FlexCam – Using Thin-film Flexible OLED Color Prints as a Camera Array

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CHI'12, May 5–10, 2012, Austin, Texas, USA.
ACM 978-1-4503-1016-1/12/05.

Abstract
FlexCam is a novel compound camera platform that explores interactions with color photographic prints using thinfilm flexible color displays. FlexCam augments a thinfilm color Flexible Organic Light Emitting Diode (FOLED) photographic viewfinder display with an array of lenses at the back. Our prototype allows for the photograph to act as a camera, exploiting flexibility of the viewfinder as a means to dynamically re-configure images captured by the photograph. FlexCam's flexible camera array has altered optical characteristics when flexed, allowing users to dynamically expand and contract the camera's field of view (FOV). Integrated bend sensors measure the amount of flexion in the display. The degree of flexion is used as input to software, which dynamically stitches images from the camera array and adjusts viewfinder size to reflect the virtual camera's FOV. Our prototype envisions the use of photographs as cameras in one aggregate flexible, thin-film device.

Keywords
Organic User Interfaces; Flexible Camera Arrays; Flexible Displays; Tangible User Interfaces.

Figure 1. Close-up of FOLED display on the front of the device

ACM Classification Keywords
H5.2 [Information interfaces and presentations]: User Interfaces – Interaction styles

General Terms
Design, Human Factors, Performance.

Introduction
In the past 100 years we have seen incredible advances in camera design and technology. Camera developments such as the Kodak "Brownie," the Single Lens Reflex (SLR), and the Digital Camera have all contributed to the global "camera culture" that we live in today. Through the combination of photography and image processing, we have developed new ways of seeing that expand our ability to perceive and understand our world. Camera development continues and we now have novel "computational cameras" that exhibit unique additions to both the art and science of photography. FlexCam contributes to this space by combining two emerging concepts in consumer electronics and photography: the trend towards camera arrays and the trend towards flexible display devices. In this paper, we discuss our FlexCam prototype implementation of a photographic print that is also a camera (Fig. 1). It incorporates flexibility as an input device, using a flexible camera array on the back that allows image stitching and on-the-fly FOV changes (see Figure 2).

Related Work
Steve Mann's "Video Orbits" [1] employs a single camera, which records images of a single scene from different orbital angles. Photos are then stitched together via post-processing, which computes relationships between images to produce a single coherent collage. This technique allows photographers to vastly enhance the FOV and resolution of a single fixed-lens camera. Nomura et al. [2] achieve a similar effect to Mann, but employ a flexible camera array that can be configured to capture many orbital angles simultaneously. Using a method similar to Mann's, resulting images are compounded using post-processing. Systems like Gummi [3] and PaperPhone [4] describe flexible computers that sense flex-based interactions in realtime and react accordingly.

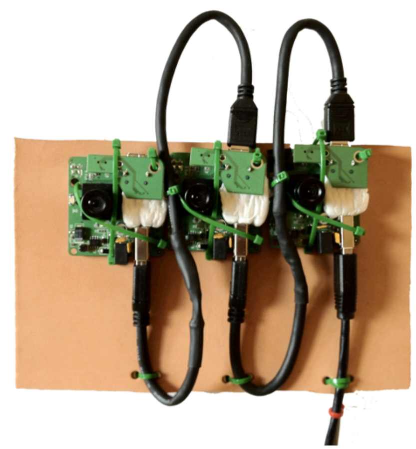

Figure 2. Back of FlexCam showing camera-array, Firewire chain and leather chassis.

Design Rationale
Mann's and Nomura's camera systems require a potentially lengthy post-processing period before any resulting image can be viewed. This makes it difficult for photographers to compose photos, and may have a negative impact on the quality of the resulting image. By using flexion data from a simple flex sensor,

FlexCam has access to information about its own configuration in real time, rather than computing the same data using costly image processing techniques. As shown in Figure 4, this makes it possible to dynamically position composite images in a viewfinder, resulting in a real time display that enables photographers to accurately compose images.

