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Abstract

Geometric modeling and haptic rendering of textile has attracted significant interest over the last decade. A haptic representation is created by adding the physical properties of an object to its geometric configuration. While research has been conducted into geometric modeling of fabric, current systems require time-consuming manual recognition of textile specifications and data entry. The development of a generic approach for construction of the 3D geometric model of a woven textile is pursued in this work. The geometric model would be superimposed by a haptic model in the future work. The focus at this stage is on hand-woven textile artifacts for display in museums. A fuzzy rule based algorithm is applied to the still images of the artifacts to generate the 3D model. The derived model is exported as a 3D VRML model of the textile for visual representation and haptic rendering. An overview of the approach is provided and the developed algorithm is described. The approach is validated by applying the algorithm to different textile samples and comparing the produced models with the actual structure and pattern of the samples.

Keywords

woven, hand, textile, 3d, geometric, modelling

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3D Geometric Modelling of Hand-Woven Textile

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ABSTRACT

Geometric modeling and haptic rendering of textile has attracted significant interest over the last decade. A haptic representation is created by adding the physical properties of an object to its geometric configuration. While research has been conducted into geometric modeling of fabric, current systems require time-consuming manual recognition of textile specifications and data entry. The development of a generic approach for construction of the 3D geometric model of a woven textile is pursued in this work. The geometric model would be superimposed by a haptic model in the future work. The focus at this stage is on hand-woven textile artifacts for display in museums. A fuzzy rule based algorithm is applied to the still images of the artifacts to generate the 3D model. The derived model is exported as a 3D VRML model of the textile for visual representation and haptic rendering. An overview of the approach is provided and the developed algorithm is described. The approach is validated by applying the algorithm to different textile samples and comparing the produced models with the actual structure and pattern of the samples.

Keywords: Fuzzy rule based, haptic modeling, textile woven fabric recognition, textile 3D geometric modeling, Fourier image analysis techniques

1. INTRODUCTION

Geometric modelling and haptic rendering of textile is an area of research in which interest has significantly increased over the last decade. A haptic representation is created by adding the physical properties of an object to its geometric configuration. While research has been conducted into geometric modelling of fabric, current systems require textile data to be manually entered into the computer simulation by a technician. The aim of this study is to develop an automatic and systematic approach for developing the 3D geometric model of a woven textile and then superimposing the haptic model over it. This cannot be achieved unless the modelling algorithm is scalable and adequately generic for a specific class of woven textiles. This work has its focus on hand-woven textile with the aim of developing haptic rendered models of such artefacts for display in museums.

Communicating the experience of touch through haptic interfaces that will render the textures of textiles displayed on a computer terminal is the goal of this project. Communication through texture and touch is fundamental to craftspeople and to textile designers making prototypes for industry. Touching the texture of a fabric by fingers or body creates a complex multi-sensory emotional and cognitive experience. The emotional aspects of this primary sensation are obvious in the linguistic complexity of touch. This is well understood and defined by textile professionals in terms of qualitative parameters. Developing a quantitative evaluation of these parameters and an objective understanding of the associated processes and relationships, particularly in the context of generating them through interaction with a virtual reality system, are the challenges pursued in this project.

The *Fabric Hand* of a cloth or garment is defined as the overall fabric quality perceived through operations such as touching, squeezing, or rubbing [1]. Many factors affect the Fabric Hand including flexibility, compressibility, elasticity, resilience, density, surface contour (roughness, smoothness), surface friction and thermal characteristics of the fabric. The properties of the textile raw material, yarn structure, planner structure (woven or knitted pattern) and finishing treatment could be employed in a mechanical model for predicting the fabric hand and its factors [2]. In many industrial applications, manual objective assessment methods by employing Kawabata machine are being deployed for fabric hand assessment rather than analytical models.

Application of image processing for recognizing fabric weave pattern has been a popular approach since the mid 1980's. Various methods such as neural networks [3], fuzzy logic [4] and Fourier image analysis techniques [5-7] have been applied to still images of the textile artifact with varying degrees of success. The major drawback of such methods has been the rigidity of the models identified for the artefacts.

The structure of a hand-woven textile sample is not always linear, and exposes some degree of non-linearity, randomness, and uncertainty. The patterns also are not uniformly repeated. For example, the warp and weft of the sample are not always aligned along a straight line or do not cross each other at right angles throughout the sample. In addition, there are random variations in the thickness of the yarn. Such features pose serious challenges to the physical modelling process. The warp and weft shape and cross section change dramatically especially in the fabrics because of the variable yarn structure and compression and elasticity forces in the fabric structure. On the other hand, many other factors affect the pattern complexity, especially in hand-woven fabrics.

