RESEARCH ON DEVELOPMENT OF SHAPE AIDED DESIGN SYSTEM WITH CASE-BASED REASONING AND GREY PREDICTION THEORY

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Abstract: For pruning shears handle design, the author proposes to create a product database by collecting all information including handle size, mechanics for engineering, and biomechanics. Then, a knowledge database will be created through a parametric coordinate file by applying Extension Markup Language (XML). Finally, a shape design system will be established which integrates Case Based Reasoning (CBR) theory and internet browser user interface. The system can help designers to cope with difficult market environments, preserve original design style, shorten design time, and reduce the possibility of design mistakes. The system also develops a network user interface for which designers can discuss a design project together for improving the design quality and efficiency. In addition, the knowledge database combines Grey Prediction Theory to create a variety of shapes, which can transform automatically according to the design parameters. This system can achieve the purpose of concurrent design, and decrease the mistakes forthcoming from production.


1. Introduction

In the industry, the use of the old case is a very common design behavior. The designers use the old cases to analyze and to solve the design problems and to increase the creativities in the concept design step. However, if large amounts of cases were collected, it would be very difficult to process. Therefore, fast and convenient computer database becomes a very important issue to the design industry. Appliance computer not only can get the new design knowledge but can also grow the area of the databases. Adding a decision-making mechanism in the searching process can make this database more efficient, comprehensive, and specialized.

Taiwan's Horticulture handy tools enterprises have been making great efforts in research and development in building up brand names by their own manufacturers. These efforts have earned them high accomplishments. However, the sale volume of their products does not appear to reach these manufacturers’ expectation. Upon analyzing the situation, several factors were found to have a significant impact on the sale: (1) High cost in research, development, and manufacturing processes, (2) Novel grips that are uncomfortable when handled, (3) Not according with usual usage habits. It is recommended that the manufacturers can take an auxiliary analysis and design system to process swiftly and to consider not only in engineering mechanics, biomechanics and multiple thoughts in shapes, but also in the coordination of the moldings to reduce the stumble cost when manufacturing (Nanaa Singh[1]).

The purposes of this research are to resolve the enterprises' problems as listed below:
1. Information circulation and designer training:
   Fast designer turn over is a serious problem in the industry. How to help and solve this problem and how to shorten the learning time gap between the new designers and the experienced ones are the key issues in this paper.
2. To extend in compound fields and to assist in making the research and development more rapidly:
   To help designers get vast knowledge in different fields. Designers can quickly acquire the most current research and development data, which in turn will shorten the procedure in research and development.
3. To create a concurrent design model for serial products and the module:  
While concurrent design concepts are involved in the process of design research and development, it will be very useful to incorporate the concepts for designing the serial product and module parts.

4. Remote discussion and revision in designing:  
This paper developed a method to integrate designers and marketing information via the network, which can help domestic designers to revise and develop products based on both the domestic and foreign market information in a timely manner.

2. Design method  
Palm horticulture shears belong to hand tools design area. It is necessary to understand the assortment of design factors such as human factors engineering and hand tools biomechanics from literature research. This paper will discuss the case-based reasoning theory and its application. This paper will also discuss the XML language because access of the database will be transformed to the language. Finally, this paper will discuss the creation of serial transformation shapes, which will be displayed via the web interfaces. Both shapes and interfaces are taken from commercial drawing software and the programming language based on Grey Prediction Theory.

2.1 Horticulture cutting and classification:  
Palm horticulture shears have many styles depending on their usage. Basically, they can be classified into two groups: metal cutting shears and branch shears (as shown in Table 1). This research is focused on the branch shears.

2.2 Design reasoning  
We know that the expert system is a storage format, which can be understood by the computer. This system can become an expert with added control strategy that can resolve problems based on accumulated knowledge and experience. In other words, the system is a knowledge-based database program, which can be used to resolve problems in a specific domain, and this database can also offer the same professional answer as a human expert. Therefore, the purpose of this research is to develop a database structure that can help designers to make a drawing promptly and to offer a new concept via searching out a proper old case. The processes of this research are explained in Fig.1.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="1" /></td>
<td>Pruning shears — it has a lighter weight and is suitable for family gardening and floriculture, especially for pruning the tiny leaf.</td>
</tr>
<tr>
<td><img src="image2" alt="2" /></td>
<td>Harvesting shears — The function is similar to the cutting shears, but the grip contains a protection loop which will prevent its falling when cutting the fruits and protects the fingers.</td>
</tr>
<tr>
<td><img src="image3" alt="3" /></td>
<td>Cutting shears — It has a shorter blade and is suitable for pruning off thicker and tight branches. It is the major item in exporting, and this research has also taken this item as priority.</td>
</tr>
<tr>
<td><img src="image4" alt="4" /></td>
<td>Cutting shears with a seal. It has a similar function to the cutting shears, but there is a seal on the lower blade. This shear can prune thicker branches into plain slices.</td>
</tr>
</tbody>
</table>

Table 1 Classification of horticulture cutting tools.

