Implementation of Ruled Base Knowledge Database for Sofa Frames

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[Abstract] The implementation of a ruled base database system for the synthesis of sofa frames design showed that the system is able to define associated specific frame constructions. This frame is based on evaluation of limited input data of artists’ sketches of sofa appearance.

[Keywords] Ruled base, Knowledge Database, Sofa frames.

沙發框架規則法知識資料庫實作

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[中文摘要] 實作後的沙發框架規則法知識資料庫可以有效地定義一沙發框架。這個框架可以僅由設計師所設計的沙發外觀草圖或者結構資料有限的沙發框架結構來決定。

[關鍵詞] 規則法，知識資料庫，沙發框架。

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1. Introduction

When a new upholstered sofa is put into production, the product engineer together with "model shop" personnel design its frame. Owing to the upholstery materials, the sofa frame may be difficult to visualize: often, only a few major features can be identified, such as the relative positions of the arm and top rail, stump and arm.

On the other hand, the furniture market is largely "style" driven in the world. Thus a manufacturer of household furniture needs to introduce and produce new furniture showings with minimum lead time in order to fulfill market demand. To maintain long-term success in the industry, changing product lines rapidly, making profitable short production runs, and maintaining minimum ship times are essential. Presently, most work in the industry is labor intensive. Translation of artists' sketches into working drawings by "detailers", for example, is a laborious hand process. The solution to these problems lie in the application of computer based design, product engineering, and production techniques.

An expert system or a knowledge base system offers a good approach to classifying and synthesizing sofa frame system. Merritt (3) states that expert systems are computer applications which embody non-algorithmic expertise for solving certain types of problems. One feature of expert system is the ability to cope with uncertainty, that is, the systems has the ability to reason with rules and data which are not precisely known. Many applications and developments in forestry have been reported. For example, Gibson et al. (2) developed an expert system for selection of timber harvesting equipment.

Another study undertaken by Picado (4) indicated that thousands of styles of upholstered sofas are used in the world, but ordinarily, their frames may be categorized into a relatively few specific types. And the basic frames for sofas could be synthesized through the application of a set of rules. But these rules have not been incorporated into computer programs. In keeping with the general objective of Picado's rule base, two divergent approaches were covered in this study.

1. To determine whether a classification system for synthesizing appropriate furniture frames to meet the needs of most sofa designs could be created.
2. To determine whether a knowledge base could be developed for
the selection of an internal furniture frame which was based only on an evaluation of limited measurements of artists’ sketches of the external appearance of sofas.

2. Background

To develop a rule-based system, a classification system for sofa frames must first be defined. According to Eckelman’s (1) definition, a frame may be defined as assemblages of members which are joined together at selected number of points called joints. A typical sofa frame is shown in Figure 1. Many frame styles and construction details are used in sofa construction. As a result, it is difficult to categorize frame styles into groups. Therefore, Eckelman (1) presented an appropriate description system for sofa frames. In the system, he defines three identifiable subsystems, namely, the seat system, the back system, and the side frame system.

The seat support system for a sofa consists of the front rail, the back rail, the side rail and the stretchers. The seat system may also contain a back spring rail if sinusoidal springs are used in the seat foundation system. The back support system is considered to consist of the top rail, the center rail, back interior uprights, backrest interior uprights, and all associated braces. The side frame system of a sofa usually consists of a stump or a front post, arm, back post, side rail, and a side slat.

Owing to the large variety of seat foundation supports, these supports are described as they occur in the following topics.

3. Construction of Sofa Frames

3.1. Seat Support System

3.1.1. Front Rail (Figure 1, B)

The front rail is often joined to the lower inside edge of the stump (Figure 1, D). Sometimes, it is attached directly to the side rail when the stump is set to the rear of the frame.

The front rail can also be joined to the front posts. These are usually placed in a flat position if they are part of the internal covered frame. The post will have its flat side positioned perpendicular to the longitudinal axis of the rail.

