ISSN 1330-3651
UDC/UDK 004.896:514.11

THE PROPOSAL OF A SYSTEM FOR DETERMINING THE CHARACTERISTICS OF MODELED SURFACES

Peter Pokorný, Vladimír Šimna

Professional paper

The paper describes a methodology for determining the characteristics of the modeled surfaces in CAD systems. These characteristics are of major importance for development of process planning. These main characteristics can include surface dimensions, surface orientation and its type. The main role in determining the characteristics of areas is given to the design of a system for storing the CAD data which describe the surface. The file system format STEP AP 214 will serve as input CAD data. The programming language C# 2008 will serve as a tool for CAD data processing using object oriented programming principles. For storing CAD data will be used related database management system MySQL 5.3.

Keywords: *CAD data, database system, normal vector, surface*

Prijedlog sustava za određivanje karakteristika modeliranih površina

Stručni članak

U članku se opisuje metodologija određivanja karakteristika modeliranih površina u CAD sustavima. Te su karakteristike od bitnog značenja za razvoj planiranja procesa. Mogu uključivati dimenzije površine, orijentaciju i tip površine. Glavnu ulogu u određivanju karakteristika površina ima projektiranje sustava za pohranu CAD podataka koji opisuju površinu. STEP AP 214 format sustava datoteke će poslužiti kao ulaz CAD podataka. Programski jezik C# 2008 će poslužiti kao alat za obradu CAD podataka primjenjujući objektno usmjerene programske principe. Za pohranu CAD podataka koristit će se sustav upravljanja bazom podataka MySQL 5.3.

Ključne riječi: *CAD podaci, sustav baze podataka, normalni vektor, površina*

1 Introduction

Process planning converts design information into the process steps and instructions to efficiently and effectively manufacture products. As the design process is supported by many computer-aided tools, computer-aided process planning (CAPP) has evolved to simplify and improve process planning and achieve more effective use of manufacturing resources. Manual process planning is based on a manufacturing engineer's experience and knowledge of production facilities, equipment, their capabilities, processes, and tooling. Process planning is very time-consuming and the results vary based on the person doing the planning [1].

Integration of CA systems is not just that systems can communicate together, they must "understand" together too. That is they must share data that are often saved in different types of models with different information's format [2].

There is a number of modeling methods designers can choose from including interpolating splines (cubic splines); basis-spline (B-spline) of which there can be rational B-splines and non uniform rational B-spline (NURBS); and Bezier mathematics [3].

CAD software packages use two basic methods for the creation of surfaces. The first begins with construction curves (splines) from which the 3D surface is then swept (section along guide rail) or meshed (lofted) through. The second method is the direct creation of the surface poles/control points.

From these initially created surfaces, other surfaces are constructed using either derived methods such as offset or angled extensions from surfaces or via bridging and blending between groups of surfaces [4].

There are many advantages to a mathematical form. Much of this material was developed for CAD applications and fields like ship design where explicit shapes are an integral part of the design process [5].

2 Processing of CAD data

CAD data processing takes place in stages. The aim is to obtain the necessary data and relations which are located between the entities.

All data are stored in a relational database system which ensures the integrity of the original data and work with the information thus obtained is simpler and more flexible with regard to the use of SQL (Structured Query Language).

The file which is inserted into the system is not altered in any way. Thus, such data would be difficult to search and process. A new file which stores only data is the section in the DATA STEP file. The next phase is to find the rows that contain keywords and subsequent separation and collection of values that are in this line. An example is illustrated in Fig. 1. *Cartesian_point* method accepts one required input parameter and the text line which is located in the definition of a point in space.

```
public string[] cartesian_point(string input_text)
{
    char trimchar = '#';
    string temp_value;

    temp_value = input_text.Replace("));", "");
    temp_value = temp_value.Replace("(","");
    temp_value = temp_value.Trim(trimchar);
    string[] array = new string[4];
    array = temp_value.Split(',');
    string[] cartesian_point = new string[3];
    for(int i = 0;i<=2;i++)
    {
        cartesian_point[i] = array[i+1];
    }
    return cartesian_point;
}
```

Figure 1 Example of separation and subsequent acquisition values

The return value of this method is an array of 3 elements which are the stored coordinates of the point. This example are also obvious that to obtain necessary data from the row, which is located definition DIRECTION method can be used resulting overload methods cartesian_point. Likewise they are adjusted each row which are keywords. Thus prepared data can be inserted into the database system. The data which were inserted are without defined session. It is necessary to create a relational table which describes relationships between entities.

