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Data Extraction From CAD Model For Rotational Parts to be Machined at Turning Centres

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Abstract

Among the most important data produced and stored is product data. CAD data forms one of many contributors to product data. Although in most circumstances CAD data can be processed within the CIM environment by integrated software components to produce information like manufacturing data, assembly data, etc., there are a significant number of cases where an external CAD resource needs to be processed. An external CAD resource comes in the form of a neutral file format such as DXF, IGES, STEP, etc. Extracting the necessary information from an exchange file to generate manufacturing parameters thus becomes an important task. In this paper we present the results of our research efforts which were intended to extract information from the defacto industry standard DXF files to determine features existing on rotational parts to be machined on turning centres, and later utilise this information in the context of a software package implemented to develop a post-processing expert system. The feature extraction module presented in this paper, forms part of that expert system, which is named ASALUS (Aslan, 1995) and is illustrated in Figure 1. ASALUS is designed to manage the life cycle of rotational parts from the design all the way to the production by performing process planning using a generative approach and applying post-processing for two different CNC lathes.

Key Words: Data Extraction, Process Planning, DXF, Post-Processing.

Silindirik Parçaların Tornalama Merkezlerinde İşlenebilmesi İçin BDT Modelinden Bilgi Çıkarımı

Özet

Bir BTÜ sisteminde oluşturulan ve kaydedilen bilginin en önemlilerinden biri ürün bilgisidir. BDT'den elde edilen bilgi, ürünün bir kısım bilgisini içerir. Bir çok durumda BDT bilgisi tümleşik yazılım elemanları yardımıyla, imalat ve montaj gibi gerekli bilgileri elde etmek amacıyla BTÜ ortamında işlenmekle beraber, BDT programından bağımsız olarak da işlenmesi gerekebilir. Bu yüzden üretim parametrelerinin oluşturulması için dönüşüm dosyasından gerekli bilginin çıkarılması önem arz etmektedir. Bu makalede;

silindirik parçalardaki işlenecek özelliklerin tanımlanması amacıyla DXF dosyasından bilgi çıkarımına yardımcı olacak bir çalışmanın sonuçları sunulmuştur. Buradan elde edilen bilgiler bir son işlemci uzman sistemin geliştirilmesi için kullanılmıştır. Bu makalede sunulan özellik çıkarım modülü ASALUS (Aslan, 1995) uzman sistemin bir parçasını oluşturmuştur ve sistemin genel şeması Şekil 1'de verilmiştir. ASALUS, silindirik parçaların tasarımından üretime kadarki döngüyü içeren, üretken işlem planlaması yaklaşımıyla oluşturulmuş ve iki tezgah için son işlemci içeren bir programdır.

Anahtar Sözcükler: Bilgi Çıkarımı, İşlem Planlaması, DXF, Son İşlemci.

Introduction

One of the core tasks in a CIM environment is to extract and identify the information in the CAD model file. The conventional approach to feature extraction is accomplished by the human planner examining the part and recognising the features designed into the part. Automed feature recognition can best be facilitated by CAD systems capable of generating the product geometry based on features, thereby making it possible to capture information about tolerance, surface finish and so on. However, such CAD systems are not mature yet and their wide usage in different application domains remains to be seen (Hannam, 1997) (Rembold et al., 1993). It is therefore necessary to consider building software modules to extract features from part geometry. This can be achieved either by examination of the internal data structures used to store the geometric modelling information for a particular CAD system in an integrated CAD/CAM environment or by interpreting geometric parameters in an exchange file representing a certain CAD model. In our research we have adopted the latter approach by examining DXF format, which is one of the most popular data exchange formats. The reason for such an adoption is that the feature extraction module introduced here forms an integrated component of the expert system ASALUS developed for post-processing. Figure 1 illustrates interrelations between the components of the system as well as its communication with the outside world. At present the communication of the other components of the system with the CAD model is conceived to be through exchange files rather than a specific CAD system. In the future, it is planned to adopt a CAD system, open to run-time interfacing and consider interpreting the geometric primitives on the fly as they are created by the user.

