Poster Abstracts of Computational Aesthetics in Graphics, Visualization, and Imaging (2011)
B. Riecke (Editor)

Kindalike Cubism: Using Programmable Cameras for Photography in More Dimensions

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Abstract

We use a widely-available, programmable digital camera to create four-dimensional volumes of images that become part of an interactive art installation. The four dimensions we use are the two spatial dimensions of the camera image plane, plus focus and camera position. Analyzing the subject from multiple vantage points, we capture hierarchies of information about our subject. This visual data is then reconstituted into viewable two-dimensional images from the four-dimensional volume. The resultant images bear a resemblance to cubist art in which the informational sum of the individual parts is greater than any single photograph.

Categories and Subject Descriptors (according to ACM CCS): J.5 [Arts and Humanities]: Fine Arts

1. Introduction

With the advent of programmable consumer cameras, processes such as creating *focus stacks* are now available to non-expert photographers. As an example, using the Canon Hack Development Kit (CHDK) [CHD], one can access different lower-level features of many Canon cameras. Photographers can now perform many types of *bracketing* (taking several shots with varying camera settings) and *stacking* (assembling sets of bracketed images) of their photographs. We describe our use of an inexpensive programmable camera for acquiring four-dimensional bracketed images. We then take these images and slice through them to get a two-dimensional image that can be viewed in an interactive art installation.

2. Background

Bracketing and Focus: When bracketing images with different focus settings we get a *focus stack*. Focus stacks have conventional application to high-depth-of-field images, and to confocal microscopy [NN94]. Exposure bracketing techniques have been used to create high-dynamic-range images [Blo07].

High Dimensional Data in Artistic Display: Although we can only ever see a two-dimensional image projected onto the retina of the eye, displays of higher dimensional data are possible by sampling high dimensional data onto a two-dimensional *manifold*, or by integrating along dimensions (analogous to X-ray projection). When bracketing a subject photographically, we can view the resulting stack as a high-dimensional volume that we then visualize with a two-dimensional projection, e.g., Cassinelli's *Khronos Projector* [Cas06].

Programmable Cameras: It has become practical for inexpensive cameras to be customized with user-developed software [CHD]. Features such as taking raw sensor photographs or remotely triggering an exposure are now possible. For example, the *Frankencamera* project [Lev10] explores the possibilities that arise from embedding image processing algorithms on a Nokia N900 series mobile phone.

3. Higher Dimensional Stacks

We are interested in bracketing focus and camera position. While we can control focus through the programmable camera settings, we leave it to the photographer to manually control position by moving the camera throughout the bracketing process. To achieve this, we program the camera to acquire a sequence of images at different focus settings, and to coordinate the manual position bracketing. The camera then produces a set of images along with the data necessary to assemble the images into a four-dimensional stack.

We face the question of how to view the images. While it is possible to visualize the images with a goal of fidelity

CAe 2011, Vancouver, British Columbia, Canada, August 5 – 7, 2011.
ISBN 978-1-4503-0908-0/11/0008

of comprehension, we take an aesthetic view that targets visualization in the context of an interactive art installation. Our approach is akin to that of Cassinelli [Cas06] and Fels et al. [FLM00], forming two-dimensional images by sampling on a two-dimensional manifold embedded in the four-dimensional stack. Images created this way evoke associations with cubism, or *Kindalike cubism*.

We embed the acquired stacks in a four dimensional volume with coordinates (x, y, f, p), where x and y are spatial image coordinates, f is the focus distance, and p is an index into the set of photographer-controlled positions (Figure 1(a)). To sample two-dimensional images on a manifold, we created a set of mappings from image coordinates (x', y') to four-dimensional stack coordinates (x, y, f, p) (Figure 1(b)).

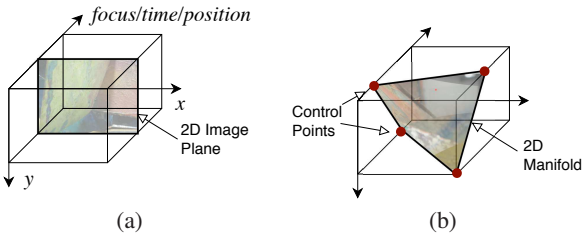

Figure 1: *Illustration of high dimensional data as a three-dimensional image stack: (a) volume of data built by stacking, and (b) sampling on a manifold.*

4. Interactive Installation

We assembled an interactive installation as an interesting way to view and interact with a four-dimensional stack. Figure 2(a) shows the installation schematically. A projector projects rendered images of the stack onto a screen for observers to view (e.g., see Figure 2(b)). We also placed the sculpture that is the subject matter for the stack in the room so that observers may view both the sculpture and the rendered representations.

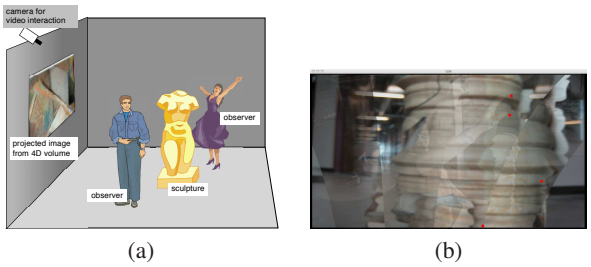

Figure 2: *Our installation: (a) schematic diagram, and (b) sample display image.*

A video camera aimed at the area in front of the screen captures the motion of observers as a basis for interaction. Observers see a set of four red *balls* (discs rendered on the display) that they can manipulate through their motion using the *motion swarm* method of Nguyen et al. [NNB*06]. The positions of the balls provide the parameters for mappings used in rendering. We used quadrilateral mappings for both the focus parameter f and the position index p, each requiring four parameters. The four moving balls manipulated by observers, have eight degrees of freedom in their positions, providing the eight values for the mapping parameters.

5. Discussion

Interaction with the display is intuitive in the sense that observers can see and manipulate the red balls. However, the relationship between the balls' positions and the rendering is not obvious. Nevertheless, the manipulation of the balls is fun for observers, and provides some kinetic activity to engage observers as they enjoy the images.

Part of the artists intention with the sculpture shown in Figure 2(b) was to evoke shapes from both the foreground and background of object. To that end, the *kindalike cubism* process rearranges the shapes to create new views of the object and its background that could not otherwise be seen.

Although we cannot expect the same resolution and performance from inexpensive consumer grade cameras versus professional models, programmability features in some consumer cameras opens a door to customized bracketing and acquisition of image stacks. Conventional applications of bracketing such as high depth-of-field and high-dynamic-range techniques are well-known but there is an aesthetic dimension still to be explored. This aesthetic dimension poses new questions about stack acquisition and visualization.

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