A Knowledge base System for Carton Package Design

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Abstract

The purpose of this paper is to build a knowledge-based system for carton package design to solve the package design problems and satisfy designer’s requirements. This study of the participants is package designer. In order to gather the package design problem and design knowledge, we interview the package designer at first. Requirement analyze is taken after interview. Then, to gather the related research and the package design knowledge are for planning of knowledge design. When make sure the requirement and the prototype, and then we do the system develop and implementation. Finally, we’ll to do the system evaluation. The findings revealed the knowledge base system of computer-aided design can support the designer easy to design, and reduce try-and-error times and costs. In this study, the main of the knowledge is the paper material and thickness, and the paper material using corrugated paper for an example. In the future, the system can input other knowledge for package design, like color, typography, graphic and other paper materials to make the system more completely.

1. Introduction

In the package design domain, one single product can have variable geometry and complexity. Therefore, when designer design the carton box, it requires lots of innovation, and the ability of the three-dimensional concept, and imagination from the designer to create various 3D packaging structures and the corresponding flat pattern layout [19]. However, internal package designer usually uses unprofessional vector software that is not major in the package design to do the 3D packaging structures design and to draw the proportional unfolding layout. It’s to create the internal package designers have a lot of problems when they are doing design. Based on this reason, there are five problems exist in package design process when designers work on it: 1. The professional package software is expensive and the interface is not good to use plus not having the specific designer of using this software; 2. At the design initial stage, designer doesn’t have suitable software to support designer to
thinking about the design idea; 3. During the design process, designer need to do heaps of try-and-error to produce the corresponding unfold flat pattern layout; 4. It is not easy for designers to imagine a 3D result from the unfolding flat pattern layout in operation stage; 5. During the design process, because of the thickness of paper, designers needs to do the prototype without the visual design again and again. 5. When designer finishes the design, it is unable to store the package design knowledge. So of that, in this paper we aim to build a knowledge-based design system for paper packaging design, and assists package designers to build and design unfolding flat pattern layouts in an easy, fast, friendly, and intuitive way.

2. Background and Related Work

2.1 Background

![Diagram](image_url)

*Fig1. Background Architecture*

This research will discuss the factors of shape and materials of the structural design of commercial package of package design, and major to talk about the shape of carton box and the corrugated paper of materials for the most part. The purpose of current study was to consider how to using the knowledge base design, generative system, computer graphics, and the HCI of the computer science domain to assist the carton box package design.

2.1.1 Package design

‘Package’ is a quiet salesperson that is a tool of marketing. It can attracts customers sight and sales by itself [18]. Nowadays, related research shows the package itself affects two-thirds of the customer expenditure decision [17]. In the marketing domain, packaging abreast of price, product, place and promotion jointly called as ‘5P’. Package design is very important. It affects the value of customer [27, 30]. So, it shows the package design is valuable of daily life.
2.1.2 Present position of package design

Present package connect with production and consumption. Package integrate with science technology and art thinking of business acts to protect product, encourage consumption, and increase the storage and transportation [28].

Most of researches classify the present package design by the purpose. It mainly differentiates two parts: commercial package and industrial package [23, 28, 30]. In this research, we aim to talk about the carton box package design of commercial package. Commercial package also called consumer package, and mainly retail-based business transactions. It point on the sales of easy to sell, so the beautiful appearance of the packaging is important in order to arouse consumer desire to buy [23, 28, 30].

2.1.3 The essential factors of package design

The visual design of packaging includes two parts: structure design and graphic design. The message and information through the visual comprises structure design of packaging is the shape form design and the graphic design of the container surface [31]. This research will talk about the shape of structure design of carton box, and the paper material using the corrugated paper for an example.

![Visual design of packaging](image)

*Fig2. The factors of package design*

2.1.4 The structure design of carton box package design

In the packaging materials, paper products is one of the commonly used materials, including carton packaging [28]. The structural design of carton packaging means the paper will be the plane into three-dimensional form, and using cut, folded, adhesive, insert into paper method such means as the use of friction with other auxiliary materials assembled out of commodity structures and patterns [24]. Carton box to start the process by a number of the mobile surface, piled up, folded, and surrounded by the box body.

In the structural design of packaging, ‘form’ design is often the important key to the success or failure of packaging. A successful form of packaging can attract enough attention form consumers, and to promote the sale of goods [29].
During the design process, in addition to the design process must be have flexible and creative design idea of professional package design, and also need the computer-aided design process. If a lack of computer-aided design process, it will take more time and cost, and even may be a result of the calculation error which led to more wear and tear and increase the cost of a burden [29]. It can be seen computer-aided design is very important.