The feature extraction technique introduced in this paper is based on step-wise examination of geometric data and gradual identification of basic meaningful features which were specified and classified in a structured way. Vertices which define intersection between faces and surfaces of the part are initially extracted from DXF. Diameter, length and other important quantities of the segments are defined according to the vertices extracted. Later on, decisions are made concerning the process types on the part. The details of the technique are discussed in the Data Extraction section.

1. Related Work

Since the birth of the first NC milling machine at MIT in 1947, a huge number of process plans for machine parts have been developed all over the world. Every one has tried to interpret part data into various formats that are reliable and quick. Some of these are standard and some are non-standard. Two of the most popular formats used for CNC machine tools are Initial Graphics Exchange Specification (IGES) and Data Exchange File (DXF). Srinivasakumar et al. (1992) have used IGES format for automatic extraction and recognition of part features directly from a CAD model. Pande and Prabhu (1990) have presented a paper on the design and implementation of data extraction from DXF and tool selection for rotational components manufactured on Automats. Abdou and Cheng (1993) have developed an expert system to generate alternative process plans for mechanical parts with tolerance requirements by retrieving data from DXF. Şeker and Aslan (Aslan and Seker, 1995) have used DXF format for data extraction and feature recognition for prismatic parts to be machined in milling machines. As Subrahmanyam and Wozny (1995) have pointed out that data extraction and feature recognition play an indispensable role for computer aided process planning. Tekiner (1998); Kim and Cho (1994); Gökkaya (1994); Jagirdar et al. (1995); Allada et al. (1994); Çelik (1998) and Singh (1998) have all used DXF for feature recognition, data extraction, data conversion, and for allowing the surface profile to be viewed and manipulated within AutoCAD software or other applications that support DXF output.

2. Data Extraction

The data extraction process begins with an initial pass over the DXF file during which all the vertices defining the intersection points between faces and surfaces are identified and stored for later processing as shown in Figure 2. Diameter, length and other variables of the features are defined by examination of the vertices extracted as illustrated in Figure 3. The next task is to decide on the process types on the part. This is accomplished by comparison the X and Y coordinates of the vertices sequentially. The neighbourhood of the coordinates is examined up to 4 successive vertices to determine whether the feature under examination is identified by 2, 3 or 4 vertices. The decision on the feature type is based on the production rules defined for each feature. The identification of the recess process, however, is carried out in a different way. The recess feature has 27 variations. Consequently, a more sophisticated approach is needed to differentiate and recognise these variations. We have used a binary decision tree in which leaf nodes contain the 27 variants (and hence the decisions made), and higher-level nodes form the conditions that, according to the coordinate comparisons, direct the decision process. The data extraction process is composed of two main tasks: vertex coordinate extraction and feature extraction.