1 Establishing the standard prototype profile files.  
2 Establishing the standard prototype profile coordinates, SQL database and data profile files.  
3 Developing accessing SQL database programs.  
4 Developing download and upload programs via ASP network.  
5 Developing user interface programs (Web).  
6 Developing user interface programs (VB).  
7 Developing user interface programs for Solid Works form transformation and drawings.

Fig. 1 System Building Processes
2.3 Establishing the standard prototype profile files:

The comparing and sifting work in the database is based on case-based reasoning decision theory, which is applied to XML language that will make a better structure in the function of database parallel accessing. Due to the fact that shapes of shears cannot be expressed very precisely in word, it is necessary to create a single data profile in an electronic file format by using Solid Works software in this research. The file contains all the accurate dimensions and ratios. The next step is to define the name, form, and classification of each part of the shapes. Then, all control points can be defined according to the following conditions: human factor, functions, esthetic, and cost. Finally, the deformation of the curve created by the control points can be analyzed from the calculated and examined result, the basic dimension of the statistics sample and the curve data (as shown in Table 2). The result will be used as a criterion for the application of case-based reasoning (Xu[2], Hong[3,4]).

2.4 Compiling the standard prototype profile files database:

To extract the original data from the steps stated above, the features' coordinate data (Table 3) are used for constructing a 3-D geometric solid model. Next, we use XML language to express the structure of the wording for connecting with MS-SQL database (Lu[5], Zhuo[6]).

2.5 Programming in the case-based reasoning (CBR) decision:

The applications of CBR in design have been included in searching similar old cases from experience and then applying the search result to the existing design project. In the course of carrying out this process, we must consider carefully two important factors. First, we have to distinguish many similar old cases. Second, the designer has to confirm what kind of design case should be used in the project (James[7], Wei[8], Yan[9]). The construction of the database is created by using the tree diagram XML language as shown in Figure 3. The similarity between A and Q is compared. If the similarity is matched, then compare step by step from B1, B2 to the lowest bottom, C6. The decision of similarity can be weighted with a number from Q, which can be compared to other data. Based on the comparison result, the similitude case can be taken as a reference for resolving problems with a new design project.

Table 2 Illustration of the standard prototype profile:

<table>
<thead>
<tr>
<th>Example</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td>In order to consider the relationship between two points, we have to classify fixed and control point on the profile for obtaining a correct transformation shape.</td>
</tr>
<tr>
<td><img src="image2.png" alt="Image" /></td>
<td>To remark the name of the control potions for further transformation control</td>
</tr>
</tbody>
</table>

Table 3 The original feature data of the shear:

