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[POSTER] Pseudo Printed Fabrics through Projection Mapping

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Abstract

Projection-based Augmented Reality commonly projects on rigid objects, while only few systems project on deformable objects. In this paper, we present Pseudo Printed Fabrics (PPF), which enables the projection on a deforming piece of cloth. This can be applied to previewing a cloth design while manipulating its shape. We support challenging manipulations, including heavy occlusions and stretching the cloth. In previous work, we developed a similar system, based on a novel marker pattern; PPF extends it in two important aspects. First, we improved performance by two orders of magnitudes to achieve interactive performance. Second, we developed a new interpolation algorithm to keep registration during challenging manipulations. We believe that PPF can be applied to domains including virtual-try on and fashion design.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities; I.4.8 [Image Processing and Computer Vision]: Scene Analysis—Tracking;

1 Introduction

A fundamental challenge of Augmented Reality (AR) research is the registration of digital information with physical objects. Deformable objects are particularly challenging, as a non-planar surface requires more information to be gathered to understand its shape. In previous registration algorithms for deformable surfaces such as [3], augmentations are overlaid onto real objects on a separate display. Therefore, these methods can use rich textured surfaces to determine the shape of the object. However, because we target projection scenarios, the surface of the target should contain as little texture as possible. Punpongsanon et al. developed a projection system for a deformable object [4]. Users can interact in real-time with the deformable object, while the realistic projected graphics deform. However, this system is not applicable to our objective because it allows only tangential deformations and cannot identify each location on the surface without temporal information.

We previously implemented a system [1] that directly measures individual points on the surface of a deformable object, allowing us to project digital information onto the object. We extended the concepts of Szentandrasi et al. s' marker system [5], that allows partially visible markers to be recognized. As an object is deformed, the mapping of digital textures to the physical object is continuously kept consistent with an IR-based fiducial marker. However, the previous system had several limitations. First, its processing speed was too slow to apply it in real-time applications. Every time the target surface was moved or deformed, a gray-code pattern projection and computations for 3D information were needed, resulting in speeds of about six seconds per frame. Second, deformations were limited, as our prototype was based on a metal mesh and an acrylic foam sheet, which introduced physical limitations. As a result, the applicability of our method to other materials, including cloth, which allows more complex deformations was unclear.

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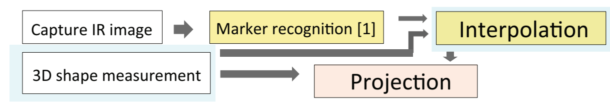

Figure 1: Overview of algorithm. The blue region denotes improved processes compared to our previous work [1].

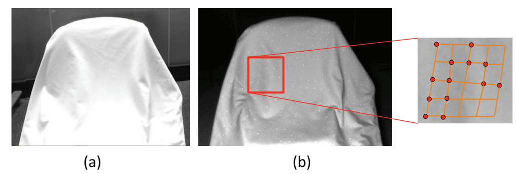

Figure 2: Marker pattern made of half-transparent retro-reflective materials. Images by an RGB camera (a) and an IR camera (b).

In order to investigate real-time projection onto a surface with rich deformations, we have improved the algorithms (as show in Figure 1) in our prototype we call PPF (Pseudo Printed Fabrics). PPF extends our previous system in two important aspects. First, we improved performance by two orders of magnitudes to achieve interactive performance with fast 3D information calculation by Kinect v2 [2] and a whole algorithm optimization. Second, we developed a new interpolation algorithm to keep registration during challenging manipulations including self-occlusions and folds. These two improvements enable us to use a neutral-colored cloth, which can be deformed more complicatedly than in our previous system.

2 System Components

Our system is composed of three major components, a camera, a projector, and a projection target cloth with marker patterns.

2.1 Camera and Projector

We employ Kinect v2 [2] that captures both visible and infrared light under computer control. The projector and the Kinect camera are calibrated in advance, and the relative position and orientation between the pair are known. Our system operates on a Window 8 PC with a Core i7-3930K 3.2 GHz, 16.0 GB of memory, NVIDIA GeForce GTX 560 Ti. A DLP projector with 1024 × 768 resolution, an RGB camera with 1920 × 1080 resolution and an IR camera with 512 × 424 resolution are employed.

2.2 Marker Pattern and Target Cloth

In order to project texture images onto the deformable object, local positions of the object need to be recognized in a camera image to make correspondences between each location of the object and each location of the texture. To achieve this goal, we developed a marker that can be partially recognized in the previous paper based on Szentandrasi et al.'s marker [5]. Their marker is a grid pattern and this grid can recognize corresponding locations on the reference pattern as long as any 4 × 4 rectangle sub-pattern within the marker is observed by the camera. Our marker-pattern is attached to a non-planar deformable object. Therefore, we employ "points" as the minimum-unit that can be easily and separately detected even if the surface is bent, instead of "rectangles" they used. We employed a half-transparent retro-reflective material for the construction of

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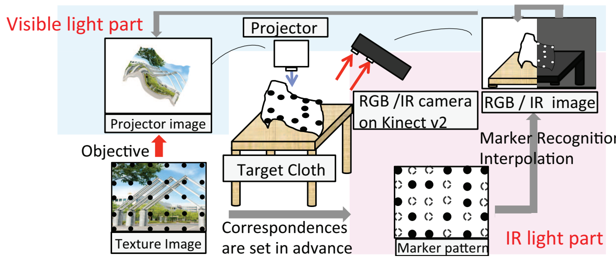

Figure 3: Overview of dataflow in our system, including coordinate transformations.

the marker-pattern. While the surface with this marker is observed as an almost white surface under the visible light region (see Figure 2(a)), the surface is observed as one with many points under the infrared light region as shown in Figure 2(b). Our projection target is a neutral colored cloth as shown in Figure 2.