In this study, a generic methodology based on fuzzy rule-based and Fourier image analysis is developed for automatic nondeterministic pattern recognition of the woven fabrics. The derived model is exported as a 3D VRML model of the textile for visual representation and haptic rendering. In the work conducted so far, a digital image of the textile is captured through scanning. A fuzzy-based algorithm is developed to identify the structure and pattern of the textile. The features derived through the algorithm are augmented with a priori knowledge about the sample. The overall model emerged in the process is deployed in constructing the 3D physical model of the sample.

The remainder of the paper is structured as follows. The algorithm developed to identify the woven fabric structure is described in Section 2. Three stages of the algorithm including scanning of the textile and pre-processing of the scanned image data, detection of crossed-points concerned with detecting the interlacing areas between warp and weft yarns, and detection of crossed-states that determines which yarn is over the other are explained. The methodology is further clarified by applying it to two textile samples and illustrating the results at each stage. The generation of the 3D model of the textile is reported in Section 3. This is achieved by creating a VRML file for a piece of textile with complete 3D variable-shape warp and weft and the weave pattern imported from the pattern recognition module. Finally, the strengths and constraints of the approach are identified and some conclusions are drawn.

2. AUTOMATIC RECOGNITION OF WOVEN FABRIC STRUCTURE

A woven fabric made of the cross combination of the warp and weft yarns has a two-dimensional lattice structure [8]. There are three major steps in identifying the fabric weave pattern:

- (a) Scanning and pre-processing the textile samples
- (b) Detection of crossed-points that is concerned with detecting the interlacing areas between warp and weft yarns, and
- (c) Detection of crossed-states that determines which yarn is over the other in the interlacing areas [9, 10].

2.1 Data & Pre-processing

The textile samples have been scanned with an office scanner with a resolution of 300 DPI. Images then have been converted to gray scale for faster processing. A series of pre-processing operations have been then applied to the images including median and low-pass filters to reduce noise. In the next step, the histogram equalization has been applied to achieve a more uniform gray level distribution.

2.2 Crossed-points detection

There are different methods suggested in the literature to detect crossed points. They are based on two primary methods. The focus of the first method is on Fourier filtering techniques for finding periodic weave pattern in a woven fabric image by either identification of the peaks in the power spectrum image [5, 6, 9] or finding the peak of autocorrelation function of the gray level data in warp and weft directions [3]. In the second method, the crossed-points are found by finding the peaks in accumulation gray level values in vertical and horizontal directions pixels [4, 11]. Both algorithms produce deterministic crossed-points as illustrated in Fig. 1. This approach is effective in some applications, but for accurate geometric and haptic modeling a more reliable nondeterministic method is required. The main assumption in

deterministic methods is based on straight and fixed shape of the warp and weft which is not the real case in many fabrics.

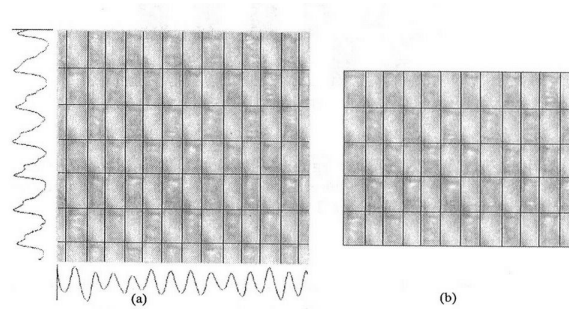


Fig. 1. Traditional deterministic methods for Crossed-points detection with fixed and straight shape assumption for warp and weft yarns.

In this work, the second method is modified to a piecewise-linear approach to cater for the non-linearities in the structure of the fabric and recognizing variable wrap and weft yarn shape. This provides a more effective and reliable method for real fabrics modeling. The proposed algorithm operates in two steps. In the first stage, the features of the image representing the peaks of local accumulating gray level values of vertical and horizontal curves are found and stored in a database. A fuzzy rule based engine is then applied to identify the structure of the textile. This approach is illustrated in Fig. 2.