<table>
<thead>
<tr>
<th>Name</th>
<th>Coordinate</th>
<th>Value</th>
<th>Name</th>
<th>Coordinate</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blade</td>
<td>D1x@DL</td>
<td>8.54</td>
<td>Left</td>
<td>U1x@LWO</td>
<td>35.13</td>
</tr>
<tr>
<td></td>
<td>D1y@DL</td>
<td>49.02</td>
<td>handle</td>
<td>U2y@LWO</td>
<td>31.5</td>
</tr>
<tr>
<td></td>
<td>D2x@DL</td>
<td>4.81</td>
<td></td>
<td>M2x@LWO</td>
<td>40.98</td>
</tr>
<tr>
<td></td>
<td>D2y@DL</td>
<td>30.68</td>
<td></td>
<td>M2y@LWO</td>
<td>38.38</td>
</tr>
<tr>
<td></td>
<td>O1x@TL</td>
<td>24.19</td>
<td></td>
<td>D3x@LWO</td>
<td>59.17</td>
</tr>
<tr>
<td></td>
<td>O1y@TL</td>
<td>25.64</td>
<td></td>
<td>D3y@LWO</td>
<td>80.13</td>
</tr>
<tr>
<td></td>
<td>O2x@TL</td>
<td>21.38</td>
<td></td>
<td>Lx@LWO</td>
<td>76.00</td>
</tr>
<tr>
<td></td>
<td>O2y@TL</td>
<td>9.47</td>
<td></td>
<td>Ly@LWO</td>
<td>103.5</td>
</tr>
<tr>
<td></td>
<td>I1x@TL</td>
<td>19.33</td>
<td></td>
<td>Rx@LWO</td>
<td>70.00</td>
</tr>
<tr>
<td></td>
<td>I1y@TL</td>
<td>42.92</td>
<td></td>
<td>Ry@LWO</td>
<td>107.1</td>
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<tr>
<td></td>
<td>I2x@TL</td>
<td>19.66</td>
<td></td>
<td>Ux@LWO</td>
<td>26.44</td>
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<tr>
<td></td>
<td>I2y@TL</td>
<td>33.26</td>
<td></td>
<td>Uy@LWO</td>
<td>28.16</td>
</tr>
<tr>
<td></td>
<td>I3x@TL</td>
<td>16.54</td>
<td></td>
<td>Dx@LWO</td>
<td>72.54</td>
</tr>
<tr>
<td></td>
<td>I3y@TL</td>
<td>17.47</td>
<td></td>
<td>Dy@LWO</td>
<td>45.63</td>
</tr>
<tr>
<td>Pad</td>
<td></td>
<td></td>
<td>Left</td>
<td>U1x@RWO</td>
<td>36.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>handle</td>
<td>U1y@RWO</td>
<td>40.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M2x@RWO</td>
<td>40.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M2y@RWO</td>
<td>78.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>D3x@RWO</td>
<td>35.88</td>
</tr>
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<td></td>
<td></td>
<td>D3y@RWO</td>
<td>121.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mx@RWO</td>
<td>32.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>My@RWO</td>
<td>128.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ux@RWO</td>
<td>23.88</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Uy@RWO</td>
<td>51.77</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Dx@RWO</td>
<td>29.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Dy@RWO</td>
<td>127.4</td>
</tr>
</tbody>
</table>

To support comparison decision strategy program, we use SQL to compile a Transact-SQL, and the program structure can be expressed as below:
<attribute _list>: Display attributes value after inquiring.
<table _list>: Table name in the databases.
<condition>: set up inquiring conditions.
\( n \): Number of attribute.
\( \sin(f_i, f_j^n) \): Input the similarity value of attribute 
of \( J \) in the case database.
\( \text{similarity}(f_i, f_j^R) \): Input the similarity value of 
cause of \( I \) in the case database.

The basic grammar, using SQL language to access information from the database, is expressed as below:

\[
\begin{align*}
\text{SELECT} & \quad \text{<table _list>} \\
\text{FROM} & \quad \text{<condition>} \\
\text{WHERE} & \quad \text{<attribute _list>}
\end{align*}
\]

Program a Transact-SQL for a comparison-based calculation formula, which will extract the attribute from the database then input to the similarity as the \( J \) does. The extracted case attribute will then be used to calculate the total similar weighted value according to the similarity (which is based on the expert's experience or the combination of the quantity algorithmic.) and the attribute weighted value (James[7], Guo[10]). The formula is shown in equation 1.

\[
\text{similarity}(f_i, f_j^R) = \sum_{j=1}^{n} \sin(f_i, f_j^n) \times W_j \quad \ldots \ldots (1)
\]

In programming Transact-SQL, by taking requesting <condition> passing from ASP, and use 'SELECT' function to collect the <table _list> also use data by FROM conditions to looping compare WHERE<attribute _list>, then take the value back to the interface of web page.

2.6 Applications of the Grey Prediction Theory:

Various shapes in shears are confined to the quantity of material. A company, when planning to design a new shear shape, will always predict the weight on the shears. It is necessary to consider the quantity of material usage. The transforming application of the Grey theory is to find out the accurate transformed quantity for designers' reference purposes (Wen[11]). For example, the dimensions of the original prototype are shown in Fig. 2.