2.1.5 Knowledge base System

The structure design of carton box is a professional knowledge and it includes many complex procedures during the design process.

A knowledge-based approach broadly means to build up a system, usually called a knowledge-based system (KBS), for solving complex decision problems in a specific domain [3]. A KBS, normally in the form of an intelligent computer program, uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution [3]. KBS supports the user’s actions or controls and prompts the user’s intention so that the user can design drawings according to the standard or the best way [21]. The knowledge-base system consists of two parts: rule base and inference engine. The system includes the task storage and the trace recorder too [21]. The figure 3 presents the knowledge-base system architecture.

![Fig 3. Knowledge base system architecture](image)

2.1.6 Reuse Design

Design company is the industry which is to production and to provide knowledge. In the process design also makes use of knowledge to generate knowledge [32]. The reuse of previous design knowledge is a potentially important way to improve design efficiency [12]. From an empirical perspective, considerable evidence exists indicating that designers do attempt to reuse previous concepts and prototypes in both routine and non-routine design work [6, 10, 12, 20].

2.2 Related research and works

2.2.1 Related research

2.2.1.1 Basic shape and structure of carton box
Classification the carton box according to the basic shape can divide into three parts: main structure, partial structure, and special structure [25, 26].

Main structure means the folding carton box form of the three dimensional structure. In accordance with the way of molding can be divided into straight carton, tray carton, and other type. Partial structure refers to the structure of the folding carton in the form of partial structure, such as the lid, bottom of the box, noodles, box angle, and so on, and also if lock, dig holes. The special structure is the performance of the features of the structure of the carton box, and most of the special structure is the local structure generally.

![Carton Box Diagram](image)

**Fig 4.** (a) Straight carton (b) Tray carton

2.2.2 Corrugated paper

2.2.2.1 Classification and characteristic of corrugated paper

According to the corrugated paper shape and different characteristic, it can be classifying five corrugated paper types: A, B, C, and E. In order to fit in with variety of packaging requirement, carton box need to be an appropriate choice of shape of corrugated paper type in order to achieve the purpose of packaging [16]. Its features are as follow table 1.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrugated number of every 30cm</td>
<td>A</td>
</tr>
<tr>
<td>Corrugated height mm</td>
<td>B</td>
</tr>
<tr>
<td>Shape of corrugated paper</td>
<td>C</td>
</tr>
<tr>
<td>Pressure strength</td>
<td>D</td>
</tr>
<tr>
<td>Side pressure strength</td>
<td>E</td>
</tr>
<tr>
<td>Flat pressure strength</td>
<td></td>
</tr>
<tr>
<td>Shrink variant volume</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrugated number of every 30cm</td>
<td>36±3</td>
</tr>
<tr>
<td>Corrugated height mm</td>
<td>4.5-4.8</td>
</tr>
<tr>
<td>Shape of corrugated paper</td>
<td>U or V</td>
</tr>
<tr>
<td>Pressure strength</td>
<td>Optimal</td>
</tr>
<tr>
<td>Side pressure strength</td>
<td>Worst</td>
</tr>
<tr>
<td>Flat pressure strength</td>
<td>Worst</td>
</tr>
<tr>
<td>Shrink variant volume</td>
<td>Biggest</td>
</tr>
</tbody>
</table>

Table 1: The type and characteristics of corrugated paper

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2.2.3 Structure design of folding carton box

Folding carton box is the widest range of carton box sales packaging, and its having variety of structure and form shape. During design, designer can base on volume of carton and the weight of contents to choose the appropriate thickness of corrugated cardboard [25, 26]. Designer can follow the table 2 to choose.

Table 2. Folding carton paper thickness selection table

<table>
<thead>
<tr>
<th>Carton volume /cm³</th>
<th>Contents weight /kg</th>
<th>Thickness /mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0~300</td>
<td>0~0.11</td>
<td>0.46</td>
</tr>
<tr>
<td>300~650</td>
<td>0.11~0.23</td>
<td>0.51</td>
</tr>
<tr>
<td>650~1000</td>
<td>0.23~0.34</td>
<td>0.56</td>
</tr>
<tr>
<td>1000~1300</td>
<td>0.34~0.45</td>
<td>0.61</td>
</tr>
<tr>
<td>1300~1800</td>
<td>0.45~0.57</td>
<td>0.66</td>
</tr>
<tr>
<td>1800~2500</td>
<td>0.57~0.68</td>
<td>0.71</td>
</tr>
<tr>
<td>2500~3300</td>
<td>0.68~0.91</td>
<td>0.76</td>
</tr>
<tr>
<td>3300~4100</td>
<td>0.91~1.13</td>
<td>0.81</td>
</tr>
<tr>
<td>4100~4900</td>
<td>1.13~1.70</td>
<td>0.91</td>
</tr>
<tr>
<td>4900~6150</td>
<td>1.70~2.27</td>
<td>1.02</td>
</tr>
</tbody>
</table>

