Interactive Video Projection on a Moving Planar Surface of Arbitrary Texture Tracked with a Color Camera

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Abstract Interactive video projection, to be effective, must track moving targets, but current solutions consider the displayed content as interference and largely depend on channels orthogonal to visible light. Instead, we propose an algorithm that considers the content as additional information useful for direct alignment. Using a color camera, our implemented software successfully tracks with subpixel accuracy a planar surface of diffuse reflectance properties at about eight frames per second on commodity hardware, providing a solid base for future enhancements.

1. Introduction

Traditional applications of augmented reality superimpose generated images onto the real world through goggles or monitors held between objects of interest and the user. The display must usually follow objects and developers often choose cameras to perform tracking, as computer vision methods are flexible and nonintrusive. Since the augmented objects remain in reality unchanged, we do not need to change the image processing algorithms either. However, with spatial augmented reality [3], we instead use projectors to display interactive video, as exemplified in Fig. 1. In this case, the appearance of the objects may be severely affected, requiring new methods.

To avoid the difficulty, current methods either exploit information channels that do not overlap with the displayed content, by using for example near infrared cameras insensitive to visible projector light, or make assumptions that restrict their usefulness, to objects for example of rectangular shapes only.

2. Direct Image Alignment

Contrarily to existing approaches that treat the displayed content as interference, we propose to harness its knowledge as additional information that can help the system align it with real world objects. More specifically, we derived a direct image alignment algorithm that takes projector illumination into account using a generative model. It models how the light coming out of the projector reflects onto a real world object and comes back in the camera. As a first step, we decided to make a few simplifying assumptions. Most importantly, the object must be planar and feature diffuse reflectance properties with no specular reflections. More information about this algorithm can be found in our previously published paper [1].

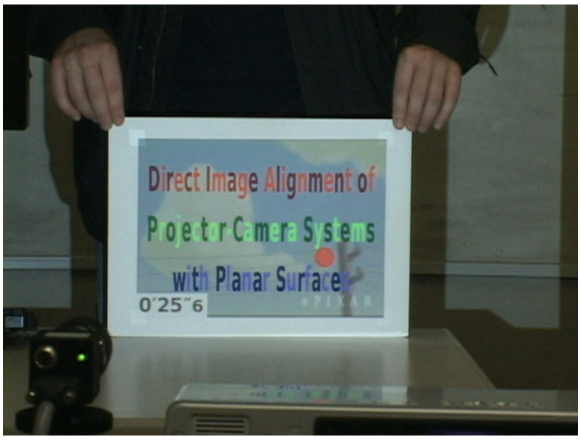
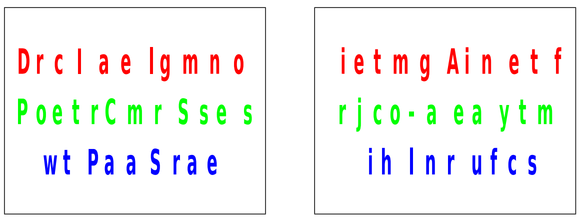


Fig. 1 Snapshot of our demo video where the system has aligned the projector displayed pattern of Fig. 2 with the printed one (alongside a chronometer, a video animation, and a red virtual ball).

Using our alignment algorithm, we can turn a perfectly normal pair of color camera and projector into a system that can track without markers a matte planar surface, while simultaneously projecting on its surface geometrically corrected and interactive video images as shown in Fig. 1.



(a) Printed on the board. (b) Projector displayed.

