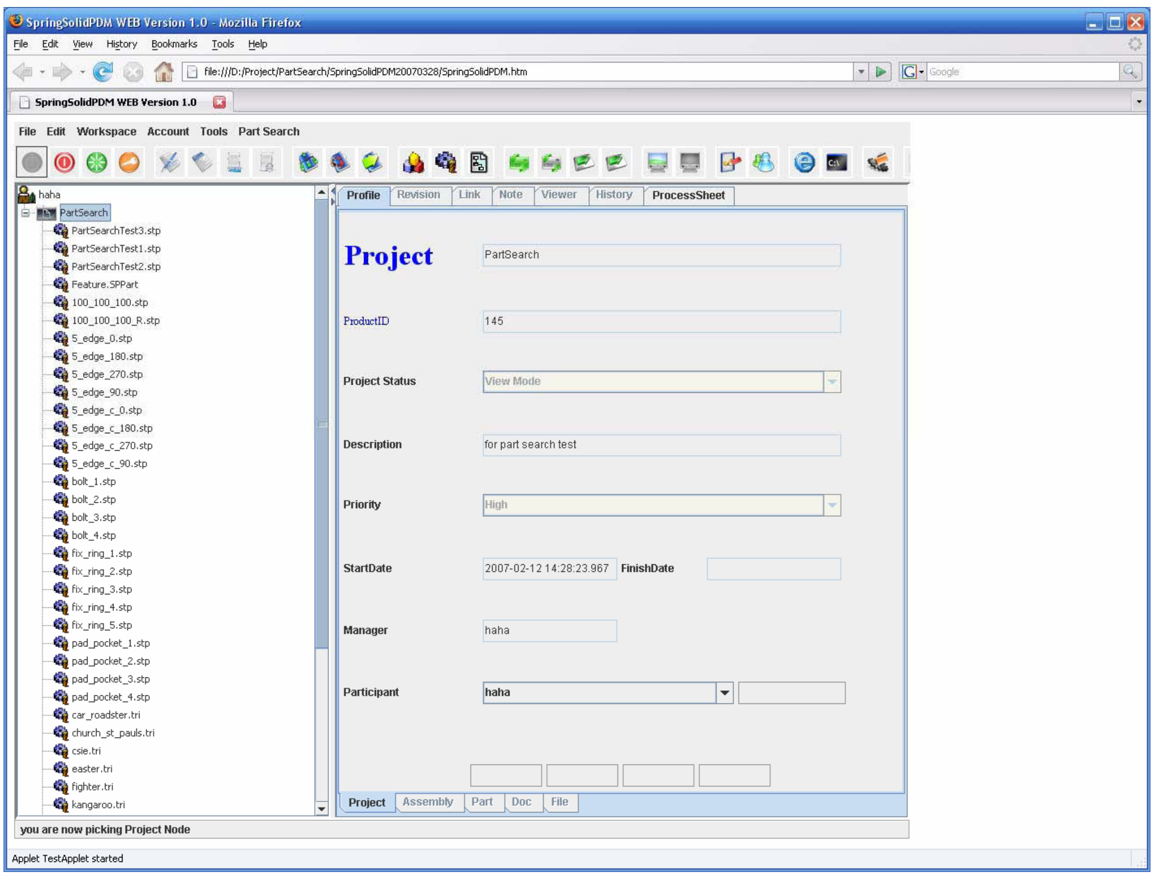


Fig. 8: PDM systems on web-page.