3.1.2. Back Rail (Figure 1, E)

Several of the back rail constructions are similar to those used with front rails such as the connection of the back rail to the back post and
the connection of the back rail to side rail. If a separate back rail is used, it may be attached to a filler block connected to the side rail. The interior uprights are commonly attached to the upper edge of the back rail. Sometimes, the back rail is laid flat to resist the high horizontal spring loads imposed on it when flat spring seat foundation support systems are used.

3.1.3. Stretcher (Figure 1, D)

The stretchers are used in the seat support system to help the front and back rails resist the lateral forces imposed by sinusoidal type springs. These members may be oriented in either a flat or edge position based on the construction of the seat support system. When they are turned on edge, they will provide larger bending resistance. Sometimes, curved stretchers are used to provide more space below the spring deck when sinusoidal springs are used so that the springs do not bottom out on the stretchers.

Basically, two to four stretchers are used in a seat system. In some coil spring constructions, however, a flat stretcher is used beneath each row of springs.

3.2. Back Support System

3.2.1 Top Rail (Figure 1, A)

Typically, the top rail is laid flat and attached to the inside edge of the arm. In this case, the arm is often laid flat and the back post is joined to the lower face of the arm. Sometimes, it is used in the edge position. In this configuration, the top rail is attached to the inside edge of the back post.

Built-up sections may also be used in top rail constructions. Most built-up sections may have the shape of a "T-section" with the top member laid flat and the bottom member laid on edge, but "L-sections" may also be used.

3.2.2. Interior Uprights (Figure 1, F)

Interior uprights are attached to the lower edge or surface of the top rail and to the upper edge of the back rail. This construction can increase the bending stiffness of both the top rail and back rail in the vertical direction.

3.2.3. Center Rail System (Figure 1, C)

The center rail system consists of the center rail itself, the members into which it frames at each end, and the center rail to interior back uprights or center rail to top rail braces (Figure 1, K). The center rail is usually constructed of a single member. It is normally laid flat, but it may also be used in a more or less vertical edge direction. Center rails which are attached to the inside faces of the side slats (Figure 1, H)
are usually laid flat. Sometimes, they may also frame into the side of a backrest end post.

The center rail may be reinforced by means of several different construction systems. It can be braced against the top rail by means of center rail to top rail braces for instance. Sometimes, the back to top rail upright and center rail to top rail brace are joined together by means of a short member. When an enlarged interior back post is used to provide sufficient back to front space, the center rail can be attached to it directly.

In another important construction, the center rail is that attached to each stretcher by means of rigid braces in order to increase the stiffness of the frame.

### 3.3. Side Frame System

#### 3.3.1. Side Rail (Figure 1, G)

Generally, the side rail frames into the stump, but sometimes it attaches directly to the front rail. When a stump frames into the side of the side rail, it does so at a distance of about 6 inches back from the front rail. Usually, the stump is attached to the inside surface of the side rail.

#### 3.3.2. Arms (Figure 1, J)

The arms are usually placed in a flat position and frame into the inside faces of the back post (Figure 1, L) and the front stump. Sometimes, the arm is laid flat on top of these members and the stump and back post doweled into the underside of the arm and the top rail. When used in the flat position, the top rail may frame into the inside edge of the arm.

In another arm construction, the arm frames into the inside edge of the top rail which is laid flat and attached to the top of back post. In this case, the arm is located on top of the stump and reinforced against the side slat by means of a rigid brace.

The arm could also be attached inside face of the back post directly or some distance from the end of it.

### 3.4. Seat Foundation Support Systems

The are five basic seat foundation support systems including coil springs, sinuous wire springs, formed wire springs, grid suspension systems, and rubber webbing. They are used to provide comfort, which is an important quality factor in a sofa.

The eight-way hand-tied double cone coil spring is the most expensive and prestigious spring construction. Basically, this construction involves fastening the coil springs
tightly to the stretchers or other base support materials and expertly tying their tops together with a strong cord. Lower quality construction are manufactured as a unit, tied with steel wire, and attached to the frame.

