A Dynamic Multi-display System Approach

Gelson C. Reinaldo, Marilena Maule, Márcio Zacarias, Anderson Maciel, Carla M.D.S. Freitas, Luciana P. Nedel
Institute of Informatics – Federal University of Rio Grande do Sul (UFRGS)
Porto Alegre - RS - Brazil
{gcreinaldo}, {mmaule}, {mrzacarias}, {amaciel}, {carla}, {nedel}@inf.ufrgs.br

Abstract

Techniques for construction and configuration of tiled display systems have been focused by a number of research groups. Arrays of monitors or projectors in a fixed size matrix NxM can be managed by computer clusters to display a single image with large dimensions and high resolution. In the present work, an array of tablet PCs is used to compose a tiled display with a specific interaction feature due to the mobility of each individual tablet. Tracking ground fixed markers with the tablets web cameras enable the system to change the virtual image region to be displayed by each tile, which allows dynamic exploration of the visualization space.

1. Introduction

In the last few years, computers are quickly multiplying their capacity on data acquisition, storage and processing power. The amount of data to treat is increasing in the same pace. One problem in this context is how to view and interact with these huge amounts of data if there is only low resolution and small conventional displays available. Additionally, computers are really becoming part of our lives.

We are more and more in face of situations where computers are completely pervasive and the interaction space is mixed with the real space, anticipating the future of computing. Among the challenges imposed by such reality, interactive data visualization using tiled displays is getting more and more attention of researchers in several areas of computer science. The central idea of tiled display systems is to use a matrix of ordinary displays as one single high resolution display. The goal is to view a high resolution image through a mosaic of small ones. Figure 1 shows a tiled display composed of four 1280 x 800 pixels each, allowing an image display up to 2560 x 1600 pixels.

However, a greater impact of this technique is in using large-format tiled displays to build-up “information” or “activity” spaces that involve the user, making possible diverse ways of interacting with multimedia data and information flows. Such environments may prove to be the successors of the desktop metaphor in information technology tasks [1]. A significant amount of previous work explored the area of tiled displays to build large scale devices, to evaluate existent interaction and collaboration techniques, and also to propose new techniques and metaphors. However, the general approach is to use fixed displays with static layout (rectangular is usual).

Figure 1. Arrangements with four tablets Pcs, allowing to display an image of up to 2560 x 1600 pixels.

In this paper we propose, for the first time, a tiled display array built from an arbitrary set of tablet PCs that allows the users to change the tile layout dynamically and in real time as shown in Figure 2. The system proposed minimizes possible space restrictions regarding visualization. It exploits mobility to allow an intuitive and distinct interaction strategy to explore the region to be viewed.

2. Related Work

Several groups have worked on building and configuring tiled displays. Hereld et al. [1] and Tao Ni et al. [3] describe a method to assemble a low cost tiled

Figure 2. Tiled display with an arbitrary arrangement allows viewing different portions of the picture.

display. They use an array of monitors (usually LCDs) or projectors arranged in a fixed tile matrix NxM. The displays are managed by a cluster of computers which can show a single image with large dimension and high resolution encompassing the whole array.

Other authors have investigated new interaction metaphors to allow collaboration on a dynamic, virtual large display. In one of these approaches, tiled displays can be formed by multiple tablet computers. When two single displays are moved close to each other, special sensors detect the orientation and direction of such “touch”, and a larger integrated display area is dynamically formed [2]. In order to dynamically enlarge the interaction area for the purpose of shared use, a flexible coupling of displays overcomes the restrictions of display sizes and borders. Hinckley [2] reports the use of synchronous gestures that are distributed patterns of activity that take on a new meaning when they occur together in time, or in a specific sequence in time. For example, the synchronous gesture of joining two mobile devices together can connect the devices in various ways. This creates a collaborative face-to-face workspace with a shared whiteboard application.

ConnecTables [4] form connections between mobile devices. They are wheeled tables with mounted LCDs that can be arranged together so that the top edges of two LCDs meet, forming a collaborative workspace. Each LCD senses the presence of the other one using radiofrequency identification (RFID) tags. Of course, these systems require special hardware, and not simple ones like the tiled displays built based on tablet PCs.

In all methods mentioned above, a fixed array (and a single image) is used, and if a single display is moved that part of the view is lost. In other words, if one changes the layout of the displays arrangement, the image (supposed to be shown in the large display) and the view does not match.

With an extra view area and mobile tiles the total view is flexible to adapt the single tile repositioning. This flexibility of arrangement and display for sure leads to new applications and requires the exploration of new interaction methods and visualization.

3. Design

As stated by Hereld et al.[1] and Tao Ni et al. [3], a cluster of computers allows using each video output to compose a single high resolution image. By partitioning the large image in a way that each computer displays its respective portion, the total image resolution is increased. *Chromium1* is a relevant tool regarding this feature. Running Chromium in a cluster, using the client/server model, any OpenGL application executed in the server can have its output partitioned and distributed through the clients. The partitioning and distribution is synchronized and transparent to the application.

Since, in our work we want to build a dynamic display topology, the position and orientation of each display must be captured in real time and passed to Chromium[1] so the image can be segmented dynamically, updating the larger display conformingly.

We developed a system with (i) a cluster of laptops (tablet PCs); (ii) digital web cameras, integrated in each laptop; (iii) a position and orientation capture method based on ARToolKit[2]; (iv) markers for capturing tablets position and orientation; and (v) an example application to show the functionality we want to demonstrate. Figure 3 shows the marker positioned above the tablets, allowing its capture by the cameras.

