Interactive Calibration of a Multi-Projector System in a Video-Wall Multi-Touch Environment

Alessandro Lai
University of Cagliari
Via Ospedale, 72
09124 – Cagliari, Italy
alessandro.lai85@gmail.com

Alessandro Soro
University of Cagliari/CRS4
POLARIS Science Park Ed. 1
09010 – Pula (CA), Italy
asoro@crs4.it

Riccardo Scateni
University of Cagliari
Via Ospedale, 72
09124 – Cagliari, Italy
riccardo@unica.it

ABSTRACT
Wall-sized interactive displays gain more and more attention as a valuable tool for multiuser applications, but typically require the adoption of projectors tiles. Projectors tend to display deformed images, due to lens distortion and/or imperfection, and because they are almost never perfectly aligned to the projection surface. Multi-projector video-walls are typically bounded to the video architecture and to the specific application to be displayed. This makes it harder to develop interactive applications, in which a fine grained control of the coordinate transformations (to and from user space and model space) is required. This paper presents a solution to such issues: implementing the blending functionalities at an application level allows seamless development of multi-display interactive applications with multi-touch capabilities. The description of the multi-touch interaction, guaranteed by an array of cameras on the baseline of the wall, is beyond the scope of this work which focuses on calibration.

Author Keywords Video-walls, Multi-touch.

ACM Classification Keywords H5.2 [Information interfaces and presentation]: User Interfaces. – Input devices and strategies.

General Terms Management, Measurement.

INTRODUCTION
With the every-day increasing diffusion of multi-touch technologies, a lot of people are getting used to this style of interaction. As a consequence, wall-sized interactive displays are becoming tools of choice for multi-user (either collaborative or competitive) applications, in fields spanning from marketing and advertising to education and exhibitions. One major obstacle to the development and spreading of such technology resides in the lack of suitable application development frameworks: this leads single groups of programmers to devise ad-hoc solutions, each of which with its own strengths and limitations.

Interactive video walls require almost invariably the adoption of display tiles, made either of LCD screens or projectors. Choosing the first solution, although possible in principle, one has to face high costs, logistic hassles, high power consumption and heat emission, all factors discouraging to adopt it. It’s true that, apart from this, arranging an array of multi-touch displays is barely a problem of setting up a scaffold holding it, and connecting the array to an appropriate hardware that supports a display of that size.

In the second case, when using projectors, the cost per surface unit is reduced, and the final result can be absolutely seamless, due to the absence of any type of frame inside or around the display; on the other hand, this seamlessness is obtained at the cost of facing and solving the problem of blending, in term of geometry, colors and lightness, the images coming from each different projector.

STATE OF THE ART
The blending problem is already theoretically solved by many previous works as it is well summarized in [1] and practically implemented in many ways; these solutions mainly relies on hardware, using expensive projectors with in-hardware blending capabilities, or in software, typically bounded to the video architecture and to the specific application to be displayed, thus restraining the portability of the system. A typical example of this is the Chromium framework, targeted to OpenGL based applications [2]. This issue appears even more important in the development of multi-touch video-wall applications. As an example, coordinate transformation (from sensor space to GUI space) is affected by the blending functionality, and is better addressed if the blending is realized at the application level, rather than at the device level.

This paper presents a possible solution to such issues: implementing the blending functionalities at an application level allows seamless development of multi-display interactive applications with multi-touch capabilities. We chose to start from a well known and largely used user interface development toolkit as Qt [3] and to extend it adding geometric calibration and blending to the, Qt based, t-Frame multi-touch application framework.

MULTI-PROJECTOR INTERACTIVE VIDEO-WALL
A projector always displays a deformed image, due to lens distortion and/or imperfection, and because it is almost never perfectly aligned to the projection surface. So, when multiple projectors are joined to realize a video-wall, this distortions are easily noticed, and just aligning projectors side by side is not a feasible solution.
This problem is already known and it was solved many times [1], typically using a partial overlap between projectors, achieving first a geometrical calibration, and then applying a darkening mask to achieve the blending and hide the double lighting in the overlapping zones. Interactive video walls have the additional constraint that users must be able to get close to the display (for interacting). Since front projection would cause the shadow of the user to be projected in the interaction area, such systems typically require rear projection or wide-angle front projectors. Our setup adopts the latter solution (see figure 1), projectors are attached upside-down over the head of the users leading to a compact setup; however, the lens distortion is further enhanced by the wide-angle lens.

![Figure 1: Setup of our multi-projector system, notice the two arrays of cameras nearby the floor.](image)

**Geometric Calibration**

Projectors get calibrated one at a time: a black and white checkerboard sample is captured by a camera positioned just in front of the projection. The camera itself need to be calibrated to avoid lens distortion (this task is easily done using OpenCV [4]). Tilt and orientation with respect to the display surface must be known. In absence of any distortion from camera and projector lenses the image projected on the screen and the one captured by the camera would have identical proportions. OpenCV allows to precisely determine the position of the internal corners of a chessboard pattern, and we use it to compute the deformation matrix for the projector.

The resulting (inverted) transformation is then applied just before the rendering phase: the application is not directly shown on the screen, but instead is captured as a texture (rendering on a Frame Buffer Object). Such texture is then divided in tiles that match the deformation matrix just captured. This compensates the projection distortion, and possible rotations, achieving geometric calibration inside each projector (intra-projector geometric calibration). Different (partially overlapping) areas of the model are then rendered separately, and each one is deformed according to the appropriate matrix before being rendered to the screen. In this way we achieve geometrical consistency between projectors, using this alignment to compensate the space wasted by overlapping projection regions. (extra-projector geometric calibration).

![Figure 2: The blending process: on the left, the two images before blending, on the right, after it.](image)

**Blending**

Once we have obtained a geometrically consistent projection, we have to apply a darkening mask to obtain a luminance consistence. With the geometric calibration, we can assume that the projections are aligned, so we can apply a graduated shading that follows a double cosine function to the two edges of the windows that cover the overlapping zones. In this way, every point in the resulting projection has a constant sum of lighting (see figure 2). Finally, the system is responsible for the transformation of user input (such as mouse events and multi-touch gestures) according to the transformed model. This is however outside the scope of this paper.

**CONCLUSIONS AND FUTURE WORK**

We have shown a solution to the issue of implementing blending functionalities at an application level to allow seamless development of multi-display interactive applications with multi-touch capabilities. The advantage of our approach is the improved portability and ease of use of the proposed technology. The design of wall-sized interactive displays is a fascinating and rich topic of research, but still in a phase of prototyping and ad-hoc solutions. Addressing the problem of display blending and calibration at the application level ensures a finer control over the interaction aspects, with great advantages in applications development. Further work will concentrate on addressing issues coming from real-world deploy in difficult sites, such as adapting on-the-fly to changing lighting conditions, projection on uneven surfaces, and absorbing vibrations and shocks.

**REFERENCES**