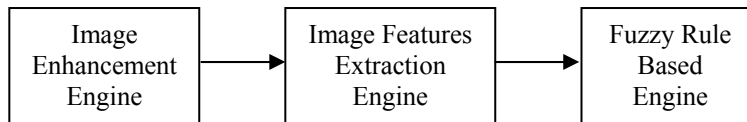


Fig. 2. Woven Fabric Pattern Recognition System Architecture

The image Features Extraction Engine operates by considering the image as a matrix of $\omega_{m \times n}$ and function $\Omega_{x,y}$; the gray level of the pixel in position x and y . The image slices SV_i in vertical and SH_i in horizontal directions are defined as elements of ω matrix. This is represented by a ‘_’ operator whereas k is the thickness of the image slice:

$$SV_i = \omega_{i*k,0} _ \omega_{i*k,n} _ \omega_{(i+1)*k,0} _ \omega_{(i+1)*k,n} \quad \text{and} \quad 0 \leq i \leq \left\lfloor \frac{m}{k} \right\rfloor - 1 \quad (1)$$

$$SH_i = \omega_{0,i*k} _ \omega_{m,i*k} _ \omega_{0,(i+1)*k} _ \omega_{m,(i+1)*k} \quad \text{and} \quad 0 \leq i \leq \left\lfloor \frac{n}{k} \right\rfloor - 1 \quad (2)$$

Considering α_i to be a vector with m elements as the accumulating gray level values for vertical slice i , SV_i :

$$\alpha_{i,j} = \sum_{z=0}^k \Omega(SV_i^{z,j}) \quad \text{For } 1 \leq j \leq n \quad (3)$$

Also, considering β_i to be a vector with n elements as the accumulating gray level values for horizontal slice i , SH_i :

$$\beta_{i,j} = \sum_{z=0}^k \Omega(SH_i^{j,z}) \quad \text{For } 1 \leq j \leq m \quad (4)$$

Feature points set μ_{vi} for vertical slice i and μ_{hi} for horizontal slice i are calculated as below:

$$\mu_{vi} = \{p | p \in \min(\alpha_i)\} \quad \text{For } 1 \leq i \leq m \quad (5)$$

$$\mu_{hi} = \{p | p \in \min(\beta_i)\} \quad \text{For } 1 \leq i \leq n \quad (6)$$

Other types of feature points such as maximum values can be also calculated. The estimated features are fed into the Fuzzy Rule-based Engine to find the structure of the sample.

Fuzzy Rule-Based Engine is a fuzzy implication algorithm represented by fuzzy rules obtained from a priori knowledge about the textile structure and warp and weft floating behavior. This engine identifies the significant feature points and filters out points which are primarily noise and do not contribute towards identifying the textile structure. The rules in the engine could be classified in two categories:

- (a) *Filtering rules* which distinguish significant feature points from noise and non-significant feature points by applying a fuzzy criterion to each feature point and their neighbours. These rules check some fuzzy criteria on every feature point based on its location and its neighbours.
- (b) *Yarn shape detection rules* which select a subset of the feature points representing the border of warp or weft based on the gradients of the border on each moment. These rules facilitate the decision making by selecting the best point to be in the yarn border as the next choice.

A prior knowledge about the yarn edge curve could be utilized in predicting the gradient of the yarn border. The yarn edge curve gradient prediction is illustrated in Fig. 3. The short lines indicate the gradients of the edge curve. The narrow cross sections show the locations where weft and warp are floating over each other. The shape is changing due to friction forces and compression in these points.

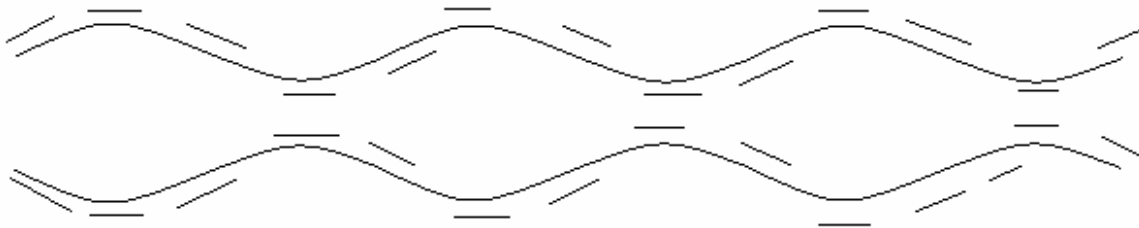


Fig. 3. The general yarn edge shape in textile.

