Performance evaluation of computer-aided knit design using software package based on ontological knowledge model

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Received 11 December 2016, www.cmnt.lv

Abstract

The article represents the original approach to computer-aided warp knit fabrics on the base of universal algorithms and modern methodology which allows to apply the methods of projecting with the given technologies. The ontological approach is represented for development and improvement of knowledge model which provides the description of object domain of computer-aided warp knit fabrics and its formalized presentation. The elaborated software allows to perform fully the proceedings of art and technological and parametric projecting of warp knit fabrics. The performance evaluation of computer-aided warp knit fabrics on the basis of algorithmical and ontological approach is elaborated. To solve this problem we used the method of hierarchy analysis of Thomas Saati. The results of the evaluation represent that software grounded on ontological approach in totality of functional means is more effective than CAD on the base of algorithmical approach.

Keywords

warp knit fabrics
ontological approach
knowledge model
program-methodical package

1 Introduction

Computer-aided warp knit fabrics (WKF) design, as less studied and the most complicated knitted technology object in terms of its structure, is a complicated multiple-task problem, which solution is obstructed by the fact that the knowledge of this object domain is not enough structured and formalized.

Therefore, the task of intellectualization of computer-aided warp knit fabrics on the basis of universal algorithms and modern methodology of projecting to increase the effectiveness of technological preparation is actual nowadays.

2 Materials and methods

In our study, we have proposed an ontological approach to development and improvement of a knowledge model that describes the object domain of computer-aided design of warp-knitted fabrics and its formalized representation (Kochetkova 2012a). A system conceptual model of WKF, as the object of functional, design, and process engineering, has been developed to organize structured information that allows the expert support subsystem of computer-aided design to generate and manipulate knowledge in the object domain effectively.

3 Results and discussion

Conducted theoretical studies allowed us to develop program-methodical package of WKF which structure and composition (Figure 1) reflect the generalized algorithm for solving the knit design problem on the basis of ontological model of knowledge (Kochetkova 2012b).

Within the framework of the "PMA-WKF" (poly(methacrylic) acid - warp knit fabrics), subsystems for art-technological and structural-parametric knit design were developed through forming a pattern matrix, reproducing knitwear pattern, selecting materials, establishing structure and parameters of the WKF and selecting knitting machines.

As is obvious from Figure 1, "PMA-WKF" consists of four functional blocks: 1) database; 2) knowledge base; 3) simulation and design system; 4) ontological descriptions output block.

Raw materials and types of WKF interweaving. It also includes graphical objects libraries, intended to produce different patterning effects to move from the pattern matrix to the WKF structure matrix as well as to ensure the coupling of the art-technological and structural-parametric subsystems of the computer-aided design.

The knowledge base is intended for storing of ontological representations of the knowledge model components (task, solution method, and object domain), as well as procedural component of the problem solving process, i.e., the standard techniques of methods strategies implementation presented in the subsystem "Methods". Special attention in this functional block should be paid to the internal organization of solution methods subsystem. It consists of components that contain the ontological representations for solving different classes of problems, and is used for storing this knowledge in a form that is handy for their search and further application (Kochetkova 2012a).

The modeling and design system is used for visual modeling of the problem solution and further use of the resulting ontological models by design solutions formation procedures. Multi-window interface subsystem represents on-line data input interface. Output of the results is carried out upon receipt of all required ontological descriptions of knowledge model components and implementation of project procedures in subsystems of art-technological and structural-parametric design of the WKF.

The ontologies obtained by means of this system are displayed in the ontological descriptions output block that allows control of the design process at all stages of its implementation. Consider the operation stages of the user working with "PMA-WKF" program-methodical package (Figure1).

