About the automated pattern creation of 3D jacquard double needle bed warp knitted structures

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Abstract. Three dimensional structures can be produced on jacquard warp knitting machines with double needle bed. This work presents theoretical considerations about the modelling and simulation of these structures. After that a method is described, how to obtain production parameters from the simulation data. The analysis demonstrates, that the automated pattern creation of 3D structures is not always possible and not all mathematical solutions of the problem can be knittable.

1. Introduction
The jacquard warp knitting machines were initially used for production of samples with different decorative effects. In the last decade their control and programming allow as well the production of almost seamless clothing and other warp knitted pieces with tubular or another three dimensional form [1, 2]. The development and the production of such fabrics requires very good understanding of the warp knitting process and pattern and suitable CAD software for designing and manipulating the pattern before the production. This work does not concentrate on the modelling of the 3D configuration of the yarns axis in the structure, it considers the structure at one lever higher – at the macro level. The main question at that level is how one complex 3D shape can be split into several regions and after that programmed on the warp knitting machine, which in generally produce flat structural elements on its both needle beds and is able to make connection between these beds.

2. State of the art
In the area of the modelling of the yarn geometry of the warp knitted structures are existing several investigations and models [3–9], but the problem of the decomposition of one 3D profile into several parts and the generation of knitted program is very less investigated. In [10] are presented general consideration about the modelling of the loops in jacquard warp knitted fabrics. The modelling of jacquard towels is presented in [11]. The principles of the separation of the areas of different interlacement of the yarns for spacer warp knitted fabrics and the formation of the matrices for the guide control in the case of shoes is given in [12].
3. Patterning for Jacquard Warp Knitting

A simple jacquard warp knitted structure can be based on vertical courses (Figure 2, left), built of lock-stitch (0-1//) and weft yarns (0-0/1-1//), where the weft yarns in some places make longer (0-0/2-2//) or no (1-1/1-1//) underlaps up to the next course.

![Figure 1. Segment of a fabric (a) and the corresponding colour pattern (b)](image)

There are three possible appearances of the fabric, depending on the number of the yarns in a unit cell formed by two courses and the jacquard needles, transparent areas (no yarns, white), not so dense areas (two yarns, green) and dense areas (four yarns, red). These unit cells are transferred to a colour pattern (figure 1, right). Jiang, Zhang, et.al reported about an automated system for image recognition and classification of the areas, based on wavelet transformation [9]. These colour pattern can be converted quite easily to control data for the machine.

The possibilities on 2 needle-bed machines are more complex. To start with a relative simple case, the right edge of a hollow structure can be considered. In this example, you can distinguish 3 different elements: 1 - front, 2 - left edge and 3 - back (Figure 2a). In order a colour pattern to be created, the model has to be cut at the left front corner and flip the backside to the right, which is common technique for the construction of clothing around human body.

![Figure 2. Model of a left edge (a), corresponding colour pattern (b) and the simulated fabric (c)](image)

The colour pattern can be regarded as a matrix MC(p, g). The rows represent the courses (p) and the columns the guides (g).
\[
MC(p, g) = \begin{bmatrix}
c_{1,1} & \cdots & c_{1,g} \\
\vdots & \ddots & \vdots \\
c_{p,1} & \cdots & c_{p,g}
\end{bmatrix}
\]

The algorithm to compute the simulation requires a Matrix MM(q, g), with \( q = 8p \).

\[
MM(q, g) = \begin{bmatrix}
m_{1,1} & \cdots & m_{1,g} \\
\vdots & \ddots & \vdots \\
m_{q,1} & \cdots & m_{q,g}
\end{bmatrix}
\]

Again each column represents a Jacquard-guide and the rows contain the underlap and overlap movement for one unit cell. This movement \( m \) (8 values) is taken from a look-up-table.

4. Simulating for two needle bed Jacquard warp knitting

Starting from sketch of the fabric, several steps have to be performed in order the machine control data to be generated in automated way:

1. Create 2D sketch of the fabric to be produced.
2. Generate a 3D model with existing elements.
3. Generate a matrix with the element or for more intuitive use - image in .BMP-format.
   The front is on the left side and the rear side is mirrored on the right.
4. For each thread create a list of movements for the guides (yarns) through the needles (chain-link).
5. Compute the 3D-Geometry of the warp knitted structure.

Steps 1 to 3 have to be done by the designer manually or using some standard CAD system with 3D capabilities. Step 4 was implemented within MATLAB® and presented in [10]. The principle, implementation and different aspects of performing of Step 5 are reported in several papers, as for instance [1, 8].

In figure 3 these steps are illustrated with a simplified example of an alien glove with a thumb and two ‘fingers’. Figure 4 presents the simulated warp knitted structure for this example.

![Figure 3. Alien Glove: Sketch (a), 3D model (b), colour pattern (c).](image-url)
5. Transferring to a jacquard warp knitting machine
Jacquard warp knitting machines have one or more jacquard guide bars, whose guide needles can stay at its position or can move to one position to the right if a command is given (Figure 5a). Earlier realizations used classical mechanics [13] and the modern solution uses the Piezo-effect [14]. Such individual motions of the single guides allows creation of complex samples, which are used on curtain machines to create pictures on the structures (Figure 1a), on lace machines to produce ground variations, on two needle bed machines to produce ‘ready to wear’ bodies or hollow structures like gloves or tubes.

The movement of the threads has to be given in absolute values to compute the simulation. These absolute values contain the position of the guides on the Jacquard bar. The control unit of the Jacquard-machine demands two different set of control-data; one for the shogging movement of the jacquard bar (in former times known as pattern disc) and another set of data to control the individual movement of each jacquard guide (in former times given on punched cards). In order to automate the design process, some algorithms have to be developed which take the guide motion as input and generate data for both shogging movement and high-low information for the Jacquard guides.
Figure 5. Principle of Jacquard movement (a) and the realization on modern jacquard warp knitting machine (b; Patent for the piezo guide bars [14])

6. Problems

Not every geometry can be transferred to warp knitting program for the currently available machines. Figures 6 and 7 visualize one problem during the creation of the warp knitting program. If at a given place two guides have to be “missing”, in order for instance to produce a hole at that place, then this cannot be done with bars, placed at one guide bar, because these can move only to one direction (Figure 6b). If in the future the piezo material can be placed on both sides of the metal guide probably such guide can move to left and right and could be able to solve this problem, but at the current technique this is not possible.

Figure 6. How to produce a hole in the area of two guides, if these are required during the remaining time of the process (a)? If motion in the opposite direction were possible (b), then moving one guide to left and one to right would be a solution, but the current piezo guide bars can move only at one direction.

Possible solution of this problem will be to distribute the problematic guides on a separated guide bars (Figure 7b). In this case the single guide can be moved with the complete bar at a different position and back on the same place at later cycles. This solution has its disadvantage – for more complex
structures it can happens, that a large set of guide bars with single guides are required, which can become impossible to be produced from the technological point of view. In such case the structure has to be simplified and adjusted, so that it becomes knittable. But this is a demonstration, why the fully automated production of a warp knitting program from 3D data from the profile cannot always have technologically suitable solution.

Figure 7. Solution of the problem – the problematic guide has to be placed on another guide bar which can be moved as well.

7. Conclusions
This overview presents a possible method for simulation of 3D Jacquard warp knitted structures and generation of the machine data for production of these. The simulation uses fast and simple geometrical models which can be used only to generate initial geometry of the structures for mechanical simulations, but which is enough to give a rough idea about the fabric during the design process. The explained algorithm make clear which tasks has to be solved in the future in order automated design process from sketch to machine data to be possible.

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