A recursive backtracking procedure is developed to add a feature point to yarn edge set $warp_i$ and $weft_i$ by employing the Fuzzy Rule-Based Engine. A prior knowledge about the yarn edge shape curve gradient is used in this procedure. This backtracking procedure is defined by the pseudo-code below:

Select the point p with minimum x from μ_{h0}

Find_edge($p, warp_i$)

{

For each $i \in \{1, \dots, n\}$

{

Find the distance of p with the feature points in μ_{hi}

Fuzzify the distances based on **distance** fuzzy set degree of membership

Calculate the gradients of each connection lines between p and feature points set μ_{hi}

Choose **f**; the feasible feature points set in slot i based on fuzzy rules and edge gradient paradigm

For each **p**, a member of **f**; call the find_edge ($p, warp_i$) procedure for slot $i+1$

}

}

This procedure starts from an initial point and attempts to find the neighboring points which can be part of the yarn edge using gradient and the fuzzy distance of these points. All possible conditions are checked in the fuzzy rules including negative gradients, zero gradients and positive gradients. Using a backtrack approach, all the possible states are examined. This results in selection of a subset of feature points satisfying the fuzzy rules. The same procedure is applied in finding $weft_i$ set and μ_{vi} .

The *distance* fuzzy variable membership functions are shown in Fig. 4. The Fuzzification of the distance is carried out by calculating the distance of point p relative to all the points in slot $i+1$ and normalizing the distances between 0 to 1. The fuzzy set consists of very small, small, small-medium, large-medium, large and very large values.

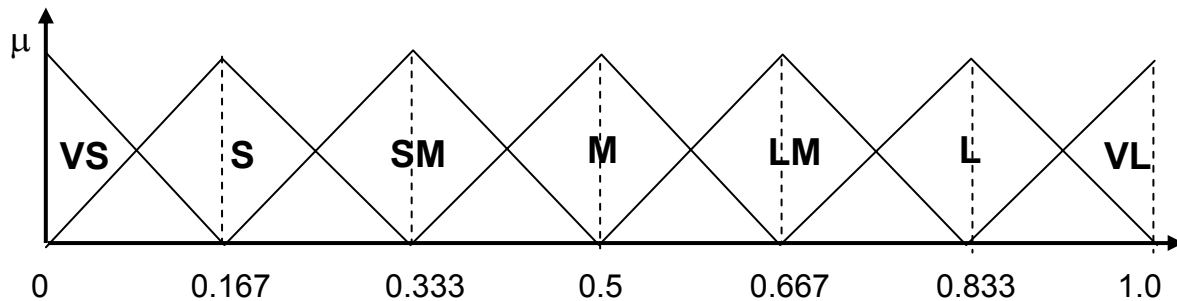


Fig. 4. The *distance* fuzzy variable membership function using for fuzzification

Consequently after tracking the yarn edge, for each edge of warps and wefts, a set $warp_i$ or $weft_i$ of nominated points are established respectfully. After detecting each set of $warp_i$ or $weft_i$, all the points located in a rectangle of min and max points in the set have been removed from the feature points to deny the procedure for rechecking that area.

As the last step for all the points in each $warp_i$ or $weft_i$, a quadratic spline interpolation is applied to the yarn edge points. Fig. 5 demonstrates all the steps applied to two small pieces of hand woven fabrics referred to by a and b. Indexes 1 to 4 represent the following stages, respectively:

1. The original scanned images of textiles.
2. Textile image with its vertical and horizontal feature points
3. First iteration of fuzzy rules implication for removing noise points and finding the yarn (warp and weft) edges.
4. Final step of fuzzy rules implication for finding the yarn shape. The white color shows the space between two neighbouring yarns. The non-linear nature of the algorithm is well represented. The yarn's edge is produced by quadratic spline interpolation estimated by the Fuzzy Rule-Based Engine for each yarn border.

2.3 Crossed-states detection

The next step in fabric weave pattern recognition is crossed-states detection. Many different methods have been suggested for this problem in the literature including employing texture orientation features in each one of the detected cells [10], normalized aspect ratio of an ellipse-shaped image at crossed points of the fabric [12], Fuzzy C-Means Clustering [4, 11], and Fourier image analysis techniques [5-7, 13, 14]. The outcome of this stage is a weave pattern diagram showing the warp over weft or weft over warp in each cell of cross points. Fig. 6 shows some of the fundamental weave patterns [15].

In the proposed system, for each detected cell bordering 4 different yarn edges- texture orientation features and Frequency Spectrum based on Fast Fourier Transform are calculated. The results produced in this process are deployed in crossed states detection process. A typical weave pattern diagram produced in the process is illustrated in Fig. 7.

