Time-Delay Compensation for Dynamic Projection Mapping

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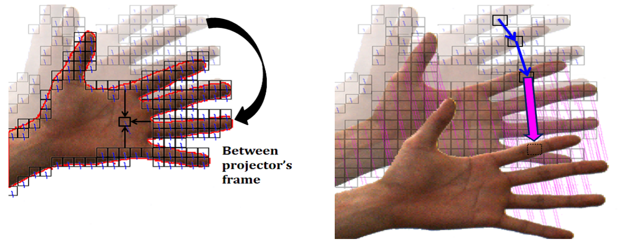
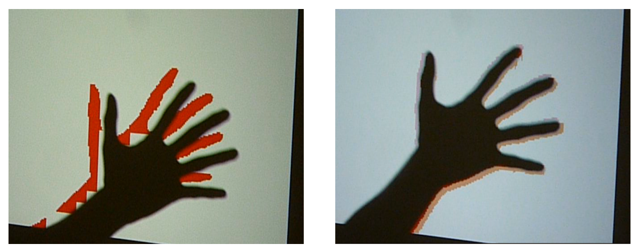
1 Introduction

In this research, we propose a technique of compensating a time-delay of projection on moving objects. Recently, a projection mapping is a technique to turn objects into a display surface for image projection. And it is widely used in various attractive events, for adding extra dimensions, optical illusions, and notions of movement onto previously static objects. However, this technique is limited to the static objects. In general ProCam systems, it is difficult to project images on moving objects because it has potential time-delays of cameras and projectors in addition to various delays with target's position estimation, image processing, and etc. Our preliminary study shows a maximum of 80[ms] delay with ordinary ProCam system. This time-delay generates misalignment between targets and projected images, and it leads us to feel sense of incongruity. Therefore, we present a time-delay compensation technique with fast motion prediction by using a high-speed ProCam system. And we provide a dynamic projection mapping on moving objects.



(a) motion estimation (b) motion prediction

Figure 1: *How to estimate motion and predict motion. A left figure shows captured hands, characteristic edges (red line), reduced Block-Matching targets (black boxes) and calculated motion vectors (blue lines) between projector's frame. A right figure shows a result of motion prediction (pink lines) from the motion vectors.*



(a) projection with time-delay (b) our approach

Figure 2: *A result of constant-color projection on a quickly moving hand.*

2 Our Approach

In order to compensate the huge time-delay, we need to predict target's position accurately. A general projector's refresh rate is 60 fps. If we capture images at 60 and more frames per second using a high-speed camera, we accurately recognize target's movement between projector's frames (16[ms]), and are able to predict the future position for compensating the time-delay. On the other hand, the more capture rate increases, the more motion estimation rate increases. Block-Matching[Barjatya 2004] is commonly used for motion estimation and its performance is very stable. However the calculation cost of Block-Matching is quite huge, so this algorithm is not suitable for our purpose. Therefore, we propose a fast Block-Matching technique with considering human's perceptual characteristic.

When the time-delay generates misalignment between targets and projected images, we perceive it acutely in the parts including edges or patterns. On the basis of this characteristic, we limit the target area of the Block-Matching to the region in which people easily find the misalignment. At first, we calculate the difference between captured sequential frames in order to find moved regions. Next, we apply an edge-detection process to those differential regions, for further limitation of the Block-Matching target. The limited region has strong effect to viewers, but is a relatively small part of the whole captured image. So we apply the Block-Matching to that region and obtain its motion with reduced process time. On the other hand, for the region including no edges, we compensate their motion from neighboring regions including the edges. Although this region accounts for most of the whole, we are not sensitive to the misalignment in that. So we can use the simple but fast interpolating strategy(Figure 1). As the result, we can achieve the fast motion estimation difficult to perceive differences with real motion. This algorism is implemented on GPU (NVIDIA GeForce GTX 690), and applied for the images captured by a high-speed camera (640 x 480 pixels, 200Hz).

In our high-speed ProCam system, the motion of targets for projection mapping was estimated at 180 fps, and the change rate of its acceleration was also calculated at 60 fps which is synchronized with a standard projector. The change rate of acceleration is more effective in motion prediction than usual factors such as acceleration and velocity. By using this system, we predicted the motion of the further 80 [ms] ahead to compensate the time-delay of projection on moving objects. In this process, the projected images disturb the motion estimation. Therefore we removed the projected images from the captured images by using the photometric response model of the projector[Hashimoto and Watanabe 2010]. And finally, we projected the predicted images precisely on moving targets(Figure 2).

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References

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