Spatio-Temporal Video Warping (sketches_0999)

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1 Introduction

While spatial image warping is extensively used in image and video editing applications for creating a wide variety of interesting special effects, there are only very primitive tools for manipulating the temporal flow in a video. For example, we can compare temporal speeding up (slowing down) of the video to image zoom, or the "in-out" video selection to image crop and shift. But there are currently no tools that implement the spatio-temporal analogues of more general image warps, such as the various image distortion effects found in common image editing applications.

In this sketch we outline *evolving time fronts*, a new framework for spatio-temporal warping of video, which provides much more general *time flow* manipulation capabilities. The proposed framework is simple yet general, allowing a large variety of warps to be specified in an intuitive manner, resulting in many interesting and useful operations on video, ranging from subtle timing changes to eye-catching special effects. In this sketch we mainly focus on one novel effect: the *spatio-temporal magnifying glass*, which appears to be particularly well-suited for instant replays in sports broadcasts. Additional effects are discussed in [Rav-Acha et al. 2005b] and [Rav-Acha et al. 2005a], and the reader is referred to the following URLs: `http://www.vision.huji.ac.il/dynmos` and `http://www.vision.huji.ac.il/videowarping`.

2 The Evolving Time Fronts Framework

Our framework consists of three conceptual stages:

1. Given an input video sequence, a 3D space-time volume is constructed. Certain warping effects require this volume to be aligned using computer vision techniques for video motion analysis. For the effect described in this sketch such alignment is not necessary, so the space time volume is constructed by simply stacking the frames along the time axis.
2. A sequence of *time slices* is generated by sweeping an evolving *time front* surface through the space-time volume, and taking snapshots of this surface at different times.
3. A region on each time slice is spatially warped to yield a frame of the warped output video sequence.

Specifying the spatio-temporal warping in this manner separates between the manipulation of the temporal and the spatial components of the video and provides an intuitive interface for controlling such warps. For example, we can slow down or speed up the time flow in various regions at will by varying the speed at which the time front advances in the corresponding regions of the space-time volume.

3 Spatio-Temporal Magnifying Glass

In a general spatio-temporal video warp the spatial coordinates are warped simultaneously with the temporal ones. This general mechanism provides a tool for creating interesting and useful effects. For example, we can apply a spatio-temporal magnifying glass to videos of sport events. Such a device enables us to magnify a spatial region in which some particularly interesting action takes place, while simultaneously slowing down the action. Unlike in ordinary instant replay, in our case the spatial and temporal magnification occur in the original context of the action, with a continuous transition between the magnified and the surrounding regions. Thus, when a basketball player dunks the ball into the basket, the viewer is able to see the dunk in greater detail, and at the same time keep track of the other players. This effect is demonstrated in the accompanying video clips.

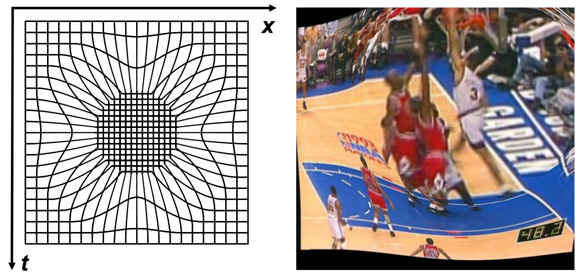

Figure 1: A spatio-temporal magnifying glass. Left: A *x-t* slice of the space-time volume. Right: A frame from a basketball game, where the action under the basket is inside the focus volume of the magnifying glass.

The magnifying glass effect is achieved by deforming and warping the time fronts as illustrated in Figure 1(left), which shows a slice of the space-time volume with horizontal curves describing the evolution of the time front. The vertical curves define the warping on the time slices to the frames of the output video. The dense grid in the center of the diagram is the *focal volume* of the lens. Action taking place inside this volume is both magnified and slowed down, while action outside this volume (but still inside the lens) is compressed and accelerated. Everything entirely outside the lens remains unaffected. In other words, time flow is accelerated when entering the lens, slows down in the central focal region, and accelerates again when exiting, to "catch up" with the time flow outside the lens. The spatial dimensions are affected in an analogous way (shrinking when entering/exiting the lens and expanding inside the focal volume). Specifically, we use a slightly modified version of the clamped focal radius lens with the Gaussian drop-off function, as proposed by Carpendale *et al.* [2004].

Obviously, the amount of useful spatial and temporal magnification depends on the spatial and temporal resolution of the source video. The duration of the effect should also be limited to a short period of time, if temporal continuity is to be maintained: if we let a subject spend too much time inside the lens, the temporal disparity between the time flow inside and outside the lens becomes too great.

References

CARPENDALE, M. S. T., LIGHT, J., AND PATTISON, E. 2004. Achieving higher magnification in context. In *Proceedings of the 17th annual ACM Symposium on User Interface Software and Technology*, ACM, vol. 6, 71–80.

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