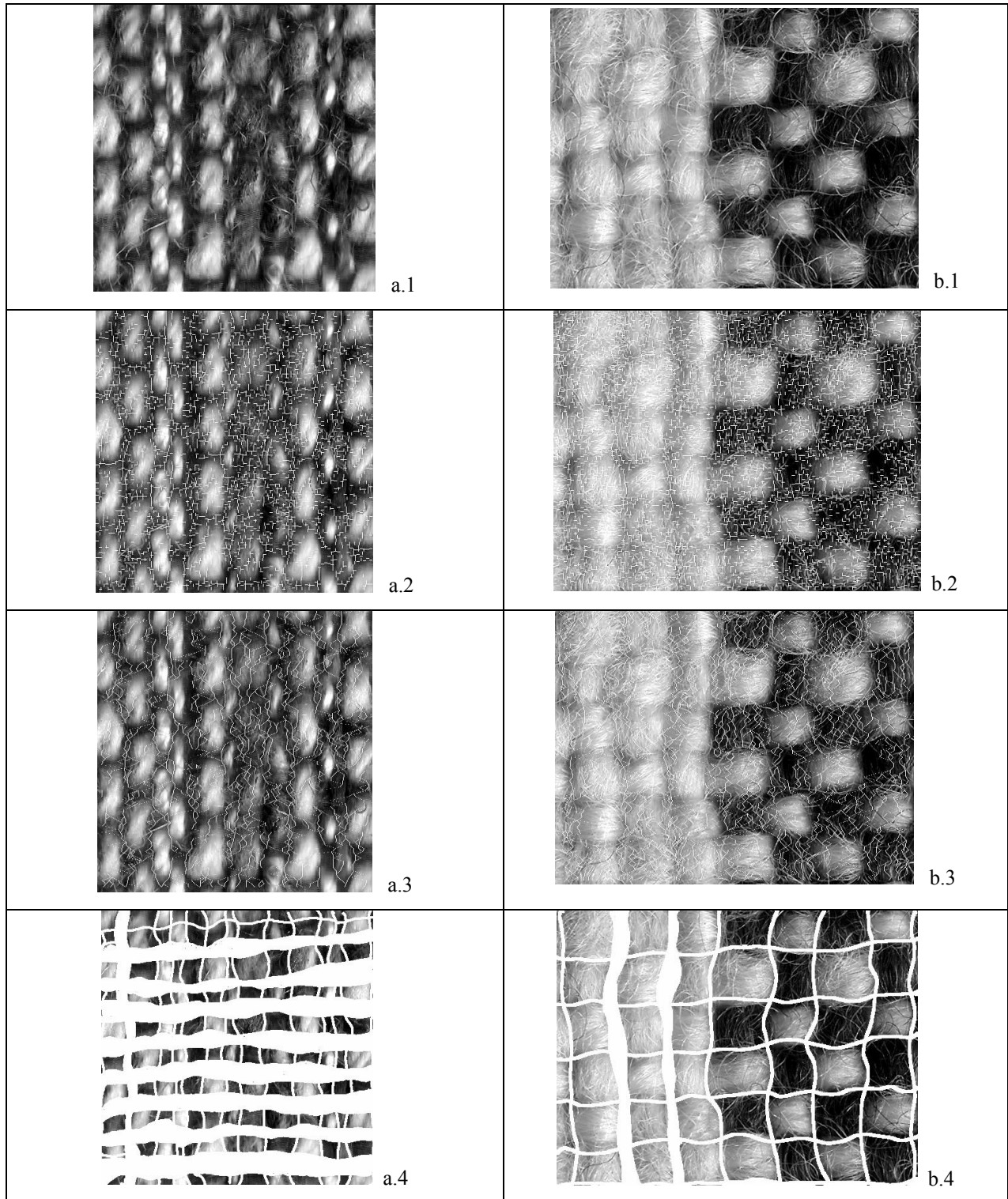


Fig. 5. Crossed-points detection steps for two small pieces of hand woven fabrics