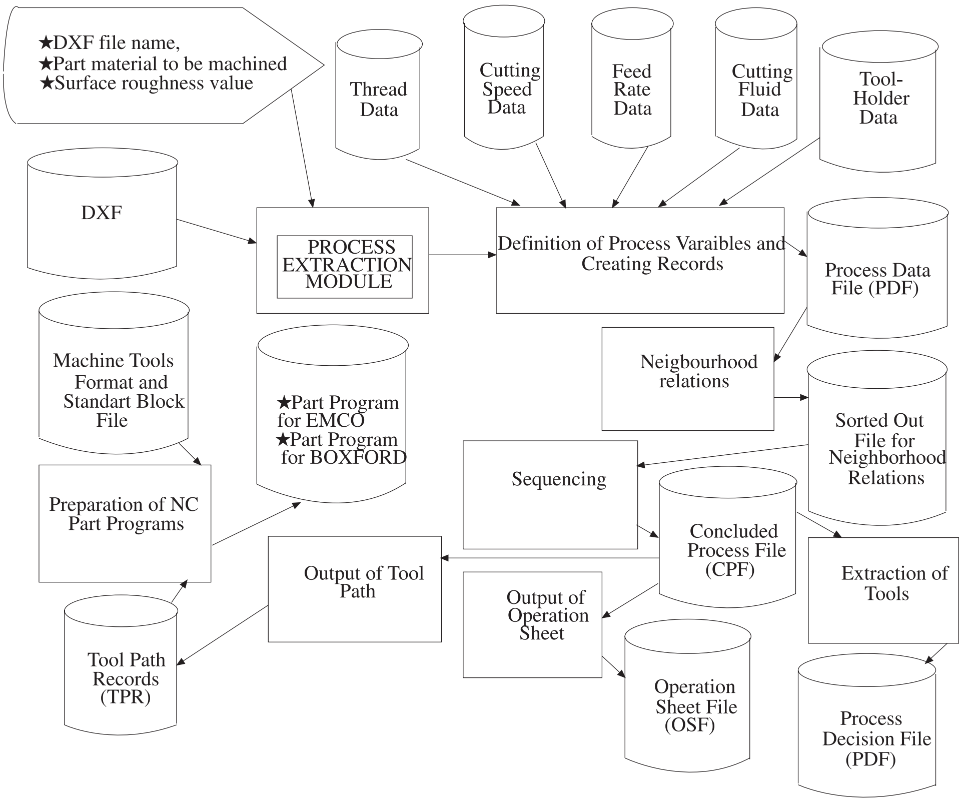

Figure 1. General View of Expert System.

3. Vertex Coordinate Extraction

The vertex coordinate extraciton algorithm utilises headers and flags used in DXF files to identify coordinate values. The VERTEX header, for instance, indicates the beginning of vertex coordinates of edges. All X and Y coordinates are placed under specific flags following this header. The 10 flag precedes an X coordinate value, whereas the 20 flag precedes a Y coordinate value. The flow chart of the algorithm is given in Figure 2. As illustrated in the figure, the coordinates that represent the part are identified and stored into the Vertex Coordinate Array (VCA). Other attributes, such as the X and Y coordinates of fillet beginning, sweeping and beginning angle of the fillet and fillet radius, are extracted and stored into the Fillet Array (FA). Both arrays are saved for further processing.

