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ScienceDirect
Signal Processing: *Image Communication* 21 (2006) 755–769
SIGNAL PROCESSING: IMAGE COMMUNICATION
www.elsevier.com/locate/image

Image warping for compressing and spatially organizing a dense collection of images

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Received 21 July 2006; accepted 25 July 2006

Abstract

Image-based rendering (IBR) systems create photorealistic views of complex 3D environments by resampling large collections of images captured in the environment. The quality of the resampled images increases significantly with image capture density. Thus, a significant challenge in interactive IBR systems is to provide both fast image access along arbitrary viewpoint paths and efficient storage of large image data sets.

We describe a spatial image hierarchy combined with an image compression scheme that meets the requirements of interactive IBR walkthroughs. By using image warping and exploiting image coherence over the image capture plane, we achieve compression performance similar to traditional motion-compensated schema, e.g., MPEG, yet allow image access along arbitrary paths. Furthermore, by exploiting graphics hardware for image resampling, we can achieve interactive rates during IBR walkthroughs.

Keywords: Image-based rendering; Spatial hierarchy; Compression; Hierarchical; Random access

1. Introduction

Computer graphics applications such as telepresence, virtual reality, and interactive walkthroughs require a three-dimensional (3D) model of real-world environments. Students can "visit" famous historical sites, such as museums, temples, castles, battlefields, and entire history rich cities; archeologists can capture excavation sites as they evolve over time; soldiers and fire fighters can train in safe simulated environments; real estate agents can show potential buyers the interiors of homes for sale via the Internet; and, people all over the world can enjoy virtual travel and multi-player 3D games. Thus, a growing desire exists for methods which can efficiently capture important and visually stunning environments.

In recent years, image-based modeling and rendering approaches (IBMR) have addressed this problem [15]. They do so by directly resampling images to generate new views, thus avoiding the need for a detailed geometric model. The 7D plenoptic function describes the light intensity passing through every viewpoint (x, y, z), in every direction (θ, φ), for all time t, and for every wavelength λ [1,16]. All existing IBMR techniques

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0923-5965/$ - see front matter
doi:10.1016/j.image.2006.07.005

generate lower-dimensional plenoptic functions from a set of images [2,5,6,9,13,25].

IBMR techniques require a large collection of images that must be efficiently stored and accessed. In particular, for interactive walkthroughs image access cannot be limited to coincide with the capture paths, but instead requires access along arbitrary viewpoint paths. Furthermore, disk-to-memory bandwidth limitations require algorithms that reduce both the size of the images on disk and the amount of data that must be transferred to main memory as a virtual observer navigates through a captured 3D environment.

Traditional compression techniques do not provide both access flexibility and full exploitation of data redundancy. Image compression, such as JPEG [27], JPEG2000 [11], and 2D wavelets [26] exploit intra-image redundancy to reduce individual image sizes but do not take advantage of inter-image redundancy. Video compression achieves a significant improvement in overall compression by encoding sparse reference images and using motion-estimation algorithms to determine the coherence for interpolation between reference images (e.g., MPEG [12]). However, motion-estimation is expensive and is intended for pre-determined linear sequences of images, making it ill-suited for image access along arbitrary viewpoint paths.

We propose a spatial image hierarchy combined with a model-based compression algorithm that provides quick access to images along arbitrary viewpoint paths during interactive walkthroughs and enables efficient compression of high-resolution images whose centers of projection (COPs) irregularly sample a plane (Fig. 1). Specifically, our method arranges reference images and residual images into a binary tree. A captured image is extracted via a sequence of image warping operations. Each operation warps a reference image to the viewpoint of a residual image and the two are added together. We eliminate the need for costly motion estimation by using a simple user-supplied geometric proxy of the environment. The proxy, which may consist of only a dozen polygons approximating the environment, helps compensate for the translation between the two viewpoints and provides an inexpensive but accurate mapping from the reference to the residual image. We further reduce the size of the residual images by employing occlusion camera reference images (OCRIs) [20]. These images store samples visible from the reference viewpoint as well as samples likely to become visible from nearby viewpoints (see reference image of Fig. 1). Warping OCRIs images instead of regular images produces more compact residuals when disocclusions occur and thus may achieve improved overall compression.

Residual images primarily account for surfaces that are visible from the viewpoint of the residual but not from the reference viewpoint. In the case of non-trivial scenes, even small viewpoint translations disocclude many surfaces that are not sampled in the reference image. Furthermore, the disocclusions are not grouped in one contiguous region of missing samples, but are rather scattered throughout the scene. Therefore, when regular reference images are

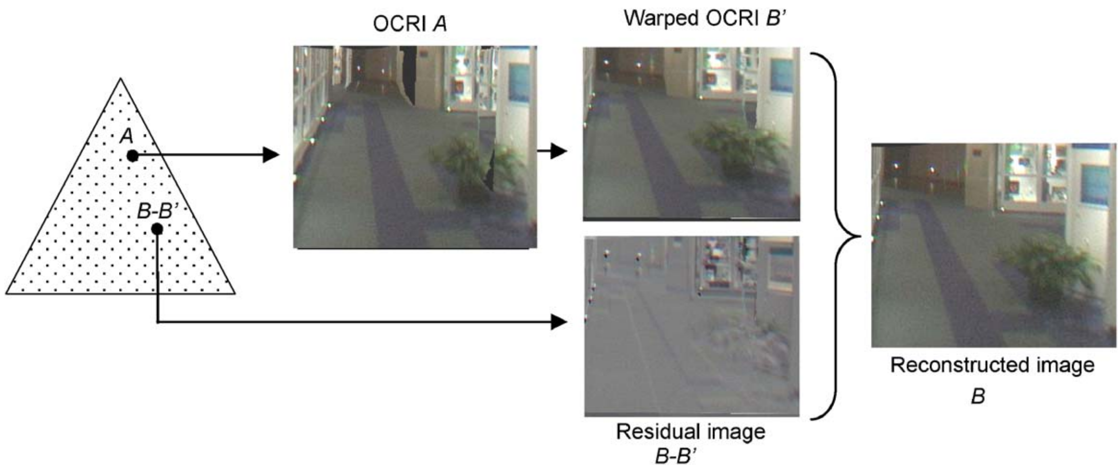

Fig. 1. Image hierarchy and compression. We present a spatial image hierarchy combined with a compression scheme that uses image warping and coherence to provide quick efficient image access for IBR applications.