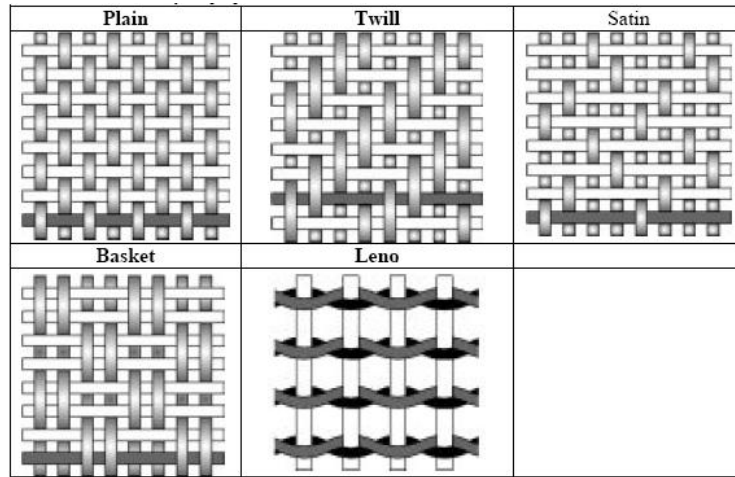


Fig. 6. Different fundamental weave patterns

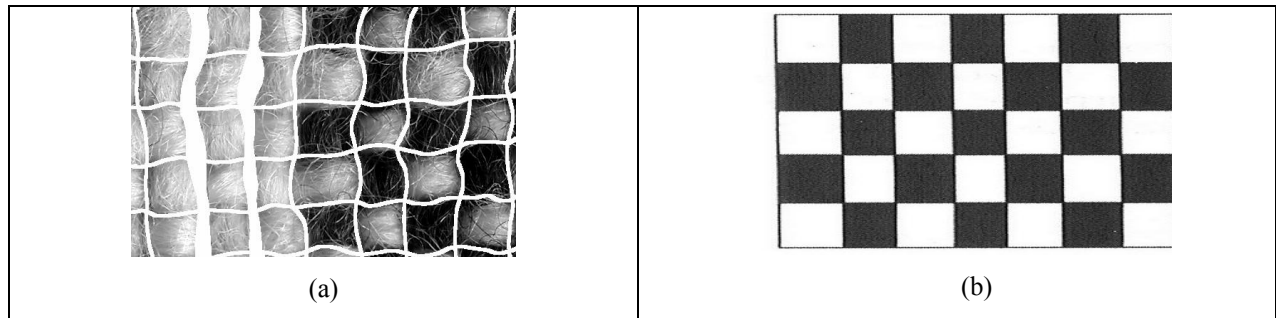


Fig. 7. (a) A piece of fabric with its warp and weft edge detection (crossed-points detection)

(b) Weave pattern diagram, black ones are warp float areas and white ones are weft float areas (crossed-states detection)

3. 3D GEOMETRIC MODELING OF THE TEXTILE

The results of the pattern recognition phase are deployed in developing the 3D geometric model of the textile. This includes warp and weft variable shape and their yarn edge, space between neighbor warps and wefts, the pattern of wrap and weft float (weave pattern) and the measurements of the yarn cross sections in warp and weft directions (by counting the pixels and knowing the scanning resolution). A 3D geometric model generator is developed to produce an accurate VRML 3D model of the textile based on the data obtained in pattern recognition stage. The 3D VRML model of the textile can be exported to a virtual reality environment for complete 3D representation of the textile and its haptic rendering. The haptic rendering can be achieved by calculating the fabric hand of the textile and its mechanical properties estimated based on the fabric and yarn structure.

The 3D geometric model generator creates a VRML file for a piece of textile with complete 3D variable-shape warp and weft and the weave pattern imported from pattern recognition module. Fig. 8 demonstrates two generated models for plain and twill patterns.