As the relational database management system (RDBMS) has been used database system called MySQL in version 5.3. The data of the surfaces could be stored in standard text file, but using the RDBMS causes more simplicity and more efficiency.

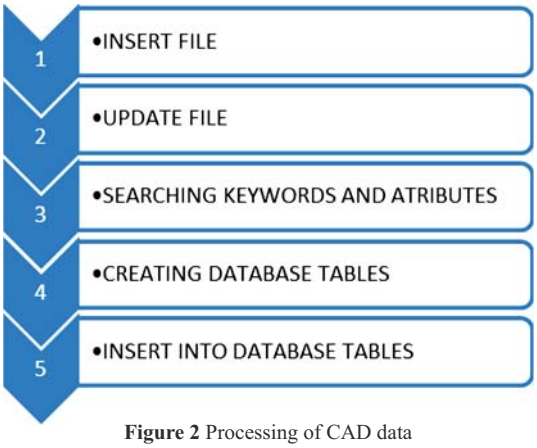

Figure 2 Processing of CAD data

C# 2008 has been used as the programming language. This language has many tools for communication with relation database management systems. In the data processing but also in determining the properties of surfaces are used principles of object oriented programming (OOP). This method brings greater simplicity and it allows expandability of the application. In this case the principles of OOP are mainly used for computing the normal vector in any point of the surface.

3
Determining the properties of B-spline surface

In STEP 214 the B-spline surface can be defined as shown in Fig. 3. The Bézier surface or NURBS surface is defined in a similar manner.

The first line defines the type of the surface numerical values in brackets in the first line define degree of curve which the surface consists of (in this case 3, 3). The second to the fifth line defines the network of the control points that describe the surface. The seventh and eighth row defines the number of nodal values vector for the curve. In the ninth and tenth row absolute values are expressed.

According to the definition of B-spline surfaces there should be used a method of deposit where the relationship between the values will be maintained.

The definition of B-spline surface in STEP 214 does not always have the same structure. It depends on the number of control points and values of nodal vectors. Before we determine the properties of surface we need to know the structure of data. One possible way is to count the number of rows and find what type of information is stored in row.

When determining the properties of B-spline surface the most important task is to find values of the basis

```
#104 = B_SPLINE_SURFACE_WITH_KNOTS ( 'NONE', 3, 3, (
 ( #91, #58, #30, #48, #85, #76, #56, #90 ),
 ( #44, #67, #49, #38, #53, #77, #95, #41 ),
 ( #88, #51, #78, #86, #50, #75, #98, #42 ),
 ( #80, #54, #82, #81, #94, #59, #93, #99 ) ),
 .UNSPECIFIED., .F., .F., .F.,
 ( 4, 4 ),
 ( 4, 1, 1, 1, 1, 4 ),
 ( 0.0000, 1.0000),
 ( 0.0000, 0.1866, 0.3733, 0.5600, 0.7800, 1.0000 ),
 .UNSPECIFIED. ) ;
```

Figure 3 B-spline surface definition in STEP 214

functions. The basis function is defined by (1) and (2).

$$N_i^k(t) = \frac{u - t_i}{t_{i+k} - t_i} \cdot N_i^{k-1}(t) + \frac{t_{i+k+1} - u}{t_{i+k+1} - t_{i+1}} \cdot N_{i+1}^{k-1}(t), \tag{1}$$

$$N_{i,1}(u) = \begin{cases} 1 \text{ if } t_i \le u \le t_{i+1} \\ 0 \text{ otherwise} \end{cases}. \tag{2}$$

To compute the basis functions a class called *b_spline* is used which defines the method called *basis_function*. The basis functions are computed through cycles which are controlled by data from input STEP file. In this case can be seen the advantages of object oriented programming because the formula to compute derivate of basis function is similar to the formula to compute basis function and therefore the principle of heredity can be used.

4
Computation of the surface parameters

The coordinates of normal vector in any point of the surface present important information for each surface. B-spline normal vector is defined by (3).

$$\vec{N} = \frac{\mathrm{d}P}{\mathrm{d}u} \times \frac{\mathrm{d}P}{\mathrm{d}v}. \tag{3}$$

Where $\mathrm{d}P/\mathrm{d}u$ and $\mathrm{d}P/\mathrm{d}v$ are the tangents. The tangents are defined by (4) and (5).

$$\frac{\mathrm{d}P}{\mathrm{d}u} = \sum_{i=1}^{N} \sum_{j=1}^{M} P_{i,j} N_{j,i}(v) \frac{\mathrm{d}N_{i,k}(u)}{\mathrm{d}u}, \tag{4}$$

$$\frac{\mathrm{d}P}{\mathrm{d}v} = \sum_{i=1}^{N} \sum_{j=1}^{M} P_{i,j} N_{j,i}(u) \frac{\mathrm{d}N_{i,k}(v)}{\mathrm{d}v}. \tag{5}$$