2.2.4 Related unfolding algorithm

The folding of paper or sheet materials is treated in the mathematical studies of origami [7, 8, 15] and also in computational algorithms for developing the crease pattern for folding into various origami designs [11]. However, in origami, the sheets of paper are usually folded into objects which are flat or piecewise flat structure [19]. Another related work is the geometric modelling and simulation of pop-up books [22] and origami architecture [9] in such work deal mainly with shape and motion information of the popup mechanisms and not the topology. But it can process the box detail part, like the pup-up of broken line of unfolding flat pattern. Graph search algorithms (such as breadth-first, depth-first or A* algorithms) have also been proposed to arrive at a flat pattern of a given object [14]. But it just supports one kind of flat pattern. W. Liu and K. Tai bring up a suggestion of optimal unfolding flat pattern design of corresponding 3D object in the 3D unfolding structure. Enumerating all possible patterns allows for a subsequent interactive selection by the designer to choose the best pattern [19]. However, this algorithm not includes the paper thickness factor. The algorithm can support our research in the 3D object transfer into the corresponding 2D unfolding flat pattern, and we will add the paper thickness factor into it.

2.2.5 Related works

Nowadays, there are many professional package design software such as Artios CAD [2], Impact Design Software [13], KASEMAKE [1] using the international corrugated/FEFCO and folding carton/ECMA standards. Although these software have powerful capability, it doesn’t have internal package designer to use them. Because of the software is not suitable for internal requirement. For example, the
professional vocabulary is too complex, the software is expensive, and interface is not intuitive for designers. The software, Fold UP! 3D [4] and BOX-VELLUM [5] from Connect Company in Japan. The design process of this software is design the unfolding flat pattern at first, and then shows the corresponding 3D structures in Adobe Illustrator. However, this process is different from internal package design process. It is hard to provide idea thinking, and unable to store the package knowledge database for effectively re-use. Moreover, most of internal research mentioned from the visual design aspects, but not computer-aid design aspect in package design and less structure design aspect of package design. Also, these related works not having the knowledge mechanism.

3. Methodology

3.1 Research architecture

Fig5. Research Architecture

Here is the research process: Firstly, this research deeply interviews with internal package design experts to confirm the needs and problems. Then, requirement analyze is taken after interview. Then, to gather the related research and the package design knowledge are for planning of knowledge design. The relationship is between important variables such as the use of packaging use, length, width, height, the basic type, the type of lid and base, etc. to build an abstract conception of trees, and then using this structure to do classification according the purpose. At next step, it will build a package of knowledge conceptualization standard. When make sure the requirement and gather enough knowledge and the prototype, then we do the system develop and implementation. Finally, we’ll to do the system evaluation.

3.2 Requirement analyze

After the interview with the package design experts, the result shows that internal package designers need a package design system with the following requirement: 1.
when package designer build the basic 3D modal or to set the classification, the system can provide the recommend 3D package structures to support the designer to think about the design idea; 2. The interface must shows the interaction of the 3D view and the unfolding flat view; 3. The interface need to have mark of dimensions, length, wide, high, etc.; 4. The interface should be simple and intuitive; 5. The vector software can read unfolding flat pattern layout design format from this system created; 6. Build up the knowledge-base system for reusing the design knowledge; 7. The system can add the paper thickness and material for calculate the paper thickness for unfolding flat pattern.

In order to improve the designers encountered various problems and needs during the design process, this study proposed a design process to improve the design of the solution, follows the figure 6.

![Fig6. Computer-aid design process](image)

### 3.3 Unfolding algorithm

Enumerating all possible patterns allows for a subsequent interactive selection by the designer to choose the best pattern [19]. This research will based on this algorithm from W.Liu and K.Tai, and add the paper thickness calculation.
To facilitate unfolding and the construction of the flat pattern, an appropriate geometric representation of the 3D structure (as well as the flat pattern) must contain two types of data: one is shape geometry data which defines the shape and position of the structure; the other is topological data, which defines the connectivity between faces [19]. A hierarchical data structure similar to that often used in a boundary representation (b-rep) model is applied to define the 3D folded structure with each stratum in the hierarchy containing a list of data.