Sinuous wire springs, which are fastened directly to the front rail and back rail at both ends, are manufactured in a zigzag shape. Their action is accomplished by having a number of these springs fastened by means of parallel seat wires.

Formed wire springs are constructed like the sinuous wire springs, but they are formed into long rectangular bends and angles rather than the zigzag shape. The formed wire springs are also attached directly to the rails just as is done with sinuous wire springs.

Grid suspension systems are composed of a wire grid or mesh, sometimes covered with paper or plastic-coated wire. Basically, one side of this covering material is fastened directly to the front rail while the other side is connected to the back rail by helical springs to provide a springing action.

Instead of the previous spring systems, rubber-webbing systems are used in some sofa frames. The webbing is fastened directly to the frame. Although its attachment is simple, the webbing allows little design flexibility. Basically, there are two methods of attachment. In the first a metal clip is attached to the frame and the webbing is then inserted through an opening in the clip. In the second case, the rubber webbing is simply tacked to the frame.

4. Implementation of the Rule Base for Sofa Frames

The rule base system programs were written in Microsoft Quick Basic™ version 4.50 which works under DOS environment and can be executed in IBM compatible personal computer. The system adopts most of the rules proposed by Picado (4) in his master thesis, removes duplicates and revises descriptions, then encodes every rule to respective variables that the programs can handle logically. The entire rule base is classified into 16 sub-rule bases by element properties. Some members are determined by two sub-rule bases because of independent properties. The main program of the rule base, namely RULE.BAS, is composed of 16 major rule subroutines according to 16 sub-rule bases.

To describe the flow of the rule base, the first sub-rule base for the front rail is taken as an example.
At the beginning, the user should decide one feature of the relation between front rail and stump, then answer the following question alone with the previous result. Finally, the program will encode these features to a variable and output the result. The structure of the first subrule base is shown in Figure 2.

The main program can provide a simple report, namely SOFATYPE. DAT, of a sofa frame configurations when a sofa frame is determined. The relationship of programs is shown in Figure 3.

5. Example of a Sofa Frame Properties Result

An example is illustrated in Figure 1. which uses a wire-mesh seat system in the artistic design. The type of sofa frame was determined by the rule base program; members configuration was defined as follow:

1. Front Rail :
   Condition:
   Front rail is flush with the stump.
   .and. lower edge is flush with lower edge of stump.
   .then. The end of the front rail is connected to the lower inside surface of the stump.

2. Arms :
   Condition:
   Arm is straight
   .then. external arm is flat on top, not deeply padded; arm is in flat position; and the top of the stump frames into the bottom surface of the arm at its front.

3. Arms :
   Condition:
   Arm and top rail are at different elevations.
   .then. The rear end of the arm frames into the front face of the back post.

4. Stump :
   Condition:
   Stump is in flat position.
   .then. Front leg is separated from of the stump. And the front rail frames into the inside edge of the stump near its bottom.

5. Back posts :
   Condition:
   Rear leg in not an extension of the back post
   .then. Rear of the external arm is attached to the side of the back post.

6. Top rails :
   Condition 1a.:
   Top rail is straight
   Condition 1b.:
.and. slightly wider than a 1" board turn on edge the top rail is in edge position.
.then. back post is in flat position, top rail is in edge position, and the end of the top rail is attached to the inside edge of the back post near the uppermost position on the backpost.

7. Center rails:

Condition:

Sofa frame has side slats.
.then. the center rail has the same elevation as the side slats and the center rail is connected at each end to the side slats.

8. Center rail end supports:

Condition: (null)

9. Center rail braces:

Condition 1a:
Center rail is in the edge position

Condition 1b:
.and. Sinuous springs are used in the back.
.then. the center rail is braced against the interior uprights; the brace should be located in the flat position between the natural divisions of the sitting positions.

