# THERMAL DIFFUSION IN FABRICS AND A GRAPHICS ALGORITHM FOR APPAREL PATTERN RECONSTRUCTION

by

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Short paper
DOI: 10.2298/TSCI1205484S

*This paper proposes a new apparel pattern-reconstruction method, which breaks sets of patterns into multiple parts according to special thermal characteristics in different parts of human body.*

Key words: *thermal diffusion, inverse problem, pattern-reconstruction, clothing, fabric, graphics algorithm*

## Introduction

Thermal diffusion of water vapor is quite different from different parts of human body. A new designed apparel should consider the heat and moisture transfer from skin to environment through fabrics. We developed an empirical model to simulate the thermal diffusion in different parts of human body, and this research aims to find a new apparel pattern-reconstruction method for automatic generation of clothing patterns.

## Experimental design

Computer-aided design (CAD) technology has been caught much attention recently in clothing design, but previous work never considered the thermal requirement [1-3]. Considering the governing equations for heat and moisture transfer through fabric is very difficult to be solved, we divide the solution domain into different sub-domains for easy treatment, and the pattern for each sub-domain is designed according to thermal and geometrical properties of different parts of human body, and a database for each apparel component is built. For an individual design, when the body size and the fabric are fixed, the boundary conditions for the governing equations in each part is prescribed, and an optimal patter is produced considering the requirement of thermal and geometrical properties and aesthetics as well, alternative candidates are also available for the individual's free choice, and a whole clothing pattern is generated, the process and steps are shown in fig. 1.

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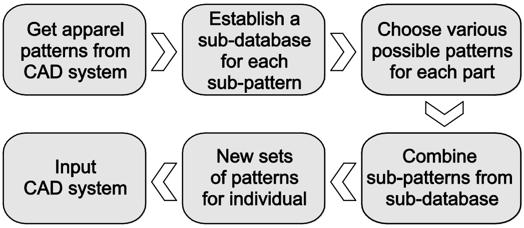


**Figure 1. Experimental process flow**

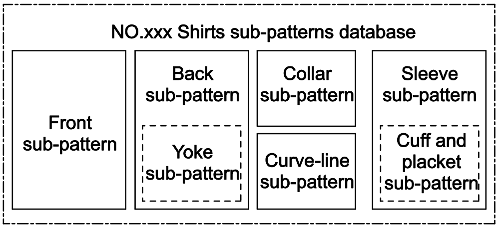


**Figure 2. Shirts components patterns database**

### Constructing patterns-database of apparel components

Taking shirt patterns as an example, the whole set of shirt patterns are divided into several components based on human body characteristics, and patterns-database of apparel components is built based on apparel CAD system, as shown in fig. 2. Each pattern satisfies the thermal requirement.

## Apparel pattern-reconstruction process

### *Mathematical model for heat and moisture transfer*

A 3-D model is needed for complete simulation of heat and moisture transfer through fabric. In order to elucidate the basic idea of the simulation procedure, we consider a 1-D model for temperature alone.

For a steady case, the temperature satisfies [4]:

$$k_{\text{air}}\frac{\mathrm{d}^2T}{\mathrm{d}x^2}=0 \quad \text{and} \quad k_{\text{fabric}}\frac{\mathrm{d}^2T}{\mathrm{d}x^2}=0 \tag{1}$$

with boundary conditions:

$$T(0)=T_{\text{body}}, \quad T(L)=T_{\text{environment}} \tag{2}$$

and at inner side of the fabric, $x = x_{\text{design}}$, it follows:

$$k_{\text{air}}\frac{\mathrm{d}T}{\mathrm{d}x}(x_{\text{design}})=k_{\text{fabric}}\frac{\mathrm{d}T}{\mathrm{d}x}(x_{\text{design}}) \tag{3}$$

where $k_{\text{air}}$ and $k_{\text{fabric}}$ are the thermal conductivity of air and fabric, respectively, $x_{\text{design}}$ is determined by a suitable thermal requirement; if the value meets the one required by the pattern model in the database, it is an optimal one, if not, some candidate values are suggested for choice. Moisture transfer can be done in a similar way.