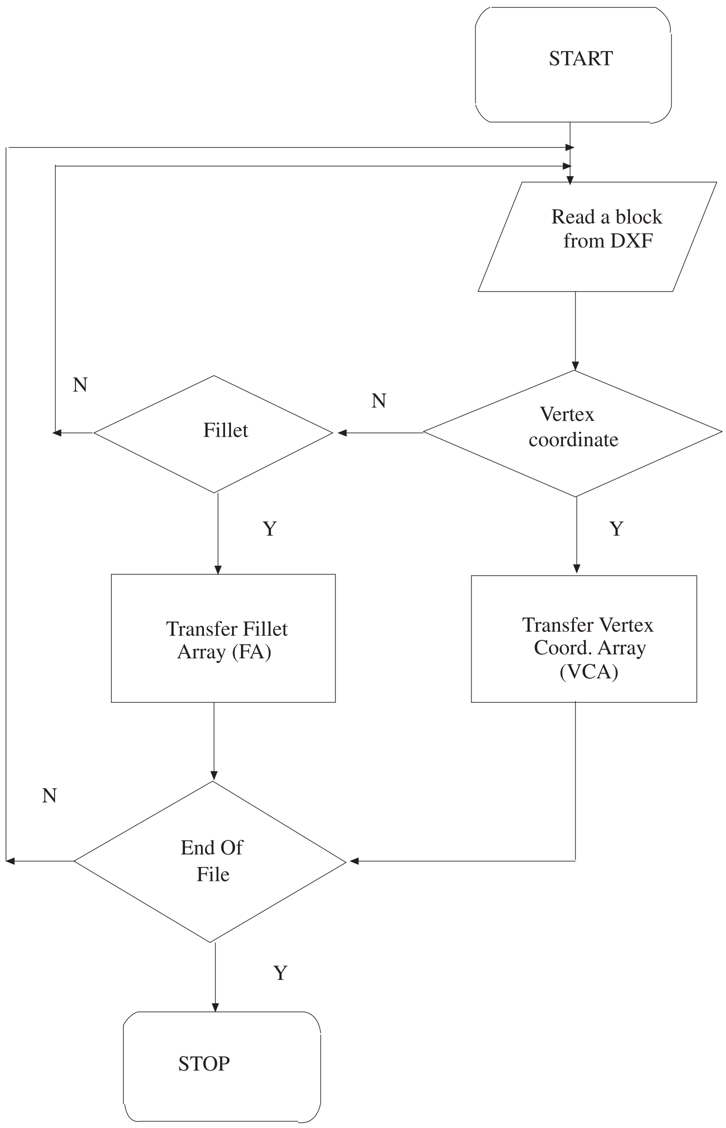

Figure 2. Extraction Algorithm for Coordinates that Define Part Profile

4. Feature Extractions

The system evaluates the coordinates extracted by comparison of 2, 3 or 4 of them to define features. To illustrate how the process works, we elaborate on angled recess as an example in Figure 4. The procedure takes the 1st record from DXF and compares it with its immediate successor. If there is inequality between X coordinates (X1=X2, False), the procedure is carried out by checking against another inequality (X3=X4, False). These conditions constitute intermediate nodes in the binary decision tree used to detect 27 variants of the recess feature as mentioned in the overview section above. The occurrence of inequalities between X1 and X2, and between X3 and X4 is not enough to eliminate the possibility of a radius, so the procedure goes down one more level in the tree to check against the existence of a radius. The absence of the radius causes the algorithm to branch right down the tree. This node is for the deduction of equality between Y1 and Y4. The correctness of the rule leads to a decision and identification of the feature to be an ANGLED RECESS. The binary tree with its condition (intermediate) and decision (leaf) nodes is shown in Figure 5 (Aslan and Alpdemir, 1996) Recess features consist of variations of ANGLED, PERPENDICULAR and FILLETED types. All the variations with validating conditions are listed in Table 1 (Aslan and Alpdemir, 1996). All the extracted data related to feature properties are saved into Feature and Machining Parameters Array (FMPA). Everything for any feature defined by the system has been identified in this array as shown at Table 2 (Aslan, 1995).