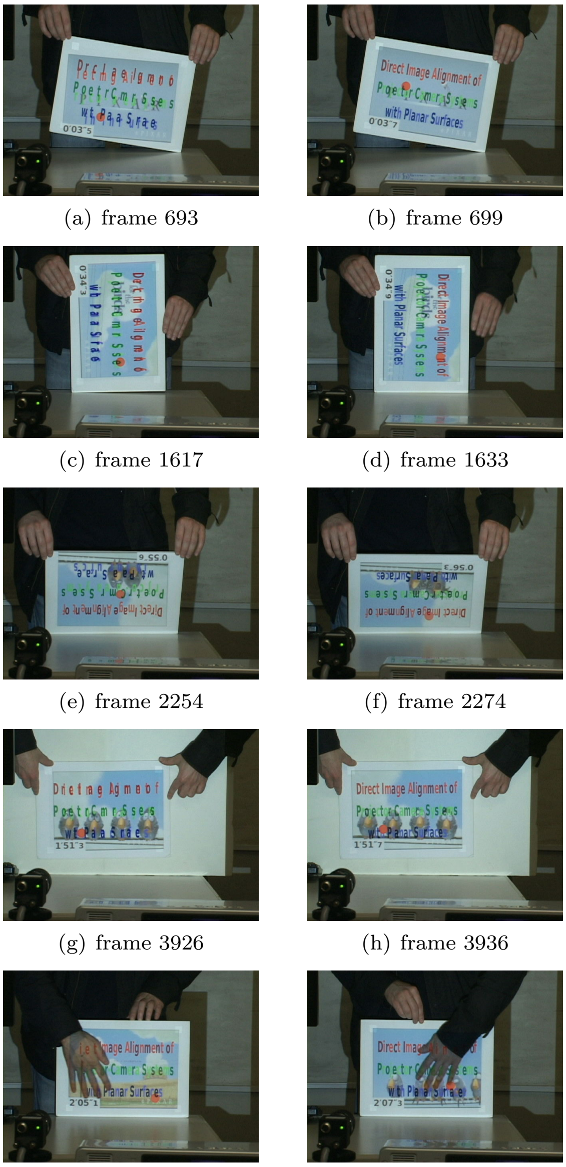
Fig. 2 The images used for our demo video.

3. Results

To provide results, we developed an application in Java, which integrates OpenCV and libdc1394 as appropriate, and that implements the procedures and algorithms introduced in our paper [1]. Our test hardware consisted of a Casio XJ-S68 (1024×768 color DLP) projector, and a PGR Flea2 FL2G-13S2C-C (1280 × 960 Bayer color CCD) camera attached to a Pentax H1212B (12 mm) lens, both connected to a Dell Vostro 400 computer with an Intel Core 2 Quad Q6600 2.4 GHz CPU.

To show that our program works in real time even with poor and arbitrary textures that easily overlap on the surface, we ran it on the images shown in Fig. 2, the first inkjet printed on an A4 size sheet of paper and pasted on a (mostly) flat foam board, and the second displayed by the projector, along with other graphical elements as shown in Fig. 1. More precisely, after each frame, the system warped the projector image to achieve a geometric correction on the physical plane. (Although we could also correct the projector colors to match the printed one, we intentionally left them as is for simplicity as well as to differentiate them.) Fig. 1 shows the system in action. We placed more shots of the demo video in Fig. 3. The full sequence can be found in the supplementary material as well as on our Web site:

http://www.ok.ctrl.titech.ac.jp/~saudet/procamtracker_2010-04-05.mp4 .



(a) frame 693 (b) frame 699

(c) frame 1617 (d) frame 1633

(e) frame 2254 (f) frame 2274

(g) frame 3926 (h) frame 3936

(i) frame 4337 (j) frame 4405

Fig. 3 Frames from our demo video. We grouped them in pairs of a misaligned image caused by user motion followed by its correction.

We found that the algorithm successfully converged given any displacements reasonable for a direct alignment method [2]. At this time, the program runs at about eight frames per second on commodity hardware, and this restricts the speed at which a user can move the object, but it achieves subpixel accuracy [1].

4. Conclusion and Discussion

Obviously, the algorithm can be further accelerated, by implementing it for example for graphics processing units (GPUs), as well as generalized to more complex reflectance properties and 3D surfaces, by using for example a piecewise planar model and aligning multiple planes simultaneously.

Although much future work remains, our results demonstrate the feasibility of the approach. With some enhancements, it may even become a major component of spatial augmented reality. To encourage future research in this direction, we are making the whole software system available as open source on our Web site:
http://www.ok.ctrl.titech.ac.jp/~saudet/procamtracker/ .

Acknowledgments

This work was supported by a scholarship from the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of the Japanese Government.

References

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