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# DEVELOPMENT OF HOLE RECOGNITION SYSTEM FROM STEP FILE

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**ABSTRACT**

This paper describes the development of Hole Recognition System (HRS) for Computer-Aided Process Planning (CAPP) using a neutral data format produced by CAD system. The geometrical data of holes is retrieved from STandard for the Exchange of Product model data (STEP). Rule-based algorithm is used during recognising process. Current implementation of feature recognition is limited to simple hole features. Test results are presented to demonstrate the capabilities of the feature recognition algorithm.

**Keywords**: Feature recognition; Feature; STEP file.

## 1. INTRODUCTION

A Computer-Aided Process Planning system is a vital link between CAD and CAM in a Computer Integrated Manufacturing (CIM) environment. Its main elements are extraction design information, process selection and sequencing; machine and tool selection; machining steps and their sequence; dimensions and tolerances; operational parameters selection. Regardless of how the information is input into CAPP, a majority of the current systems rely on an experienced planner to provide the necessary translation between the 'geometry' (lower level) language of the CAD and the higher-level language of CAPP [1].

When manual process is used in this translation, it is often error prone, inconsistent and time consuming. Direct information transfer using feature technology from CAD to CAPP will reduce some of these problems. But, most of existing CAD system does not provide part feature information. In other word, CAPP systems do not understand the three dimensional geometry of the designed parts from CAD systems in term of their engineering meaning related to manufacturing or/and assembly [2]. To solve the CAD and CAPP interface problem, the feature recognition is one the most efficient approach.

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Many techniques have been proposed for the feature recognition problem [3 - 7]. The type and format of data provided by the geometric modeller greatly influence the feature recognition techniques that were developed.

Some research works have been undertaken for the feature recognition from STEP file [8,9]. The purpose of STEP is to build a common standard that ensures the product data can be communicated electronically across different platforms, e.g. CAD, CAM and CAE.

Cicirello and Regli [8] presented the approach to using machining features as an index-retrieval mechanism for solid models. One of the technical approaches for this research is to perform machining features extraction to map the solid model to a set of STEP machining features. The machining features that were recognised in this approach were hole and pocket. The technique that was used to extract the machining features is a graph-based approach, namely Model Dependency Graph (MDG). The MDG is a mechanism for archival and retrieval of models in CAD databases and can be employed using a query by example paradigm. In addition, based on MDG, it can create query artifacts that partition the database of solid models into different morphism classes. The proposed approach considers only plain, unattributed solid models; where there is no tolerances, manufacturing attributes, surface finish specifications, etc.

Han et al. [9] proposed the work to integrate the feature recognition and process planning in the machining domain. The purpose of the work is to achieve the goal of CAD/CAM integration. The system that was proposed uses STEP as input and output formats. STEP is the interface for portability between CAD and planning systems, feature recognition for manufacturability and setup minimisation, feature dependency construction, and generation of an optimal feature-based machining sequence. The geometric reasoning kernel of Integrated Feature Finder ($IF^2$) that were used in this work was able to recognise holes, slots and pockets. $IF^2$ is a hint-based reasoning system.

Bhandarkar and Nagi [10] developed feature extraction system takes STEP file as input and to define the geometry and topology of a part. In addition, the system generates STEP file, as output with form feature information is AP224 format for form feature process planning. The STEP file can be exchanged between various companies and can serve as input to further downstream activities such as process planning, scheduling and material requirement planning (MRP). The feature recognition algorithm in this work is boundary-representation (B-Rep) based and follows a sequential approach through an existing classification of features. The algorithm in this work currently developed for prismatic solids produced by milling operations and that contains elementary shape such as plane and cylindrical surfaces (possibly using non-uniform rational B-splines (NURBS)). The feature extraction system can store the feature data in a computer interpretable format and which can transmitted between various locations. In addition, the system also aimed at overcoming the shortcomings of the design by feature approach, which is limited by the number of features in the pre-defined library of features.