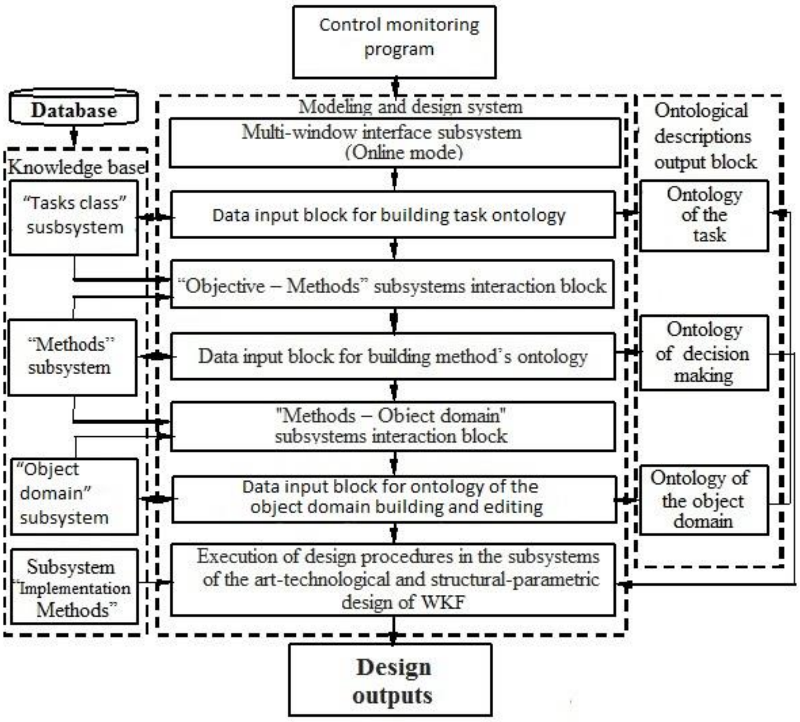

FIGURE 1 The structure and composition of the "PMA-WKF" package

Stage I. The description of a certain problem situation is put into the program. In the course of dialogue with the designer, informal and abstract description of a problem situation is transformed into the description of the specified task.

Stage II. On the basis of the received specification, the formulated task is attributed to one of the design objectives (either art-technological or structural-parametric), and the selection of appropriate ontological description components is conducted out of "Tasks class" subsystem. Then, using the data input block, the software package constructs the ontology of task by filling it with a specific content.

Stage III. Using the "Methods" subsystem, the software package selects the problem solving method. This subsystem contains various decision making methods in the context of their specific application to a particular class of design tasks. All knowledge that affect the choice of method is transmitted into the "Task – Methods" subsystems interaction block, where they are interpreted in terms of selected method to identify the indication axioms. Ontology of subsystems interaction is dynamically changed in each specific case; therefore, it is assumed setting in the subsystems interaction block the base ontology template of a given type with the most common concepts and relations that are applicable to any interaction.

Stage IV. To fill the method with data of object domain, the interaction ontology of the "Methods - Object domain" subsystem is developed, which interprets the method in terms of the object domain. Data needed by method to find project solution of the task in the object domain, is selected from the "Object domain" subsystem. At the object level, software package data input block is used to build the final version of ontology for adjustments of existing components of the object domain ontology descriptions. The designer has the opportunity to update the ontology with new concepts and relationships, as well as to change its structure.

Stage V. The desired design solution is formed on the basis of obtained ontological knowledge model, the data from object domain and executed implementation procedure, defined by the selected ontology method.

One of the most important "PMA-WKF" blocks is a knowledge modeling system carried out by the user, and subsequent design process. It was implemented as a set of data input blocks for reflection of existing ontological descriptions of knowledge model components and design outputs. The object-oriented programming language C# (C Sharp), combining object-oriented and context-oriented concepts, was selected as the implementation medium.

Testing of the "PMA-WKF" program-methodical package in terms of solving the problem of computer-aided art-technological and structural-parametric design of wefting warp-knitted fabrics has shown its correctness and suitability for solving the problems concerned the engineering preparation of sewing production.

The major task of computer-aided design development, improvement and introduction into manufacturing is the evaluation of their performance efficiency, i.e. the optimal use of the available analyzable resources system to achieve the ultimate results. In this regard, the application of efficiency assessment methods, conduction of comparative analysis, comparison of the investigated objects, as well as identification and selection of priorities is quite relevant. To solve this task, we used the hierarchy analysis technique developed by **T Saati** (Saati 1993). The method is based on the decomposition of complex problem, i.e. its presentation in the form of a structured set of components or criteria, whose interrelationships are formed in a hierarchical version of the presentation. The top of the hierarchy is the common goal, i.e. the desired state of the system. The next level is detailing of total goal in terms of selecting criteria, components or forces that influence the achievement of the indicated result. The lower level of the hierarchy contains possible alternatives, whose priority needs to be evaluated.

The hierarchy analysis technique involves the operation of pairwise comparison of individual hierarchy components (Diligensky, 2004). The results of the evaluation are presented in the form of a set of pairwise comparisons matrices:

$$B = \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ b_{21} & b_{22} & \dots & b_{2n} \\ \dots & \dots & \dots & \dots \\ b_{n1} & b_{n2} & \dots & b_{nn} \end{bmatrix}. \qquad [1]$$

In the matrix B, each element bij determines the expert's subjective opinion regarding the significance of the estimated i-th component of the hierarchy with respect to j-th component. Such matrices are compiled for comparison of the importance of each lower level elements relative to higher level. The assessment of the hierarchy elements is carried out in accordance with a nine-point scale of relative importance. On the basis of expert judgment matrices, the local priorities are calculated for each specific matrix, as well as the quality criteria of expert evaluations. Local priorities are formalized in the form of the main eigenvector of matrix V. Common way of finding eigenvectors is an approach based on finding the geometric mean. In accordance with this technique, the eigenvector component of i-th row is given by formula: $v_i = \sqrt[n]{b_{i1} \times b_{i2} \times \ldots \times b_{in}}$.