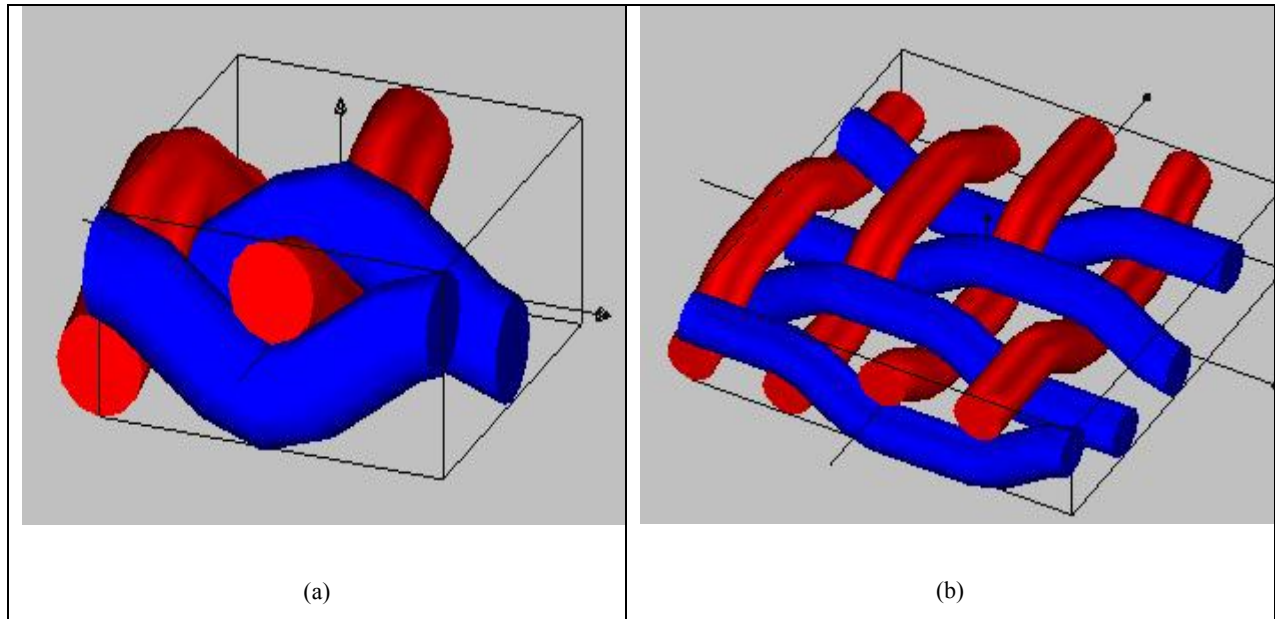


Fig. 8. a) A sample of plain pattern 3D geometric model has been generated by the system

b) A sample of twill pattern 3D geometric model has been generated by the system

Fig. 9 shows a 3D geometric model of a piece of fabric in a Virtual Reality viewer which could be explored by the user. WiseTex, a textile geometric modeling software which has been developed by MTM department of Katholieke Universiteit Leuven[16], has been customized as an engine for geometric model generator. This engine has a variety of yarn structures as the main blocks for creating a 3D model of the fabric. The warp and weft shape and measurements have been imported from the pattern recognition module for customizing the yarn block and the fabric pattern has been imported from pattern recognition module for creating the 3D model itself.

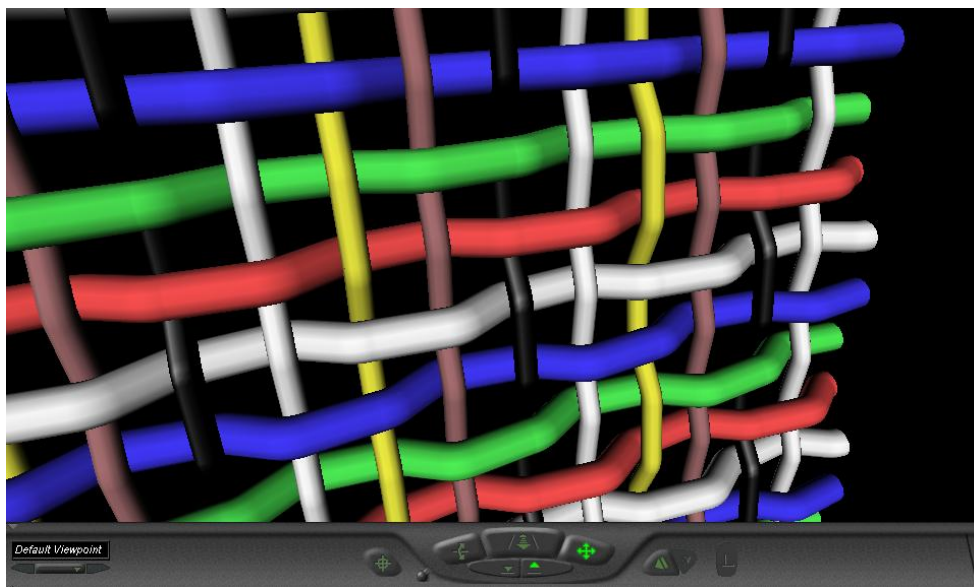


Fig. 9. The 3D Geometric model of a piece of fabric in a Virtual Reality viewer

4. CONCLUSION

A woven fabric Pattern Recognition system based on fuzzy rule based engine and image feature extraction with Fourier analysis techniques for non-deterministic crossed-points detection and crossed-states detection have been developed. The fabric pattern is then exported to a 3D geometric model generator for building a 3D VRML model which has been employed for virtual reality world representation of the textile.