Another research done by Ismail et. al. [11] developed an experiment feature recognition system to recognise simple and complex holes features using geometry and topology information from the Boundary representation (B-rep) model. In their work, spatial addressability information of geometric modellers is used as a basic of a feature recognition algorithm. Complex hole consists of multiple curve edge segments. This happens when a hole intersects with an edge or vertex of a part. The faces of the hole are either cylindrical faces or conical faces. Another advantages of the algorithm are that hole and/or boss features that exist on sloping faces and at slanting angles to the part could also be recognised.

Staley et. al. [12] described a system for recognising holes from 3D solid geometric data base and eight primitives were used to classify multi-diameter holes consisting planar, cylindrical, spherical, toridal and conical faces. The user interactively selects a hole and specifies the start and end section vertex on the cross section face. If the input string matches any of the grammars, the system returns a value ‘true’ and specifies the type of hole that is recognised.

However, none of the above researchers have concentrate on STEP file from CAD software and knowledge-based system to recognise hole features for CAPP in particular. The aim of this paper is to describe the development of a hole recognition system where majority of mechanical parts have hole features such as in tool and die industry.

## 2. HOLE FEATURE DEFINITION

The feature has many definitions and there is no consensus on a common definitions. The term feature is derived from Latin word “facture” which means the act of making or formation [13].

Hole feature is the feature that removes material in the shape of several standard holes. The standard holes are simple hole, counter-sunk hole and counter-bored hole. The holes can be created to a specific depth or completely through body [14].

Noort et al. [15] defined form features as regions of the part that have some functional meaning. The form features contain class-specific design information that is captured by means of feature elements and feature constraints. Feature elements are shapes and user-defined variables. Features constraints can be, for example, a geometric distance face-face constraint, a dimension constraint, which specifies a dimension to be within a given range, and on-boundary constraint, which specifies a feature face to be on the boundary of the part.

### 2.1 STEP file

The STEP file is a text file that contains geometrical data of a component including boundary representation data such as shells, faces, vertices; surface geometric data such as planes, cylinders, cones, toroidal; curve geometric such as lines, circles and ellipses [16]. The brief description of some STEP elements is provided as shown in Table 1.

***Table 1:*** *The brief description of some STEP elements*

| STEP Element | Description |
|---|---|
| CARTESIAN_POINT | Address of a point in Cartesian space. |
| ADVANCE_FACE | The face that associated with a type of surface |
| CYLINDRICAL_SURFACE | A face of cylinder in which the geometry is defined by the associated surface, boundary and vertices. |
| CIRCLE | A circle in which the geometry is defined by the associated surface, boundary and vertices. |
| PLANE | A plane in which the geometry is defined by the associated surface, boundary and vertices. |

Example of STEP file for blind/through hole is shown in Table 2. In general, the geometrical data of a blind/through hole is as follows:

1. The entity #27, it refers to first CIRCLE with the radius of 2.0 mm. The CARTESIAN-_POINT or centre of the circle refers to entity #23 and is described as follows:

$$X = 4.0, Y = 5.0, Z = 70$$

2. After the entity of circle, there is always a entity of plane (#72) with CARTESIAN_ POINT as follows:

X = 4.0, Y = 5.0, Z = 7.0

The CARTESIAN_POINT of the PLANE is the same with the CARTESIAN_POINT of the first circle. The entity of a plane is able to show either the circle is a circle with plane or otherwise. The entity #73 ADVANCE_FACE indicates that the entity #27 CIRCLE is circle without plane because the entities in second close quote as in line #73 have more than 2 entities (#33, #67) and it means the circle is subtracted from the plane (#72).