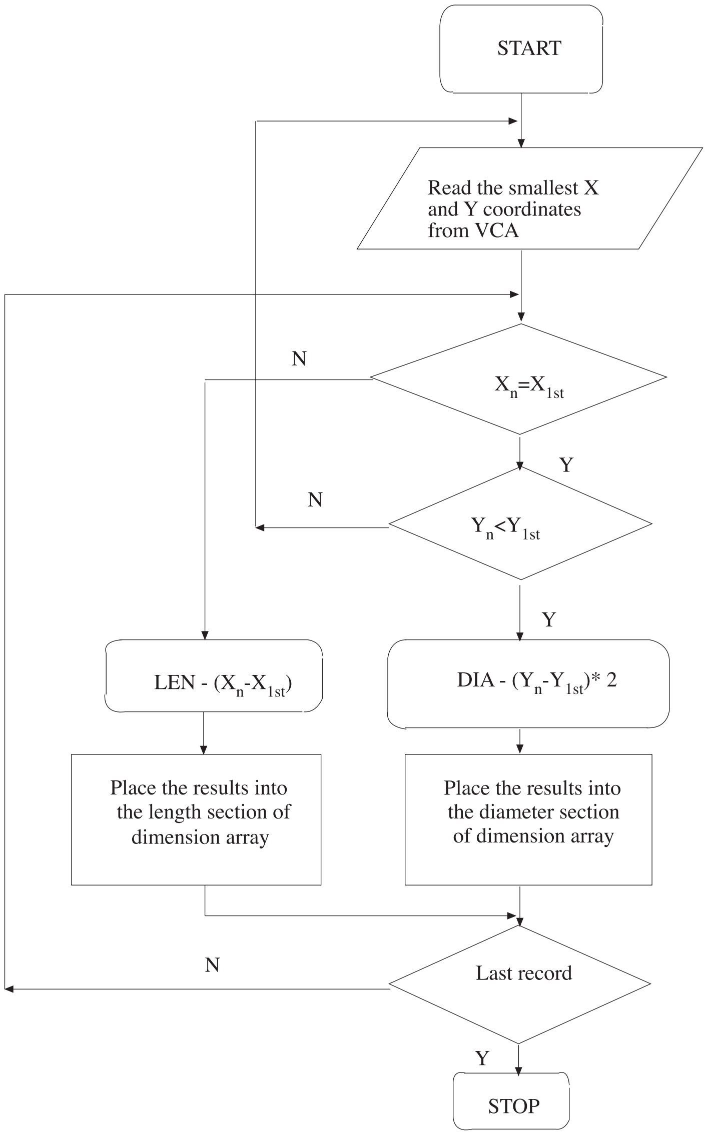

Figure 3. Algorithm for Diameters and Lengths of the Part

Table 1. Validating Conditions for the Recess Features.

SEQ. NO	PROCESS TYPE	X1-X2 COMP.	X3-X4 COMP.	Y1-Y4 COM.	RADIUS
1	F1	X1=X2	X3=X4	Y1=Y4	NONE
2	F2	X1=X2	X3=X4	Y1<Y4	NONE
3	F3	X1=X2	X3=X4	Y1>Y4	NONE
4	F4	X1=X2	X3≠X4	Y1=Y4	NONE
5	F5	X1=X2	X3≠X4	Y1>Y4	NONE
6	F6	X1=X2	X3≠X4	Y1<Y4	NONE
7	F7	X1=X2	X3≠X4	Y1=Y4	RIGHT RADIUS
8	F8	X1=X2	UNRELATED	Y1>Y4	RIGHT RADIUS
9	F9	X1=X2	UNRELATED	Y1<Y4	RIGHT RADIUS
10	F10	X1≠X2	X3≠X4	Y1=Y4	NONE
11	F11	X1≠X2	X3≠X4	Y1>Y4	NONE
12	F12	X1≠X2	X3≠X4	Y1<Y4	NONE
13	F13	X1≠X2	X3=X4	Y1=Y4	LEFT RADIUS
14	F14	X1≠X2	X3=X4	Y1>Y4	LEFT RADIUS
15	F15	X1≠X2	X3=X4	Y1<Y4	LEFT RADIUS
16	F16	X1≠X2	X3≠X4	Y1=Y4	LEFT RADIUS
17	F17	X1≠X2	X3≠X4	Y1<Y4	LEFT RADIUS
18	F18	X1≠X2	X3≠X4	Y1>Y4	LEFT RADIUS
19	F19	X1≠X2	X3≠X4	Y1=Y4	RIGHT RADIUS
20	F20	X1≠X2	X3≠X4	Y1>Y4	RIGHT RADIUS
21	F21	X1≠X2	X3≠X4	Y1<Y4	RIGHT RADIUS
22	F22	X1≠X2	X3=X4	Y1=Y4	NONE
23	F23	X1≠X2	X3=X4	Y1>Y4	NONE
24	F24	X1≠X2	X3=X4	Y1<Y4	NONE
25	F25	X1≠X2	X3≠X4	Y1=Y4	TWO RADIUS
26	F26	X1≠X2	X3≠X4	Y1<Y4	TWO RADIUS
27	F27	X1≠X2	X3≠X4	Y1>Y4	TWO RADIUS

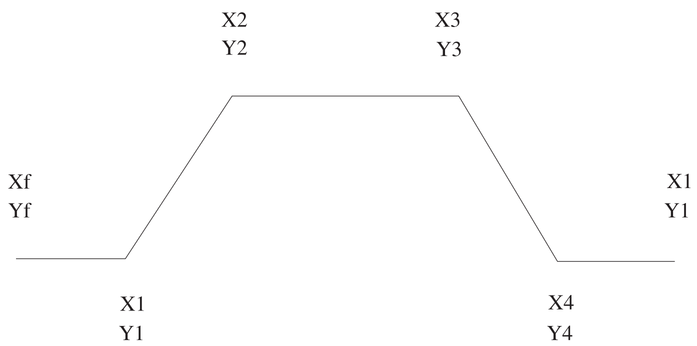

Figure 4. Angle recess.

