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A fine grained digital textile printing system based on image registration

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ABSTRACT

Printed fabrics differ from non-planar fabrics (e.g., embroidery) in their rich colours, various patterns and low costs. However, non-planar fabrics are considered more attractive, expensive in appearance and luxurious owing to their solid texture patterns, floats and luster contrasts. To produce fabrics that are both colorful and lavish and also have color gradients, this paper proposes a novel fine-grained digital printing system that combines digital textile printing and non-planar fabrics. Note that because distortion is one of the characteristics of the fabric, directly printing an ink-design pattern onto non-planar fabric gives poor performance. This work develops a solution to accurately align the ink-design pattern with the fabric, consisting of both hardware and software parts that are used to take pictures of the fabric, employ image registration-based computer vision technology to deform the ink-design pattern according to the deformability of the fabric, and print the deformed ink-design pattern onto the fabric. The system is flexible and highly automated, and it makes mass production possible. In the prototype, fine quality fabrics are produced efficiently (a fabric of 0.12 m^2 in less than 4 s).

1. Introduction

Digital textile printing is a new technology to make ink-designs on textiles, which began in the late 1990s to replace traditional analogue screen-printing [1–3]. Compared with analogue screen-printing, digital textile printing is simpler and generates fewer emissions because it skips the processes of color separation, drawing and screen preparation [4]. Digital textile printing makes it possible to create fabrics with vibrant colors, photo-quality images and personalized designs [5]. However, textile printing products are considered low-end in comparison with non-planar fabrics (e.g., embroidery, lace) due to the latter's grains and luster contrasts. The problem is that non-planar fabric products are limited in terms of colors and efficiency.

To produce colorful and lavish fabrics with solid texture patterns, approaches to combining non-planar fabrics and printing have been studied for over two decades. The tremendous challenge is how to achieve a perfect alignment of fabric with ink-design, considering the deformability of fabric. Apparatus and methods using hoops have been proposed to ensure accurate alignment between the screen-printing and automatic embroidery machines [6,7]. Kuki et al. [8] designed embroidery sewing machines that allow both embroidery and print images to be formed on the workpiece cloth.

However, there are two main drawbacks to the existing approaches. First, specific apparatus are proposed for embroidery, which cannot be generalized to different fabrics. Second, these methods require significant human intervention.

In contrast to previous works, this paper presents a novel fine-grained digital printing system based on image registration technology [9,10] that produces digital ink-designs on non-planar fabrics. This solution consists of specific hardware and suitable algorithms to overcome the deformability of fabric (as shown in Fig. 1). The key hardware components in the proposed printing system include an industrial camera, an LED, a computer and a digital textile printer. In this paper, algorithms are proposed to align the ink-design pattern with the fabric pattern. The basic idea of this solution is to take pictures of the fabric, employ image registration-based computer vision technology to deform the ink-design pattern according to the deformability of the fabric, and print the deformed ink-design pattern onto the fabric. Using the proposed system, customized fabrics on which the fabric pattern and the ink-design pattern are perfectly matched can be obtained.

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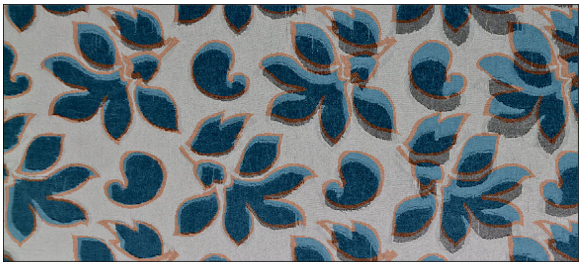

Fig. 1. An example shows that direct printing cannot achieve satisfying results. The ink-design pattern does not align perfectly with the stitch contours.

The proposed system is more flexible, highly automated and makes mass production possible.

Regarding the proposed printing system, there are several key challenges to be addressed, including a new processing flow to produce customized fabrics and several algorithms to align the fabric pattern with the ink-design pattern in real time.[1] As far as known, the proposed system is the first to combine digital textile printing and non-planar fabrics precisely to produce new customized fabrics.

The main contributions can be summarized as follows:

(i) A novel fine-grained digital printing system which combines digital textile printing and non-planar fabrics to produce new customized fabrics.
(ii) A new processing flow to produce customized fabrics on which fabric patterns and ink-design patterns are perfectly matching.
(iii) Several algorithms to perfectly align non-planar fabrics (e.g., embroidery, lace, etc.) with ink-design patterns.