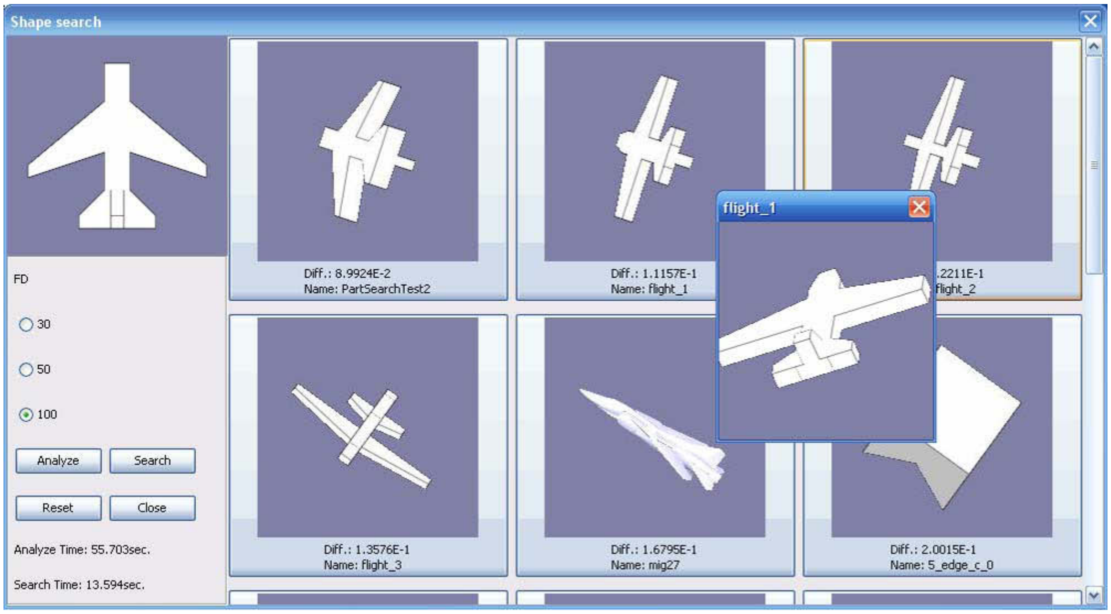


Fig. 9: Searching result of shape representation with GFD index = 100.

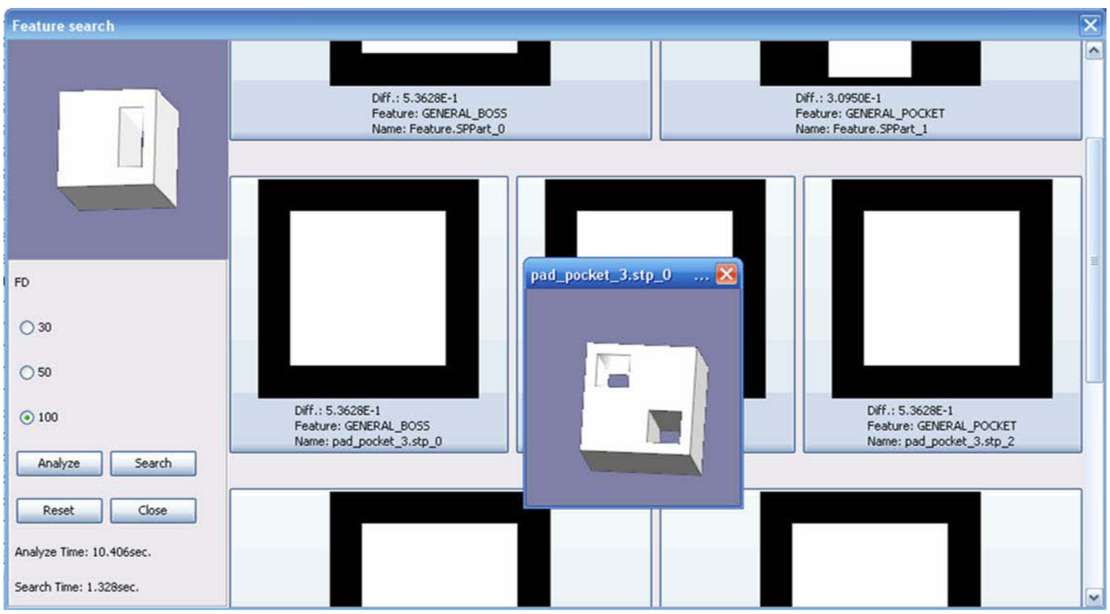


Fig. 10: Searching result of multiple feature representation.

## 5. CONCLUSION AND FUTURE WORK

The proposed method can handle the file format of Spring Solid Part, STEP AP203 and triangular mesh, and can utilize the GFD descriptor to measure the similarity of the shape and manufacturing features in the PDM system. The proposed method can be run on a standalone platform or in a web-based environment. The proposed method has the following features:

a. Given a target part with characteristic attributes, the method can be applied to search for similar parts in the database based on the shape or manufacturing feature, and sort the result in order of similarity.
b. The user can download the candidate part from the database.

Future work may include the following directions:

a. The proposed algorithm for the similarity evaluation adopts the PFT method, which is a discrete Fourier transform method with a long computation time. Fast Fourier transform can be applied in order to reduce computational time.
b. The manufacturing feature set is very limited. The range of manufacturing features could be expanded.

## 6. ACKNOWLEDGEMENT

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