Hardware

Our FlexCam hardware consists of 4 distinct elements:

1. Array of 3 video cameras
2. 2 Flex sensors
3. Leather chassis
4. 320x240 Color Flexible OLED display

The camera-array was built using 3 Unibrain Fire-I [5] DV cameras connected in series via an IEEE 1394b (Firewire) cable to a laptop (Fig. 2). The Firewire specification supports video pass-through and addressing of the signal from each camera in the array. The camera-array is affixed to a flexible leather chassis, with each camera lens aligned along the horizontal axis facing outward. On the reverse side of the leather chassis, two horizontal flex sensors are interfaced via an Arduino. A color FOLED display of 30μ thickness is affixed to the rear of the chassis showing images from the camera array. The use of a thinfilm, full color, full motion video FOLED display for a viewfinder allows for bends to occur right in the surface of the display. Without user intervention, FlexCam maintains a flat shape where the viewport from each camera effectively captures the same portion of the scene, tripling the resolution of the captured image (Fig. 3 top). When FlexCam is flexed (Fig. 3 bottom), the cameras move independently such that the viewport from each camera captures a new portion of the scene (see Figure 4). As the amount of device flexion increases, so does the distance separating the camera's viewports.

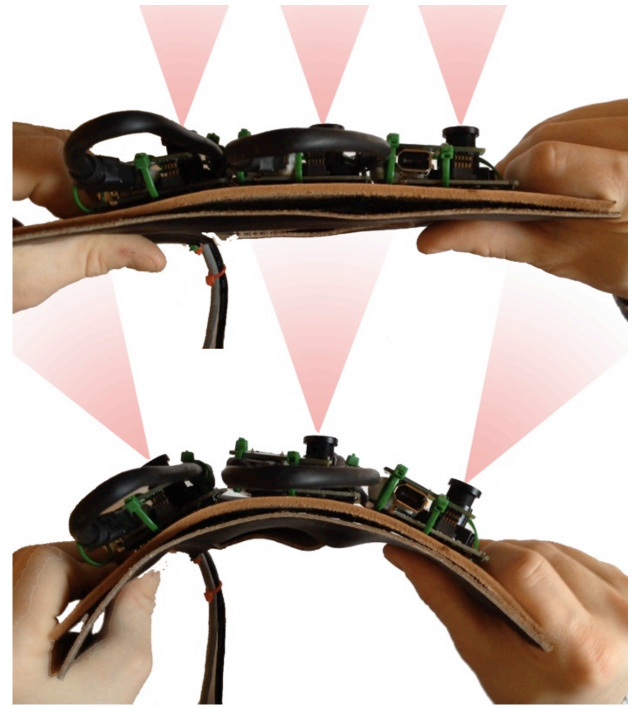

Figure 3. Shows both flat and flexed device configuration. Cones indicate the overlapping and expanded viewport of each camera.

Software

FlexCam software was developed entirely using Max/MSP/Jitter [6]. There are three distinct elements in the FlexCam software:

Figure 4. Collection of viewfinder images showing the increase in FOV parametric to the magnitude of flexion of the device.

1. Video I/O and logic
2. Flex-sensor I/O and logic
3. Viewfinder display

Video signals from each camera are mapped to a single independent plane rendered in 3D space such that each image-plane is situated relative to the position of the corresponding camera in the array. As the device is flexed, information from the flex sensors is used to inform the position of each image-plane in 3D space in a direct 1-to-1 mapping from physical to virtual space. This is then rendered into a real-time composite image to be shown on the FlexCam viewfinder (see Figure 4). In our current implementation, Max/MSP runs on a laptop processing the images, which are subsequently displayed on the FOLED using an HDMI connection and a printed circuit board that contains the video driver circuitry and firmware. Future versions will incorporate all electronics into the body of the device.

Conclusion & Future Work

FlexCam shows that it is possible to use a flex-sensor instead of data garnered from costly image processing to create a realtime viewfinder for a flexible camera-array. Although our system shows promise for future flexible mobile camera-equipped devices, there is still work to be done. Currently the quality of image stitching does not match that of software-based solutions. Our system suffers from edge artifacts, as well as calibration drift due to poor the poor quality of flex sensors. These issues are surmountable with the application of additional simple software-based considerations such as edge blurring and ramping alpha-channels. Additionally, as the popularity of flexible computers increases, the price of high-quality FOLED displays should significantly drop. Finally, our prototype currently relies on bulky Firewire addressable cameras, connected with Firewire cable. Future versions will feature the kind of miniaturized low profile cameras found in today's smartphones.

Acknowledgements

We thank Jann Kaminski and the members of the Flexible Display Centre at Arizona State University.

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