Table 2. Features and machining parameters array

VARIABLE PROCESS TYPE	B1	B2	B3	B3	B4	B5	B6	B6	B7	B8	B9	B10	B11	B12
FACING	Biggest diameter	Depth of cut	Speed	Feed	Coolant	Surface roughness								
RIGHT CYLINDER	Unmachined diameter	Diameter to be machined	Cylinder length	Cylinder length	D_CSPXPP	D_CEPXPP	Depth of cut	Speed	Feed	Coolant	Surface roughness			
LEFT CYLINDER	Unmachined Diameter	Diameter to be machined	Cylinder length	Cylinder length	D_CSPXPP	D_CEPXPP	Depth of cut	Speed	Feed	Coolant	Surface	roughness		
RIGHT TAPER	Big diameter	Small diameter	Length of conic	Process length	D_COSPF	D_COSPF	Depth of cut	Conic angle	Speed	Feed	Coolant	Surface roughness		
LEFT TAPER	Big diameter	Small diameter	Length of conic	Process length	D_COSPF	D_COSPF	Depth of cut	Conic angle	Speed	Feed	Coolant	Surface roughness		
PERP RECESS	Unmachined Diameter	Diameter to be machined	D_PRSPF	D_PREPF	Recess width	Recess depth	Number of cut	Speed	Feed	Coolant	Surface roughness			
RIGHT CONCAVE FILLET	Unmachined Diameter	Diameter to be machined	Radius	D_RCFSPF	D_RCFEPF	Depth of cut	Speed	Feed	Coolant	Surface roughness				
RIGHT CONVEX FILLET	Unmachined Diameter	Diameter to be machined	Radius	D_RCFSPF	D_RCFEPF	Depth of cut	Speed	Feed	Coolant	Surface roughness				
RIGHT CONCAVE ARC	Unmachined Diameter	Diameter to be machined	Arc radius	Arc start point	Arc end point	Start angle	End angle	Arc angle	I	K	Speed	Feed	Coolant	Surface roughness
RIGHT CONVEX ARC	Unmachined Diameter	Diameter to be machined	Arc radius	Arc start point	Arc end point	Start angle	End angle	Arc angle	I	K	Speed	Feed	Coolant	Surface roughness
ANGLED RECESS	Unmachined Diameter	Diameter to be machined	Biggest recess	Smallest legnth recess	D_ARSPF depth	D_AREPF radius	recess diameter	Recess diameter	Depth of end recess in Z	Speed	Feed	Coolant	Surface roughness	
FILLETED RECESS	Unmachined Diameter	Diameter to be machined	D_FRSPF	Recess length	Recess depth	Fillet radius	Recess small diameter start	Recess small diameter end	Recess end	Speed	Feed	Coolant	Surface roughness	
RIGHT CHAMFER	Unmachined Diameter	Diameter to be machined	D_RCSPF	D_RCEPF	Chamfer length	Depth of cut	Speed	Feed	Coolant	Surface roughness				
LEFT CHAMFER	Unmachined Diameter	Diameter to be machined	D_LCSPF	D_LEPF	Chamfer length	Depth of cut	Speed	Feed	Coolant	Surface roughness				
RIGHT THREAD	Major diameter	Minor diameter	D_RTSPF	D_RTEPF	thread length	Left/right	Pitch	Depth of cut	Number of cut	Speed	Feed	Coolant	Surface roughhess	
LEFT THREAD	Major diameter	Minor diameter	D_RTSPF	D_RTEPF	thread length	Left/right	Pitch	Dept of cut	Number of cut	Speed	Feed	Coolant	Surface roughness	