3. The second CIRCLE is shown in entity #157 with the radius of 2.0 mm. The CARTESIAN_POINT or centre of the second circle is described as following:

X = 4.0, Y = 5.0, Z = 0.0

The entity #179 PLANE that has the same CARTESIAN_POINT with second circle is used to determine whether the second circle is circle with plane or otherwise. From the entity #180 ADVANCE_FACE indicates that the entity #157 CIRCLE is circle without plane because the entities in second close quote as in line #180 have more than 2 entities (#163, #174) and it means the circle is subtracted from the plane (#179).

4. The entity #203 shows the CYLINDRCAL_SURFACE with the radius of 2 mm. The CARTESIAN_POINT or centre of the CYLINDRICAL_SURFACE is described as follows:

X = 4.0 , Y = 5.0, Z = 7.0

From the geometrical data of CYLINDRICAL_SURFACE, it shows that the x-axis and the y-axis of the CYLINDRICAL_SURFACE are the same with first circle and second circle. The radius of CYLINDRICAL_SURFACE, either first CIRCLE or second CIRCLE, will have same values. It indicates that first circle and second circle are adjacent to CYLINDRICAL_SURFACE.

***Table 2:*** *Partial STEP file of Through and Blind holes*

```
ISO-10303-21;
 HEADER;
•
 DATA;
•
#23=CARTESIAN_POINT('',(4.,5.,7.));
#27=CIRCLE('',#26,2.);
………………………………………………………..
#68=CARTESIAN_POINT('',(4.,5.,7.));
#72=PLANE('',#71);
#73=ADVANCED_FACE('',(#33,#67),#72,.T.);
………………………………………………………..
#153=CARTESIAN_POINT('',(4.,5.,0.));
#157=CIRCLE('',#156,2.);
………………………………………………………..
#175=CARTESIAN_POINT('',(4.,5.,0.));
#179=PLANE('',#178);
#180=ADVANCED_FACE('',(#163,#174),#179,.T.);
```

## 3. OVERALL SYSTEM DESCRIPTION

The proposed system comprises of user database, inference engine and interface. It was developed using KAPPA PC because it has a good programming environment composed by some graphical tools for object management, rule management and code management.

### 3.1 Database

The database of the system is from STEP file from UniGraphics CAD/CAM Software. This STEP file is postprocessed first before input to KAPPA PC [17] using C language. The holes' geometric information after postpocessing is represented in hierarchy tree as shown in Fig. 1. The overall system hierarchy tree is shown in Fig. 2. Result of feature database is also highlighted in this tree.