Another important information is that about the points which are located in the surface. This point is defined by (6).

$$P(u) = \sum_{i=0}^{N} \sum_{j=0}^{M} P_{i,j} N_{i,k}(u) N_{j,i}(v). \tag{6}$$

In Fig. 4 we can see the principle for calculating surface properties. Parameters $t_{u,I}$, $t_{v,I}$, $P(u)$ and $P(v)$ are obtained directly from the CAD data. $N_{i,k}$ and $N_{i,j}$ are the methods for computation surface basis functions. Next method is the method for computing the derivative of basis functions and the last method is used for tangent computation.

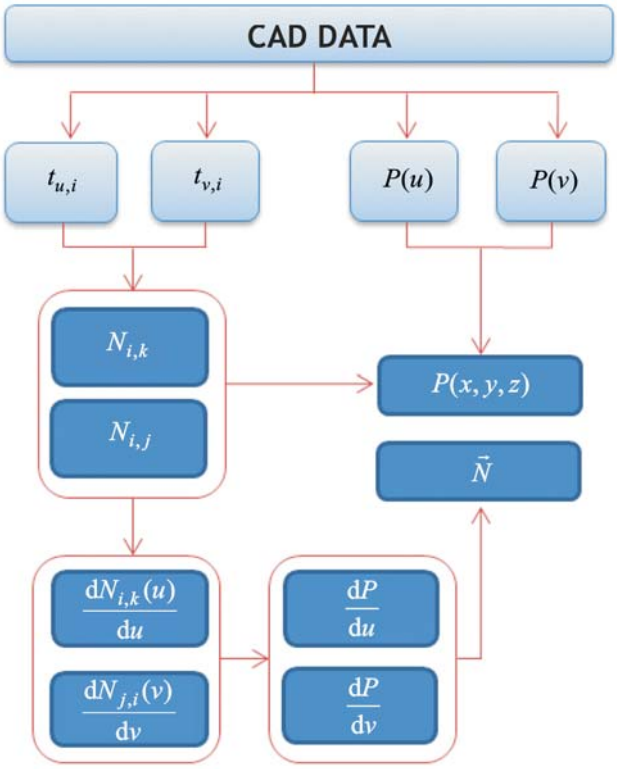

Figure 4 The principle for calculating the properties of B-spline surfaces

Using these three methods, we can calculate the normal vector. These methods must be used in a correct order. To calculate point coordinates we have to use only one method to compute the basis functions. Using this set of methods all properties of the surface are known. All methods are defined in a class called *b_spline*. A similar set of methods can be used for the Bézier surface or NURBS surface. However the formulas to compute surface properties will have to be modified.

5 Conclusion

The paper describes the system for determining the characteristics of the modeled surfaces in CAD systems. Information about surfaces is very important for CAPP systems. This solution can also be applied in features extraction from CAD data. With features extraction the entire model can be described. In data processing but also in determining the properties of surfaces the principles of object oriented programming are used. Advantage of this system is the independence of CAD systems, because it uses neutral format of data.

Acknowledgements

The article was written within the project VEGA 1/0250/11 "Investigation of dynamic characteristics of the cutting process in 5- axis milling in conditions of Centre of Excellence of 5-axis machining."

6 References

[1] Computer aided process planning, CROW. http://www.npd-solutions.com/capp.html (20.7.2011)
[2] Stroka, R.; Helis, A. Integration of CAPP and CAD/CAM systems. http://fstroj.utc.sk/journal/engl/papers/037_2002.pdf (07.07.2011)
[3] CAD and CNC integration. http://www.cncinformation.com/computer-aide-design-cad-cad-design/impact-of-cad-surface-modeling-on-cnc-machining (13.05.2011)
[4] Freeform surface modeling. http://en.wikipedia.org/wiki/Freeform_surface_modelling (15.06.2011)
[5] Dempski, K. Focus on curves and surfaces. // Premier Press, 2003.

Authors' addresses

Pokorný Peter, Assoc. Prof. PhD.
Slovak University of Technology
Faculty of Materials Science and Technology
Bottova 25
917 24, Trnava, Slovak Republic
Contact tel. +421 906 068 386
e-mail: peter.pokorny@stuba.sk

Vladimír Šimna, MSc.
Slovak University of Technology
Faculty of Materials Science and Technology
Bottova 25
91724 Trnava, Slovak Republic
e-mail: vladimir.simna@stuba.sk