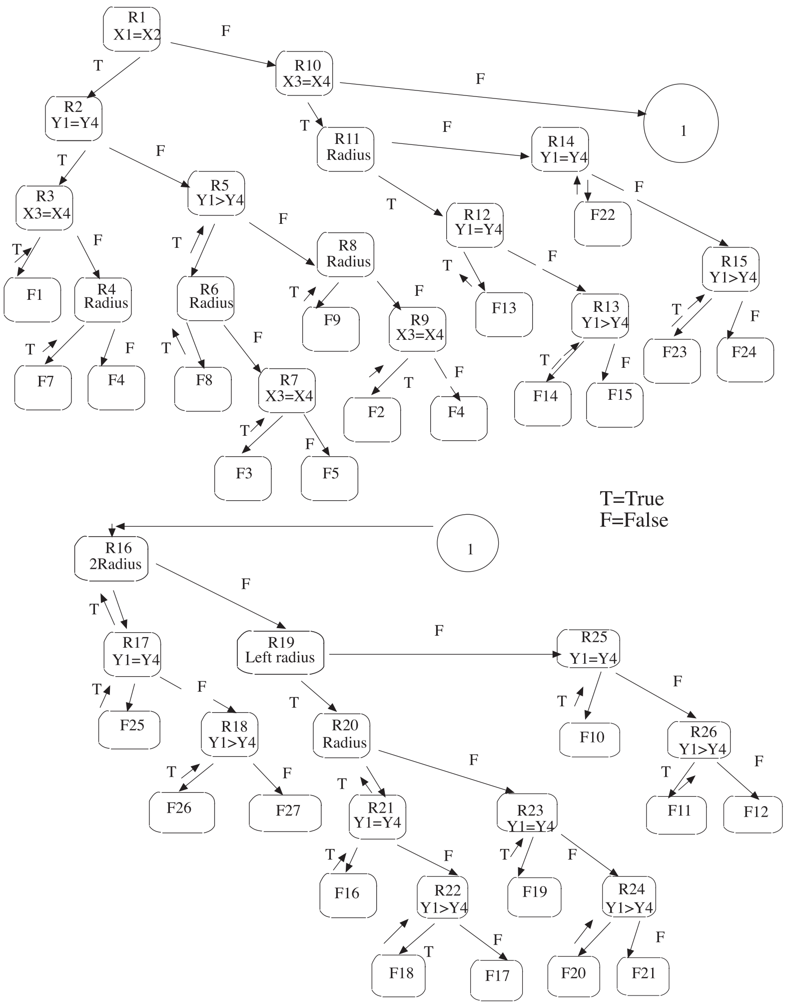

Figure 5. Pre-Defined Binary Decision Tree.

5. Conclusion

There have been 3 main purposes for this research. Part design, data extraction from CAD model, and preparation of feature and machining parameters array (FMPA) for rotational parts have been created and tested, and satisfactory results were obtained. As an output, MPA can be used for further metal removal decisions for turning centers as below:

1. All placing data for features of the part in CAD can be re-evaluated.
2. During machining of the part, the necessity data such as speed, feed and estimated time can be used.
3. The cutting tool chosen can be obtained according to the features in the array.
4. The NC part program can be created by use of machining parameters.
5. Tool life calculation can be maintained because of the speed and feed rates.
6. The preparation of operation sheet for CNC and conventional turning machines can be added as another module.

6. Nomenclature

F1	=	Perpendicular recess
F2	=	Perpendicular recess with long left side
F3	=	Perpendicular recess with long right side
F4	=	Perpendicular recess with angled right side
F5	=	Perpendicular recess with angled right side
F6	=	Perpendicular recess with angled long right side

F7	=	Perpendicular recess with filleted right side
F8	=	Perpendicular recess with filleted short right side
F9	=	Perpendicular recess with filleted long right side
F10	=	Angled recess
F11	=	Perpendicular recess with angled long right side
F12	=	Perpendicular recess with angled long left side
F13	=	Perpendicular recess with filleted left side
F14	=	Perpendicular recess with filleted short left side
F15	=	Perpendicular recess with filleted long left side
F16	=	Angled recess with filleted left side
F17	=	Angled recess with filleted long left side
F18	=	Angled recess with filleted short left side
F19	=	Angled recess with filleted right side
F20	=	Angled recess with filleted long right side
F21	=	Angled recess with filleted short right side
BTÜ	=	Bilgisayar Tümleşik Üretim
BDT	=	Bilgisayar Destekli Tasarım
DXF	=	Data Exchange File
CNC	=	Computer Numerical Control
IGES	=	Initial Graphics Exchange Specification
STEP	=	Standard for Exchange of Product Model Data
CAD	=	Computer Aided Design
CIM	=	Computer Integrated Manufacturing

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