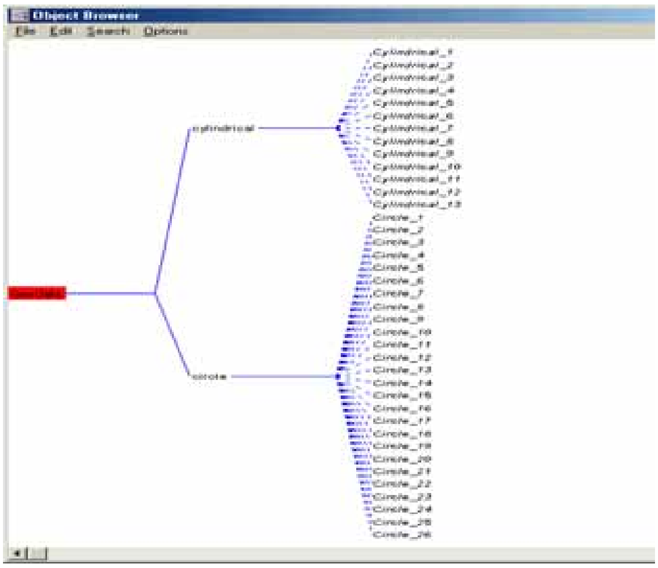



***Fig. 1:*** *Holes' Geometrical and Topological Data*

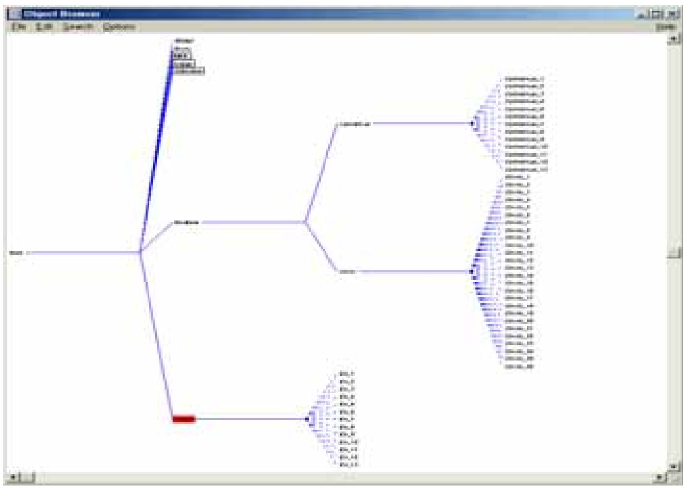


***Fig. 2:*** *Hole Recognition System Hierarchy Tree*

### 3.2 Recognition algorithm

The recognition algorithm of HRS is rule-based technique where rules are specified with a IF Condition THEN Conclusion syntax. Condition is composed by a set of tests on object attributes linked by logic operator (AND, OR, XOR).

As example, the rule for through hole at XY plane (see Figure 3) is written as follows:

*If*

*CiX* and *CiY* for a circle (*C1*) equal to *CiX* and *CiY* for other circle (*C2*), and also equal to *CyX* and *CyY* for one of the cylindrical (*Cy1*)

***And***

*CIRADIUS* for circle (*C1*) equal to *CIRADIUS* for circle (*C2*) is, and equal with *CYRADIUS* for the cylindrical (*Cyl*)

***And***

*CIPLANE* for one of the circle (*C1*) is *FALSE*

***And***

*CIPLANE* for circle (*C2*) is *FALSE*

Then

The result is***Through Hole***

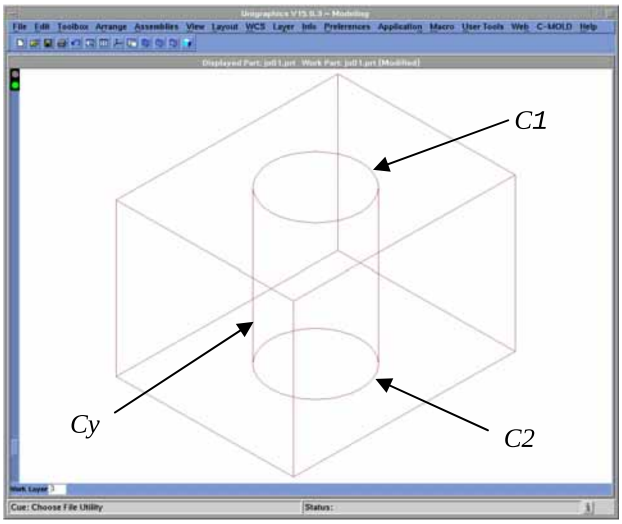



***Fig. 3***: *Definition of through hole*

### 3.3 Inference Engine

This HRS is used forward chaining, where four different strategies may be used in selecting the rule to be applied from a set of rules with same priority: bestfirst, depthfirst, breadthfirst or selective. The rule structure of through hole which is used in the recognition process using KAPPA-PC is shown in Fig. 4. The rules for recognising through and blind holes in XZ plane and YZ plane have been developed as well.