A complete, real time synchronization through the network is beyond the scope of this work. A simple case where a static picture is shown has been implemented, and it needs no synchronization. In fact, the same program running in each a tablet can calculate the position of the respective computer, and display the corresponding, segmented image portion. It should be noticed that the actual picture size is larger than one single display, and many displays are needed for showing the entire view.

The dynamic tiled display was built in the following way. A planar region, with fixed dimension and position, represents the virtual large screen, where the image will be virtually drawn. The marker is at a fixed position, at a certain distance from the image plane. Each webcam is able to capture the marker image, and obtain the position and orientation of the corresponding tablet using the ARToolKit. Each tablet has a LCD, which is used as a tile of the larger display to show the view of the corresponding synthetic

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[1] http://chromium.sourceforge.net

[2] ARToolKit is a software library for building Augmented Reality (AR)

Figure 3. The marker positioned above the tablets, allowing capture by the web cameras.

camera updated based on the marker information. This way, moving a tablet causes the corresponding image in the LCD to be redrawn as we were moving a window over the virtual large picture. Thus, each tile shows different pictures depending on their positions and orientations. Since the tablets have a LCD screen surrounded by a frame, the tiled display formed by the LCDs will show the image with some parts missing, the ones occluded by the LCD frames. However, there is no distortion, just a "natural" discontinuity in the image. An arrangement with a 2x2 tile array increases twice the dimension of the image that can be shown in relation to a single display; the resolution (pixels per inch) remains the same but there are four times visible pixels. Figure 1 shows such an arrangement with four tablets (T_{11}, T_{12}, T_{21}, T_{22}) with 1280x800 pixels each. Tablet T_{11} displays the top left image portion; T_{12} displays the top right; T_{21}, the bottom left, and T_{22} displays the bottom right image part. The size of the virtual image is determined by software, but its visualization depends on the hardware. If we add the dimensions of each LCD screen, we end up with a different value from the actual virtual image size.

4. Implementation

An example application was developed using the ARToolkit and OpenGL APIs. ARToolkit video tracking library is used to handle the signal from the tablets builtin cameras. It allows real time calculation of the camera position and orientation relative to a ground fixed physical marker. This geometric data is actually a transformation matrix that is passed to OpenGL. OpenGL then uses this information to handle a virtual camera placed at a specific position and oriented in such a way that they match the situation of the actual marker relative to the virtual scene.

The same software application runs asynchronously on every tablet. It is a simple application displaying a static plane where a high resolution image is textured. Each instance of the application estimates the virtual camera position and orientation and displays the part of the plane (and the image) corresponding to its own position and orientation.

Actually, as the physical marker represents a fixed coordinate system for the application, each tablet will display a different part of the image depending on its own position in the real world. In practice, if a few tablets are placed on a table surface and the marker on the ceiling, the system works like if a large poster was placed under the table and each tablet was a transparent window on the table surface allowing to see part of the image. If a sufficient number of tablets is placed side by side completely covering the table, the whole image will be displayed as a mosaic. If a tablet is moved, its virtual camera is updated in real time and different portions of the image are intuitively displayed:

- marker distance affects zooming. Moving the tablet up causes a zoom in, and moving it down reflects a zoom out;
- lateral movement (on plane) shows another portion of the picture respective to the tablet movement direction;
- angular movement (on plane – pitch) rotate the canvas in respect to the tablet rotation direction;
- angular movement (row and yaw) skew the image in respect to the tablet rotation;
- tablet overlap causes the same portion of the picture to be drawn on the overlapped areas of both tablets.

Note that the system compensates any move of the tablets so that the virtual image seems stationary.

Figure 4. The picture remains continuous even with the displays overlapping.

Asynchronous decentralized systems like the example described above work without communication and with virtually any number of tiles (displays). On the other hand, a synchronized distributed system is managed by a server which centralizes the communication. In conventional tiled displays it hosts the virtual image and shares portions of the image with the client tiles for display. Chromium is a free implementation with distributed characteristics for client/server communication that can be applied in the context of tiled displays. This rendering system has the advantage of being non-invasive. It means that every OpenGL application, including dynamic 3D scenes, could be used. The present paper is an ongoing work eventually aiming at a full distributed application of dynamic tiled displays. The current Chromium version is able to split a dynamic scene into a set of tiled displays, but does not allow change of display position and orientation on the fly. As a first approach we plan to use the basic functionality of Chromium and extend it to perform dynamic relocation of the partial displays. This will allow for applications to display videos or real time 3D scenes on a dynamic, interactive and collaborative tiled display.

5. Results

The above description was implemented and we conducted some experiments. Results are clearly preliminary because this is a work in progress as mentioned in the previous section.

We experimented the application varying the tablets positions, thus changing the tiled display configuration (see figures 1, 2 and 4). We had some experimental users testing the system. Even without training, they performed intuitive movements to explore the virtual image displayed “under” the tablets.

Important issues are environment illumination and marker positioning. Changes in these parameters required additional camera calibration. Good illumination and fixed marker position reduce the occurrence of problems in marker tracking.

6. Conclusion

In this paper we presented preliminary tests in the construction and evaluation of a tiled display system allowing dynamic rearrangement of its tiles. The results obtained so far allowed us to visualize a static scene, i.e., the objects in the scene do not move and we can run the displays asynchronously.

The next step is to adapt a distributed rendering system (e.g. Chromium) compatible with dynamic virtual images (animations). Furthermore, alternative interaction techniques could be used to allow for and to improve distributed applications.

Interestingly, this work has shown that mobility can establish new interaction metaphors that have revealed new application possibilities. Moreover, this dynamic view resizing flexibility opens a new branch in the area of collaboration. Tasks can be performed on a shared workspace by collaborative users that otherwise could not be accomplished if the same users work individually isolated.

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