### *Pattern reconstruction process*

For an individual, the body size is fixed, and the initial guess for $x_{\text{design}}$ can be given artificially, and eq. (1) can be solved with the given boundary conditions. The general thermal requirement is:

$$k_{\text{fabric}} \frac{\mathrm{d}T}{\mathrm{d}x}(L) = Q_L \tag{4a}$$

or

$$Q_{L\,\min} < k_{\text{fabric}} \frac{\mathrm{d}T}{\mathrm{d}x}(L) < Q_{L\,\max} \tag{4b}$$

where $Q_L$ is the required heat flux at the outside of fabric. Generally an iteration process is needed until eq. (4) is satisfied. When $x_{\text{design}}$ is determined, pattern reconstruction process can be easily proceeded.

Combination of $x_{\text{design}}$ and body size, the patterns for sleeves, collar, armhole, shoulder and bodice can be constructed easily as shown in figs. 3-7, respectively.

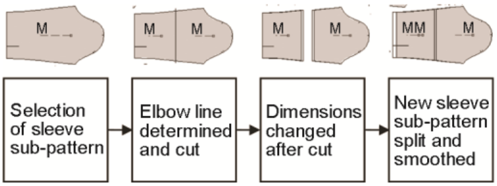


**Figure 3. Sleeve length size and pattern configuration flow**

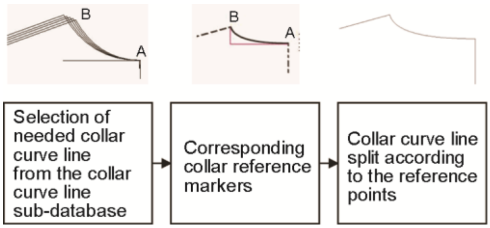


**Figure 4. Collar curve size and pattern configuration flow**

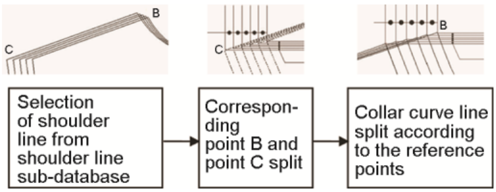


**Figure 5. Shoulder sizes and pattern configuration flow**

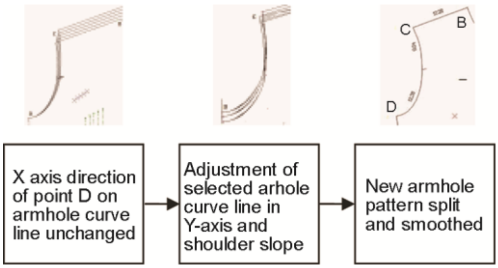


**Figure 6. Armhole sizes and pattern configuration flow**

## Conclusions

It is actually an inverse problem to determine $x_{\text{design}}$, which is still subjected to geometrical and aesthetic requirements in practical design.

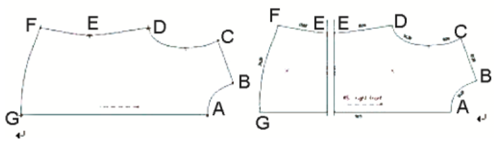


**Figure 7. Length sizes and pattern configuration flow**

A whole pattern is automatically produced after each sub-pattern is determined according to the thermal, geometrical and aesthetic requirements. The method is also suitable for mass-production of a special clothing, for example, the labour suit for high hot environment in some steel plants.

## Acknowledgments

The work is supported by PAPD (A Project Funded by the Priority Academic Program Development of Jiangsu Higher Education Institutions).

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Paper submitted: May 25, 2012
Paper revised: August 1, 2012
Paper accepted: August 26, 2012