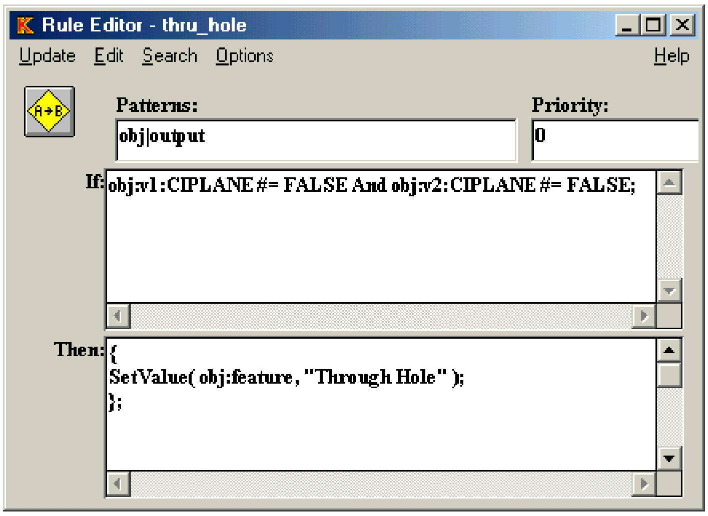



*Fig. 4*: *Rule editor for Through Hole*

### 3.4 User Interface

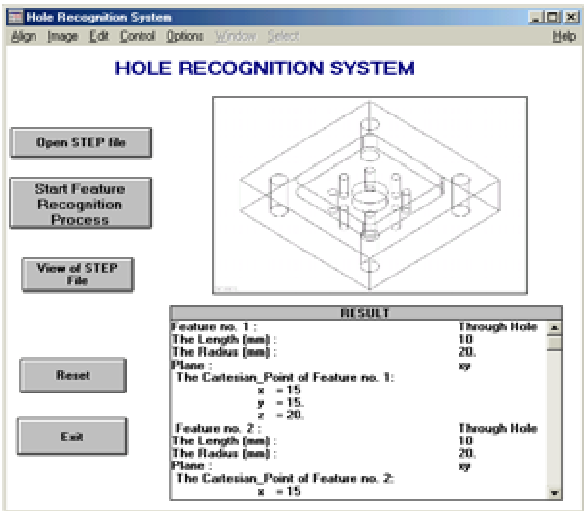



***Fig. 5:*** *The window of Prototype Hole Recognition System*

The proposed user interface for HRS is shown in Fig. 5. The HRS offers five options in main menu, namely:

i) Open STEP File

ii) Start Hole Feature Recognition Process

iii) View of STEP File

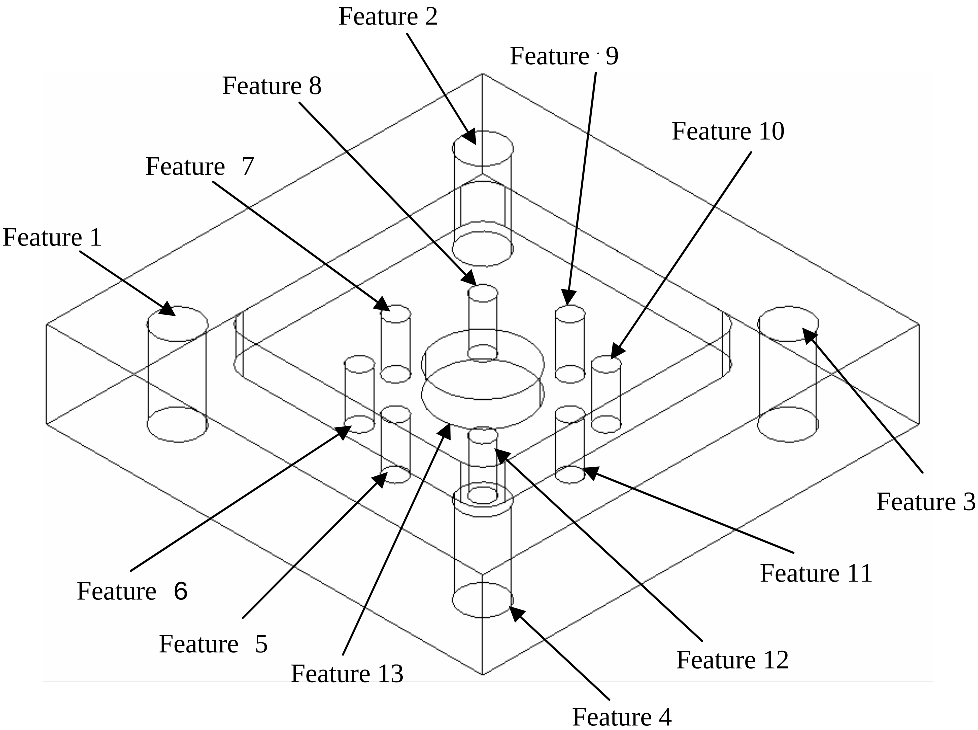
iv) Reset

v) Exit

The STEP file is generated using Unigraphics CAD/CAM software. To start the recognition process, a STEP file must be postprocessed prior to the recognition process. This can be done by clicking the function 'open STEP file'. Once processed, click the start Feature Recognition Process function to start the processing. The fist step in HRS is to preprocess the STEP files into a format suitable for KAPPA PC system. Then, rule-based technique is used to recognise the holes features. The output from system is features information in text file format. The 'reset' button is used to reset the HRS and hide the sub-window such as result window.

## 4. RESULT AND DISCUSSION

a) *Solid Model*




b) *Wireframe model and features' identification*

***Fig. 6:*** *Test Part*

The case study's test part is as shown in Fig. 6. The part consists of four through holes, diameter 40 mm, eight through holes, diameter 24 mm, and one blind hole. The partial result of the recognised features is shown in Table 7. All features labelled in Figure 6 are recognised.

HRS is also able to recognise the cylindrical features holes in xy, xz and yz plane with correct length and radius of each hole.

***Table 3:*** *Partial processed data results for case study*

| | |
|---|---|
| Feature no. 1 : | Through Hole |
| The Length (mm) : | 10 |
| The Radius (mm) : | 20. |
| Plane : | xy |
| The Cartesian_Point of Feature no. 1: | |
| x = 15 | |
| y = 15. | |
| z = 20. | |
| Feature no. 2 : | Through Hole |
| The Length (mm) : | 10 |
| The Radius (mm) : | 20. |
| Plane : | xy |
| The Cartesian_Point of Feature no. 2: | |
| x = 15 | |
| y = 85 | |
| z = 20. | |
| Feature no. 3 : | Through Hole |
| The Length (mm) : | 10 |
| The Radius (mm) : | 20. |
| Plane : | xy |
| The Cartesian_Point of Feature no. 3: | |
| x =85 | |
| y = 85 | |
| z = 20. | |
| Feature no. 4 : | Through Hole |
| The Length (mm) : | 10 |
| The Radius (mm) : | 20 |
| Plane : | xy |
| The Cartesian_Point of Feature no. 4: | |
| x =85 | |
| y = 15. | |
| z = 20. | |
| Feature no. 5 : | Through Hole |
| The Length (mm) : | 5 |
| The Radius (mm) : | 12 |
| Plane : | xy |
| The Cartesian_Point of Feature no. 5: | |
| x = 5. | |
| y = 30 | |
| z = 12 | |
| Feature no. 6 : | Through Hole |
| The Length (mm) : | 5 |
| The Radius (mm) : | 12 |
| Plane : | xy |
| The Cartesian_Point of Feature no. 6: | |
| x = 35.8578 | |
| y = 35.8578 | |

## 5. CONCLUSION AND FUTURE WORK

The HRS through the used case study has demonstrated that the STEP file and Rule-based technique is applicable for recognising simple cylindrical form features. One of the shortcoming of using this method is that, a hole that is drilled at an angle to the entrance face (elliptical edges) would not be recognised. Complex hole features are not recognised as well. The work is being extended to include:

- The integration of a rule management system into HRS.
- The development of an intelligent process planning system using feature-based as an input.
- The recognition of more manufacturing features such as slot, pocket, counter-bore, etc.

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