

# Fluid Beam - A Steerable Projector and Camera Unit

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## Abstract

*This paper presents an approach of using a steerable projector and camera unit in order to augment instrumented environments with projected virtual objects. The environment appears to be covered with a kind of invisible virtual layer on which images, texts, videos, computer desktops and other virtual objects can be placed. By steering the projector beam on particular surfaces the objects placed on them are made visible as if the projector were a virtual torch light.*

## 1. Introduction

With the ongoing development of ubiquitous computing the need of omnipresent displays is rising. Although due to the technological progress physical screens are becoming larger and more affordable it is still not possible to cover a whole room with such devices. Therefore projection is increasingly regarded as a new means of ubiquitous visual output.

In the last few years different efforts have been made to develop projectors that display images free of distortion on arbitrary surfaces. A homography-based method using a non-calibrated remote camera has been presented in [5]. It has mainly been developed for slide presentations with stationary projectors and its significant disadvantage is the need for the camera to be able to detect the screen boundaries.

The Everywhere Displays (ED) Projector [3] enables projection in arbitrary directions within a cone using a rotating mirror placed in front of the projector. Image deformation is avoided by projecting the source image as seen from the point of view of a virtual camera with the same orientation and optical parameters as the projector. In this way the distortion caused by oblique projection is compensated. Unfortunately due to the mirror-projector configuration the projection range is restricted to a cone so that not every surface can be reached.

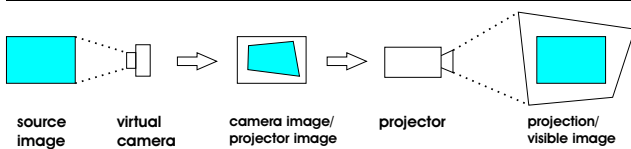


Figure 1. Fluid Beam hardware

This drawback can be relieved by placing the projector in a movable unit like the one described in [1]. This device enables projection in almost any direction. In this paper a method for distortion-free projection will be described that combines the approaches of [3] and [1] in the sense that we have a steerable projector and camera unit similar to the one in [1] which can project on arbitrary planar surfaces correcting for the distortion using the virtual camera method presented in [3].

## 2. Hardware

The device consists of a 3.300 ANSI lumen projector and a high resolution digital camera placed in a moving yoke produced by a stage equipment manufacturer, controlled via a USB/DMX interface, and mounted in the center of the ceiling of the instrumented environment (see figure 1). The brightness of the projector is important for the images to be seen even in daylight. The camera can also deliver a low resolution video stream. The steerable unit can be rotated both horizontally and vertically.



**Figure 2. Correction for image distortion by means of a virtual camera**

### 3. Creating a display continuum

In order to correct for the distortion due to oblique projection we create a virtual model of the instrumented environment in Java3D. A virtual camera is placed in this model at a position corresponding to the posture of the projector in the environment. Virtual objects like images, videos or live video streams can now be put as textures on arbitrary surfaces in the model, and by moving the projector and the virtual camera synchronously the objects appear at the corresponding surfaces in the instrumented environment (see figure 2). In this way we obtain a virtual layer on which virtual objects can be located at certain positions or even moved from one position to another.

In order to achieve high spatial accuracy both the position and the optical parameters of the virtual camera must be calibrated very precisely. Currently we are working on methods to calibrate the exact position of the projector in the instrumented room and to compute the precise transformation between projector and camera coordinates for the Fluid Beam device.

## 4. Current applications

### 4.1. SearchLight

The Fluid Beam device has been integrated into the SearchLight [2] application which implements a physical search function for an instrumented environment. It uses the movable unit of the Fluid Beam to scan the environment for optical markers and to highlight searched objects within a projected spot (see figure 3). This functionality of locating physical objects is analogous to file search on a common PC, and helps blur the distinction of physical world and virtual data.

### 4.2. Combination with wipe gesture recognition

One application that was shown at the international trade fair CeBit this year combines the Fluid Beam functionality with simple wipe gesture recognition. In this scenario the user can select images by dragging them from the PC



**Figure 3. SearchLight**

screen to a projection surface on a desk. Then by performing a simple gesture the user can “wipe” the images from the desk to a big projection surface on the wall, where a slide show of the selection is shown (see figure 4). For the wipe recognition we use the video stream delivered by the camera of the movable unit and compute the pixel differences between two successive frames. Thus we can detect the direction of the hand movement.

### 4.3. Combination with spatial audio

In our instrumented environment a spatial audio system is integrated, with which virtual sound sources can be created to appear at particular locations in the room. Combining this system with Fluid Beam enables virtual objects to be associated with their own sounds that can move together with their visual appearance. This increases the impression that the user is working with real objects.

### 4.4. Moving virtual character

Currently we are using Fluid Beam to display a virtual room inhabitant driven by a presentation planner, that plays the role of a virtual assistant for the instrumented environment. The implementation of the virtual room inhabitant combines a character engine with the spatial audio system described above and the Fluid Beam application. In this way the virtual character can “move” freely across the whole instrumented room, while at the same time spatial audio is generated which seems to come from the position of the character.

## 5. Future work

The central goal of my Ph.D. work will be to find and explore novel interaction options for the Fluid Beam, thus upgrading it to an Aware Projector [4].



**Figure 4. Wipe gesture recognition scenario: a selection of two images is displayed on the desk; the white surface on the wall is used for the slide show**

### **5.1. A system for self-calibration of the camera-projector unit**

Using methods similar to those mentioned in [5] it is possible to automatically locate potential projection surfaces. By projecting a certain (rectangular) pattern on a surface, probably not perpendicular to the projection beam, one receives a distorted image. This distortion can be observed by a camera with sufficient distance to the projector, and analyzing it the Fluid Beam will not only be able to locate projection surfaces but also to detect its own position in the environment. Thus the user will no longer need to specify a virtual model of the environment but this will be done fully automatically by the Fluid Beam itself.

### **5.2. Different interaction options like gesture or speech recognition**

As in the area of ubiquitous computing the use of keyboard and mouse will play a less prominent role, the user should be able to steer the Fluid Beam by gestures or speech. One interesting research topic deals with multi-modal interaction. One can imagine a situation in which the user is pointing to a certain wall in the room saying "Create a display!", and after analyzing his gesture and the sen-

tence the Fluid Beam will display the user's desktop at the specified surface.

### **5.3. Combining several steerable projectors**

If the instrumented environment is very large (e.g. warehouses, supermarkets, etc.) a combination of several projectors will enable the creation of larger display surfaces and the compensation of shadows on them. It will also allow passing on virtual objects from one projector to another in order to move them over large distances. In this way - if the user is tracked - he can be guided through the environment.

### **5.4. Interaction between stationary displays and steerable projection**

In our instrumented environment there is a large plasma touch screen and several smaller screens. The interaction between these screens, providing islands of higher resolution, and a projected image is also an important research topic. Potentially the projected display continuum can be used to transfer virtual objects from one screen to another.

### **5.5. Performing user studies**

Users will be invited to work with the Fluid Beam in order to evaluate its usability. I can imagine a scenario in which a projected character appears as an assistant moving through the environment helping the user by giving him advice, explaining the handling of the devices in the room, answering questions, etc. The user will be able to interact with the character applying speech and gesture, thus learning how to work with the instrumented environment.

## **References**

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