The designer can then take the curve shape parameters and section parameters into an algebraic formula as listed below:

\[
\begin{align*}
S1 &= "D2@Sketch1" \\
S2 &= "D2@Sketch1" / 2 + 11 \\
S3 &= "D4@Sketch3" = "D4@Sketch1" + 12 \\
F1 &= "D6@Sketch1" \\
Sn &= "Dn@Sketchn" = "Dk@Sketchk" + a
\end{align*}
\]

\[
F2 = "D11@Sketch1" = "D1@Sketch1" / 6 + 7 \\
F3 = "D4@Sketch3" = "D6@Sketch1" + 6 \\
Fn = "Dn@Sketchn" = "Dk@Sketchk" + a
\]

Features group of the prototype =\{F1, F2, F3, F4, ..., Fn\}, \{S1, S2, S3, S4, ..., Sn\}

Fig. 2 Dimensions of the original

Choose the best solution for the final decision according to the design target, called GM(1,1) decision strategy model. Then input decision value, obtained from GM(1,1) model, into design table (Fig. 3) to get transformation quantity based on decision matrix (D, as shown in Equation 2) (Wu[12]). Finally, use Solid Works software to create many different shapes according to each decision value obtained from the design table. The results are displayed in Figure 4.

Fig. 3 Dimension table for modifying forms

\[
D = \begin{bmatrix}
F1, & F2, & \ldots & F1n \\
F1i, & F2i, & \ldots & F1ni \\
\vdots & \vdots & \ddots & \vdots \\
F1i, & F2i, & \ldots & Fn
\end{bmatrix}
\]

\[\ldots (2)\]

2.7 Programming for user interface:

In this research, ASP was used to develop a user interface for web browser and to link the SQL database (as shown in Fig. 5). The sequence of the programming development is listed as below:

Browser \rightarrow IIS server \rightarrow SQLXML processor \rightarrow SQL calling out device \rightarrow SQL database server.
3. User Interface Operation and Test:

3.1 Webpage interface operation

This research is applied with network IIS sever, so that the testing could be done on a server or via internet. The procedure is described:

1. Fig. 6 is the home page of the operating interface with login and password input items.
2. Input design item and the weighted value to the IIS server via ASP (Fig. 7, 8).
3. A reference pattern will be created according to input parameters. A designer can view the pattern dynamically via a browser at 360 degree angle (Fig. 9).
4. Any modified parameters can be uploaded to the database. The data will then become a reference case for the designer for the next project (Fig. 10).

3.2 VB and CAD Interface Operation:

Designers can obtain final CAD model by using Visual Basic program calculation, and link Solid Works CAD software and the design table via OLE. The result of the design table and CAD model are shown in Figure 11.

3.3 Experiment and evaluation:

In order to evaluate the efficiency and accuracy of designing from this system, the system was installed on an SGI Indigo2 workstation and worked with Solid Works CAD.
system. There are 30 volunteers, 10 industrial designer and 20 master students, to test the system by using internet browser and selecting different design parameters. Meanwhile, the final design results were checked and verified according to the design standard and experience value by all users. A questionnaire was designed to assess the testing satisfaction using BORG’s CR-10 scale and the results are shown in Table 4 (BORG[13]). The results show that most users satisfy the reference pattern created by the design system according to selected design parameters, and the design parameters also match design rule well. The reference pattern not only can be used for final mass production, but also can be modified by user according to customers needs. Finally, the design case can be written into the database to increase availability and efficiency because the designer can obtain more reference case from the design database.

<table>
<thead>
<tr>
<th>Table 4 Summary of experimental results (n=30).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Satisfaction(n)</td>
</tr>
<tr>
<td>Satisfaction(p)</td>
</tr>
<tr>
<td>Accuracy(n)</td>
</tr>
<tr>
<td>Accuracy(p)</td>
</tr>
<tr>
<td>Efficiency(n)</td>
</tr>
<tr>
<td>Efficiency(p)</td>
</tr>
</tbody>
</table>

4. Conclusions and Discussion:

There are some limitations in developing an expert system, especially in the field of product design. Completing a design by the expert system does not mean that the thinking and consideration from the designers are unnecessary. The author believes that the role of designers will not be replaced by the expert system easily. However, in the future, the expert system will be improved to a better status. Future research needed to improve the expert system: (1) capability in handling common knowledge; (2) developing a better inferable system; (3) self-learning abilities; (4) distributed Data Base Management system; (5) capability of increasing and updating knowledge.

In the future, the expert system may obtain the data from the sensors directly, or obtain the data from another system database. The inference engine not only can infer but can also do planning and problem shooting. The database is not only a static inference rules and facts but is also kinetics knowledge with arrangements, classifications, structure pattern and behavior pattern.

Acknowledgement

The author would like to acknowledge the Mr. Hung’s, graduate student of Institute of Design of Chaoyang University of Technology, efforts for providing the necessary resources and information.

5. References

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