The approach operates on a scanned image of the textile. It identifies the features of the textile and constructs the warps and wefts structure based on the measured features. It caters for non-linear and random variation in the yarn and its structure in the fabric. This is probably the most distinguishing feature of the algorithm developed in this work and previous studies. This provides a generic and scalable method.

The next stage of the work will focus on further enhancement of the pattern recognition algorithm for textile 3D geometric modeling. This will require extensive validation of the developed algorithm by applying it to different types of textiles and assessing the accuracy of the approach. This will reveal the changes required to improve the accuracy and effectiveness of the algorithm.

Developing a generic algorithm to construct the haptic model of the textile and superimposing it on the geometric model is another major step in the future work. This will require both the development of the software driving the haptic model and the hardware providing tactile interface between the user and the model.

REFERENCES

- [1] C. L. Hui, "Neural Network Prediction of Human Psychological Perceptions of Fabric Hand," *Textile Research Journal*, May 2004.
- [2] L. K. Hatch, *Textile Science*. Minneapolis: West Publishing Company, 1993.
- [3] B. S. Jeon, J. H. Bae, and M. W. Suh, "Automatic recognition of woven fabric patterns by an artificial neural network," *Textile Research Journal*, vol. 73, pp. 645-650, Jul 2003.
- [4] C. F. J. Kuo, C. Y. Shih, and J. Y. Lee, "Automatic recognition of fabric weave patterns by a fuzzy C-means clustering method," *Textile Research Journal*, vol. 74, pp. 107-111, Feb 2004.
- [5] B. G. Xu, "Identifying fabric structures with Fast Fourier Transform techniques," *Textile Research Journal*, vol. 66, pp. 496-506, Aug 1996.
- [6] S. A. H. Ravandi and K. Toriumi, "Fourier-Transform Analysis of Plain Weave Fabric Appearance," *Textile Research Journal*, vol. 65, pp. 676-683, Nov 1995.
- [7] J. G. Campbell and F. Murtagh, "Automatic visual inspection of woven textiles using a two-stage defect detector," *Optical Engineering*, vol. 37, pp. 2536-2542, Sep 1998.
- [8] M. Kinoshita, Hashimoto, Y., Akiyama, R. and Uchiyama, S., "Determination of Weave Type in Woven Fabric by Digital Image Processing," *J. Textile. Mach. Soc. Jpn.*, vol. 35, pp. 1-4, 1989.
- [9] A. Lachkar, Gadi, T., Benslimane, R., D'Orazio, L., "Textile Woven Fabric Recognition using Fourier Image Analysis Techniques : Part I : A Fully Automatic Approach for Crossed-points Detection," *J. Text. Inst.*, vol. 94, pp. 194-201, 2003.
- [10] A. Lachkar, Benslimane, R., D'Orazio, L and Martuscelli, E., "Textile Woven Fabric Recognition using Fourier Image Analysis Techniques : Part II - texture analysis for crossed-states detection," *J. Text. Inst.*, vol. 96, pp. 179-183, 2005.
- [11] C. F. J. Kuo, C. Y. Shih, and J. Y. Lee, "Repeat pattern segmentation of printed fabrics by hough transform method," *Textile Research Journal*, vol. 75, pp. 779-783, Nov 2005.
- [12] T. J. Kang, C. H. Kim, and K. W. Oh, "Automatic recognition of fabric weave patterns by digital image analysis," *Textile Research Journal*, vol. 69, pp. 77-83, Feb 1999.
- [13] C. F. J. Kuo and C. C. Tsai, "Automatic recognition of fabric nature by using the approach of texture analysis," *Textile Research Journal*, vol. 76, pp. 375-382, May 2006.
- [14] M. Rallo, J. Escofet, and M. S. Millan, "Weave-repeat identification by structural analysis of fabric images," *Applied Optics*, vol. 42, pp. 3361-3372, Jun 2003.

- [15] Aono, P. Denti, D. E. Breen, M. J. Wosney, "Fitting a woven cloth model to a curved surface: Dart insertion," *IEEE Journal of Computer Graphics and Applications*, pp.60-70, September 1996.
- [16] Lomov, S. V., I. Verpoest, "Wisertext - Virtual textile reinforcement software", cited at http://www.mtm.kuleuven.be/Research/C2/poly/research/textile_modelling/textile_geometry_modelling_paper_sl.pdf, Dec. 2007.