The complete procedure can be listed according to the following steps [19]:

1. Read input of B-rep model data of 3D folded structure.
2. Form the FAG of folded structure.
3. Identify any hyper-common edges and determine their sequences.
4. Identify any inadmissible or exclusive links.
5. Compute total number of spanning trees.
6. Remove inadmissible links (if any) from FAG.
7. Enumerate all spanning trees.
8. Check topological validity of each spanning tree (check for any overlapping paths and correct splitting of hyper-common edges), and discard invalid trees.
9. Geometrically construct flat pattern for every valid spanning tree.
10. Detect and discard any flat patterns with overlapping faces.
11. Compute the three compactness measures for every flat pattern, and maintain three separate lists of the top thirty highest-ranked patterns based on each of the three compactness criteria.
12. Output resulting lists and plot patterns upon request.
3.4 Knowledge base system design

The knowledge-based module has three steps: 1. Knowledge acquisition—Knowledge should be validated, structured and relevant. Validation specifies the kinds of question can be solved. Structuring confirms how the knowledge is arranged and stored. Relevance refers to relationships among the knowledge. 2. Knowledge inference and representation—Knowledge should be expressed in specific form. It should be inferable and applied in logical manner. 3. Knowledge-based module should pass evaluation, verification, and test. Knowledge should be confirmed as enough to achieve the system goal. If not, the developer would need to acquire more knowledge to fix the module.
4. System Plan

4.1 System design process

In the user manipulate part, when the designer doesn’t have idea, designer can choose and set in the interface, then the system will give the corresponding shape of box, knowledge and suggestion support the designer to make design thinking. And then user can to do the 3D model shape design. Otherwise, if the designer has the design idea about the shape, then designer can to design directly in the 3D model view. If the designer finished the 3D model design, the system will to do the knowledge acquisition to gather the initial knowledge and information. After that, the system will provide several corresponding unfolding flat pattern for designer. Designer can choose one of the unfolding flat patterns, and then to choose the paper material and thickness, the system will calculate the unfolding flat pattern according to the paper material and thickness setting. Next step, the designer can modify the detail part, and then do the knowledge acquisition about the details. If the designer finished the 2D unfolding flat pattern, designer can store the vector format and knowledge, or designer to modify the 2D and 3D details.
4.2 System architecture

This research will implement a knowledge-based aided system for carton box package design. According to the designer requirement to do the system plan and implement. The system will include two parts, one is the user interface, and another one is the knowledge engine. The system architecture can see figure.

4.2 Interface draft

The interface will include the simple basic 3D model and the type of the box for package designer build 3D model sample and intuitive. Then, the system will show the recommend shape of paper box and package knowledge from the knowledge database according to the set of the package purpose and the 3D model that designer builds. The system also provides different unfold ways of flat pattern layout for designer. The interface will show the 3D view dynamically and the 2D unfolding flat view immediately.

5. Summary

Expect of the benefit about this research can bring the initial package designer as below points: 1. In the design early stage, package designer can refer to the package design knowledge and the 3D packaging structure from its knowledge base system to support the designer to thinking about the design idea; 2. It is convenient for designer to choose similar 3D packaging structures model to modify, setting, and design using the intuitional interface; 3. Following the 3D model decision, this system will provide some different unfolding ways of flat pattern layouts to designer to compare. And the
system supports the designer to calculate the unfolding flat pattern according to different paper thickness. It greatly reduces time of try-and-error and increase accuracy; 4. After the designer chooses the one of unfold flat pattern layouts, designer can store the vector format that vector software can read for package designer to do the visual design of the package design; 5. The system supplies re-use design mechanism to allow the package design knowledge re-use effectively.

Future related research can aim at doing the following description to go further discusses, research, and development: 1. This research only discusses the shape and the corrugated paper of material of structure design of commercial package design, but not parts of texture and other materials; 2. In graphic design of package design domain, there are still lots of knowledge such as graphics, typography, color, CIS, which can be stored into this knowledge based system; 3. This system based on the paper packaging box, canned, packaged hoses and bottled are excluded; 4. Hereafter, related research can probe into the collaboration design of the interaction between the package designer, customer, and the printing personnel and the marketing.
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