Then all the components vn of the eigenvector are normalized per unit through dividing by the sum, and these values define the local importance of relatively assessed elements. Experts' evaluation quality criteria are found on the basis of the calculation of judgments consistency indicators for each matrix of pairwise comparisons with regard to the maximum eigenvalue of the matrix.

The final stage of the method is finding of the integral generalized ratings of alternatives importance. The local priorities contraction procedure consists in determination of the weighted sums for all the elements of the same level that take into account the weighting factors (priority vectors) of higher level in the hierarchy. After determining the values of global priorities, a definitive conclusion is made about the relative importance of the evaluated alternatives.

Let conduct performance evaluation of the warp-knitted fabrics design using "PMA-WKF" by a set of the following indicators: generality, structuredness and formalization level of object domain knowledge, as well as the quality of the designed technological process. To identify, compare and prioritize we confront the investigated object with software products, based on algorithmic approach.

The elements of the considered software products include: 1) the art-technological design subsystem; 2) the structural-parametric design subsystem; and 3) servicing subsystems. The efficiency is determined by several factors: functionality, time resources, used resources, and the calculation accuracy. Figure 2 shows the hierarchy of the system for evaluation of effectiveness factors. The lower level forms the system describing variables x = (xi), i = 1, n. The resulting efficiency y is formed taking into account the weighting coefficients at the previous levels.

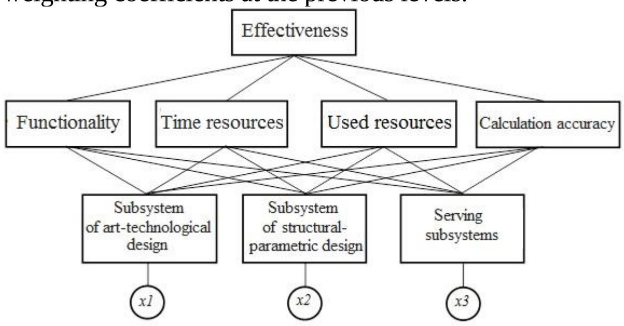

FIGURE 2 The hierarchy of the system for evaluation of effectiveness factors

In general form, the hierarchical synthesis operator can be written as follows (Diligensky 2004):

$$v_{ij(l+1)}^{l+1} = \sum_{j(l)=1}^{n(l)} v_{ij(l)}^{l} v_{ij(l+1)}^{l+1}, \; l = \overline{1, L}, \qquad [2]$$

where L – is the number of hierarchy levels; n(L) – is the number of elements at the levels [n(1)=n, n(L)=1].

Quantitative estimation of y(x) is determined by the formula:

$$y = \sum_{i=1}^{n} v_{i1}^{L} x_i, \; y \in [0,1]. \qquad [3]$$

Three the pairwise comparisons matrices filled in by the experts are presented below.

Matrix V_1^1

1	3	0.5	0.4
0.33	1	0.25	0.67
2	4	1	0.29
2.5	1.5	3.5	1

Matrix V_1^1

1	3	0.5	0.4
0.33	1	0.25	0.67
2	4	1	0.29
2.5	1.5	3.5	1

Matrix V_2^2

1	4	2
0.25	1	0.33
0.5	3	1

Matrix V_3^2

1	0.5	1.5
2	1	1
0.67	0.33	1

The uniformity indicators of the experts' judgments for compiled matrices equal to following: G11 = 0.016; G12 = 0.048; G22 = 0.050; G32 = 0.035. All indicators are less than 0.1 that testifies the consistency of composed matrices of paired comparisons. The values of the priorities vectors, resulted from processing the expert matrices of pairwise comparisons in accordance with the hierarchy (see Fig.2), are given in Table 1.

TABLE 1 The values of the priorities vectors

j	1	2	3	4
v_j^1	0.19	0.11	0.27	0.43
v_{1j}^2	0.56	0.33	0.28	0.25
v_{2j}^2	0.12	0.45	0.17	0.37
v_{3j}^2	0.32	0.22	0.55	0.38

Experts' performance evaluations of three systems in a nine-point scale are presented in Table 2, where 1 – corresponds to software products, created on the basis of the algorithmic approach; 2 – is the "PMA-WKF" program-methodical package; 3 – is the hypothetical version, which includes the best elements of software products 1 and 2.

TABLE 2 Performance evaluation of software products and WKF design

Design Subsystems	**Software products**		
	1	*2*	*3*
x1	7	9	9
x2	8	7	8
x3	7	8	8

4 Conclusions

Calculations of the efficiency of the systems under consideration, carried out according to the formulas (3) and (4), gave the following values: system 1, y = 0.68; system 2, y = 0.82; system 3, y = 0.87. Following the results of the obtained estimates, we can conclude that due to a combination of functional properties, "PMA-WKF" package is more efficient than the computer-aided systems based on algorithmic sapproach, by 14%.

Therefore the development and improvement of CAD by development and introduction of programming and methodical complex, which center is the ontological model of knowledge, is a valuable for science and practice.

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