2.3 Algorithm

Figure 3 illustrates an overview of our system construction and the transformation of each coordinate. A texture image to be projected should be deformed depending on the surface shape of the target object. The projection employs small patches surrounded by four grid points.

At first, capturing an IR image and measuring 3D shape are performed in parallel. The marker recognition is conducted with the IR image (see [1] for detailed information).

After the marker recognition process, IDs have been assigned to each of detected points, but some grids may not be correctly created in the regions of high curvature. For such unrecognized grids, the interpolation is conducted using point locations which have been associated with IDs and 3D information calculated by Kinect v2. The simple interpolation we previously proposed [1] had a problem that interpolation errors accumulated rapidly when the points were repeatedly interpolated by interpolated points including errors. In order to deal with this problem, new modifications for the interpolation algorithm were conducted. The interpolation denotes a process that selects an appropriate pixel for an unassigned ID. We applied a weight value (w_i) to each eight-neighboring point of point in process as a reliability. The range of a weight value varies from 0.0 to 1.0 and the maximum number of neighboring points is four. From eight-neighboring points, points which have the highest four weight values are employed for the following process. The weight value is 1.0 if the point is a recognized point. Following each interpolation result, weight values are updated for each interpolated point. For example, if a point is interpolated by two recognized points and one interpolated point, the weight value of which is 0.5, the value for this point is (1.0+1.0+0.5)/4 = 0.625. Let u_j a point in process and u_i an eight-neighboring point. j_{inter} is the pixel number of point in process which should be selected. $const_i$ is the static distance between two grid points (in our case, 26 or $26 * \sqrt{2}$ mm). w'_{ik} is a weight for each neighboring point in previous interpolation process. The equation for the interpolation process is as follows.

$$j_{inter} = \arg\min_{j} \sum_{i=1}^{k} w_i |distance(u_i, u_j) - const_i|, w_i = \sum_{k=1}^{4} ({w_{ik}}'/4) \quad (1)$$

Applying weight values mitigates the reduction in interpolation accuracy due to the cumulative interpolation (the interpolation by interpolated points) to some extent by preferentially using a point which includes fewer errors.

Detected 2D points in the IR image are transformed to 2D points in the RGB image by depth values and a transformation from the IR camera to the RGB camera. Kinect v2 can capture such depth values in real-time (30 fps). With a transformation from the RGB camera to the projector image calculated by the calibration step, points of the texture image are finally transformed to points in the projector image.

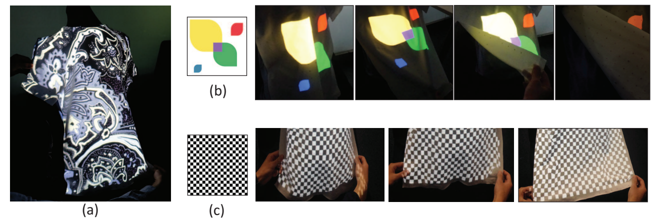

Figure 4: Projection results with various cloth situations.

3 Evaluation

Figure 4 illustrates projection results. Onto the same t-shirt-shaped cloth with the marker pattern, several images are projected. A left sub-figure on (b) illustrates a case when the cloth is folded. A second sub-figure from the left on (b) shows a case when the user flips up the edge of the cloth a little. A third sub-figure from left and a right sub-figure on (b) show cases when self-occlusions occur. In such cases, the projection image is correctly unlit in occluded regions. Sub-figures (c) show continuous projection results in a case when a user gradually flips up the edge of the cloth.

We conducted a small test to verify the difference of processing speeds of the system proposed in [1] and our new system. We used 28 × 30 dots marker pattern and the distance with two neighboring dots is 26 mm. We measured the average processing time of the system operating 50 times. In the previous system, average of the processing time of 3D shape measurement is 5.04 seconds. And each processing time of marker recognition, interpolation, and others (including a ready for projection) are 0.42, 0.21, 0.05 seconds. A total of these is 5.72 seconds. On the other hand, in our new implementation, the processing time of 3D shape measurement part is 0.033 seconds and dramatically improved thanks to Kinect v2, and an optimization of other parts. And each processing time of marker recognition, interpolation, and others are 0.07, 0.06, 0.02 seconds. A total of these is 0.15 seconds.

4 Conclusions

Inspired by projection based-AR support for design as a promising application, we proposed a Pseudo Printed Fabrics (PPF), which enables the projection on a deforming piece of cloth. We have illustrated that our technique can project a geometrically correct texture onto a cloth at an interactive rate.

In future work, we will explore improving the processing speed for the marker recognition and the interpolation with parallelization.

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