2. Related work

Textile printing originates from ancient China as the process of printing color to textiles in designs [11]. With the development of digital technology, digital textile printing emerged in the 1990s [12,13]. It includes two methods for digital textile printing: indirect heat transfer printing and direct ink-jet printing [14].

Approaches of combining non-planar fabrics and printing have been studied for over two decades. Allen [6] proposed a combination embroidery/screen printing apparatus and method are provided to substantially concurrently reproduce a pattern on textile substrate wherein a first pattern portion of each such reproduction is screen printed and a second portion of each such reproduction is embroidered. This work employed mechanic apparatus to achieve alignment between screen printing and embroidery. However, much human intervention is needed in manufacturing. Buck [7] presented one embodiment of a system, method, and apparatus for screen printing and embroidering a garment mounted in a hoop. Kuki et al. [8] suggested that embroidery sewing machines allow both embroidery and print images to be formed on the workpiece cloth. Mass manufacture is impossible for these methods because of complicated operations.

In contrast to previous approaches, the proposed system which combines digital textile printing and non-planar fabrics is more flexible, highly automated and makes mass production possible. This solution is composed of specific hardware and algorithms on top it, which performs image acquisition, distortion detection, image alignment and prints deformed ink-design pattern. The alignment between the fabric image and the ink-design image is addressed by a feature-based image registration method [15–17]. Because fabrics show different characteristics, various algorithms are employed to handle them.

3. Fine-grained digital printing system

3.1. Overview

Digital textile printing technology is becoming increasingly popular for textile printing in modern industry. It produces fabric products with vibrant colors, photo-quality images and personalized designs. This paper proposes a fine-grained digital printing system that combines digital textile printing and non-planar fabrics to produce new colorful and high-grade fabrics. Note that distortion is one of the characteristics of the fabric. To perfectly align the ink-design pattern with the fabric pattern, machine vision technology is employed. The system is a combination of hardware and software approaches. In the following sections, the system will be introduced in detail.

3.2. Approach

This work relies on machine vision to achieve perfect alignment of the ink-design pattern and the fabric pattern through registering their images. Normally, the fabric pattern and the ink-design pattern contain repeating patterns. A single fabric pattern repeat is referred to as a fab-design.

The approach is as follows. The live fabric image is acquired by a monochrome CCD camera in the imaging zone (Fig. 2) while the fabric is transported on a black conveyer and is then matched to a prototype image (a single ink-design pattern repeat). During this matching, the system determines the fabric distortions (compared to the single ink-design pattern repeat) in terms of the matching result, and rectifications are performed on the ink-design pattern to compensate for these distortions in real-time. After these corrections are performed, the deformed ink-design pattern is printed onto the fabric in the printing zone.

There are four steps in our approach: system initialization, image acquisition, image processing, and printing, which will be introduced in detail in section processing flow.

3.3. Processing flow

Once the fabric and the ink-design pattern to be printed on it are picked up, the live fabric image is processed by the proposed approach. In this section, the processing flow consisting of four steps is introduced as shown in Fig. 3. For each fabric, step 1 is performed only once at the beginning. Then, all live fabric images are processed by step 2–step 4.

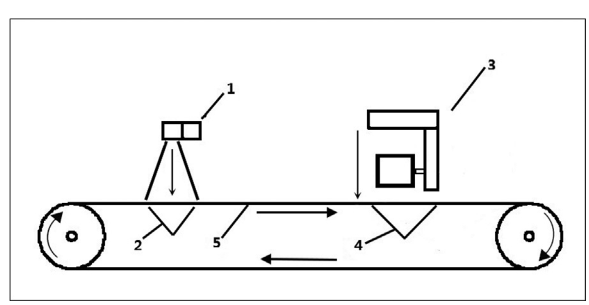

Fig. 2. Side view of the fine-grained digital printing system. (1) The industrial camera and LED. (2) Imaging zone. (3) Printing head. (4) Printing zone. (5) Conveyer.

[1] Real time means the image whose size is about 300×6000 pixels was dealt with in 4 s in which the fabric moves from imaging zone to printing zone.