Condition 2:
Backrest is covered with a webbing material.
.then. the center rail and the braces should be reinforced by means of a short member which is attached to the external face of the brace and to the internal face of the interior upright.

Condition 3:
Loose cushions are used in the backrest.
.then. the center rail should be braced against the interior surface of the top rail.

10. Stretcher:

Condition 1:
Uses sinusoidal springs in the seat
.then. the stretcher should be effectively blocked/braced at each end to resist bending forces imposed by the front and back rails.

Condition 2a:
Two stretchers

Condition 2b:
Uses drop-in units.
.then. Stretcher is located at the 1/3 and 2/3 points of the front and back rails.

11. Side Slat:

Condition 1: (from center rail and top rail)
.then. Side slat is in edge position and attached to the inside faces of stump and back post.

12. Back Rails:

Condition:
Side rail and back spring rail are at the same elevation.

Then, EITHER the stretchers are attached to the inside surface of the back spring rail.

OR the stretchers are attached to the inside surface of the back rail. The back spring rail is in flat position and attached to the inside faces of the side rails. And the back rail is in the edge position and is joined to the inside face/edge of the back post.

13. Side Rails:
Condition 1: (from stump and top rail)
Then, Side rail is in edge position and is attached to the internal faces of both stump and back post near the lowest position on the stump and back post.
Condition 2:
Uses screwed legs
Then, Side rail is attached to the inside face of the stump.

14. Legs:
Condition:
Uses corner braces between side rail and front rail.
Then, Leg is attached to corner braces.

6. Conclusion
Sofas are an important type of upholstered furniture, but manufacturers are more concerned with esthetic design than with structural design since the furniture market is largely "style" driven in the U.S. In short, it is the esthetic rather than the structural design which ultimately results in the sale of the product.

Furthermore, most operations in the furniture industry are labor intensive actions. For example, translation of artists' sketches into working drawings by "detailers" is a laborious hand process. The solution to these problems lie in the application of computer based design, product engineering, and production techniques.

The knowledge base system offers a good approach to classifying and synthesizing sofa frame system. This system provides practical means whereby furniture manufactures can use it easily with little engineering knowledge. The implementation of the system for the synthesis of sofa frames design showed that the system is able to define associated specific frame constructions based on evaluation of limited input data of artists' sketches of sofa appearance.

The concept of the study can be applied to other types of furniture. Due to the encoded properties of frame members, the system can also serve as a basis for computer-aided design (CAD) by passing variables to
design programs module. Finally, this system should not only be modified to make it more user friendly but also should be upgraded to take advantage of the new computer operation system such as WINDOWS™ 95.

Reference


Question 1:
1. Front rail is flush with stump.
2. Front rail is not flush with stump.

Variable
..then. FR1=1
..then. FR1=2

Question 2:
If FR1 = 1
1. Lower edge flush with lower edge of stump.
2. Front leg is continuous with the stump (one piece).
If FR1 = 2
1. Front rail extends across the full front of the sofa.
2. (No this property)

.then. FR2=1
.then. FR2=2

Results: (FR = FR1 *10 + FR2)
If FR = 11 The end of the front rail is connected to the lower inside of the stump.
FR = 12 The end of the front rail is connected to the inside edge of the stump.
FR = 21 The side rails are connected to the back inside surface of the front rail at each end of the front rail.
FR = 22 (Null)

Figure 2. The flow chart of the first sub-rule base for front rail.

The 16 sub-rule bases in 16 text files:
1. FRRULE.TXT : for front rail. 9. CSRULE.TXT : for center rail end support.
2. AR1RULE.TXT : for arm. 10. CR1RULE.TXT : for center rail braces.
5. BPRULE.TXT : for back post. 13. SSRULE.TXT : for side slat.
7. TR2RULE.TXT : for top rail. 15. SRRULE.TXT : for side rail.

Input files  Control program  Output file
16 sub-rule based files  RULE.BAS  SOFATYPE.DAT

Figure 3. The structure of the rule based knowledge base system.