Augmented E-commerce: Making Augmented Reality Usable in Everyday E-commerce with Laser Projection Tracking

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Abstract. Advances in network and mobile communication technologies enabled transformations of markets to the forms of E-commerce. However, current E-commerce technologies cannot provide enough information on the physical dimension, material color, and tactile impression of the products. There exists fundamental discrepancy between the internet-based cyber world and the user's real environment. By superimposing 3D virtual products on the user's real environment, Augmented Reality (AR) technologies might resolve this discrepancy. However, AR implementations often require bulky infrastructures and/or laborious installations, and hence are not easily available. In this paper, we present a marker-free, easy-to-use, and stand-alone AR system based on laser projection tracking (AR Pointer). A prototype of Augmented E-commerce system was developed based on AR Pointer technology. Using this system, untrained users can just "Put & feel a product" in order to find the match of the virtual model of a product in the real environment.

1 Introduction

Worldwide spread of Internet technologies and services enabled web-based E-Commerce services since the middle of 1990's. Up to present, B2B(Business to Business) and B2C(Business to Client) E-Commerce markets have grown steadily, and more and more people are utilizing E-commerce services. Recently, in addition to Internet-based online retailing, E-Commerce has been expanded to mobile environments and living rooms by use of mobile phones and Digital TV sets. The major advantage of E-commerce is convenience in commercial transactions: a user can easily search for a product and compare it with other products in a short amount of time simply by mouse-clicking. However, E-Commerce has deprived users of the reality. Two-dimensional images and texts on the screen are not sufficient to provide information on the physical dimension, material color, texture, tactile impression, and manipulation feedback of a product. Most of those who have on-line shopping experience would be persuaded that we might have unpleasant surprise of receiving products different from our expectations.

V. Roca and F. Rousseau (Eds.): MIPS 2004, LNCS 3311, pp. 242–251, 2004.

The difference between the impressions on the images and the actual products is due to the fundamental discrepancy between the internet-based cyber world and the real environment. To resolve the discrepancy, 3D virtual products can be provided using web 3D tools such as Viewpoint or Cult3D. They may provide rich experience to the users [1], but still 3D virtual products are not in the same context as the users' real environment. To correctly resolve the discrepancy, the user's real environments (user's office or home) and the virtual object (the product) should be seamlessly mingled. By superimposing 3D virtual environment on the user's real environment, Augmented Reality (AR) technologies are used to merge real and virtual environments [2]: the size and other physical properties of the products can be expressed in the user's real environment context. However, there have been only a few AR researches applicable to E-Commerce. ARIS(Augmented Reality Image Synthesis) is one of such systems. In ARIS project, an E-commerce system for interior decoration is under development that may improve the shopping experience of visitors (potential customers) using Augmented Reality methods [3]. However, ARIS requires various infrastructures, difficult to be practically utilized in the usual life. There have been few practical AR systems practically usable and available to the untrained users. Many technical limitations of AR need to be overcome so that AR technologies can be applied in E-Commerce services.

2 Limitations of Augmented Reality Technologies for Everyday Use

Augmented Reality, providing magical feeling of immersion, has been one of the most attractive research topics in the human computer interaction and computer graphics fields since early 1990's. Thanks to advances in hardware devices, tracking technologies, and display technologies, AR implementations are available on commercial off-the-shelf desktop and notebook computer systems. However, AR has not been successfully utilized in many practical applications, especially in E-commerce applications, because of its limitations and technical difficulties as summarized in the following.

2.1 Bulky Infrastructures and Complicated Configuration for Using AR

Because of technical similarities, AR systems have been built on existing Virtual Reality (VR) technologies. In most research and development, AR employed VR tracking and display devices that are often bulky and heavy, and/or require laboratory installations of sourcing devices (e.g., for magnetic and ultrasonic trackers). Vision-based tracking technologies, such as ARToolKit system [4], often use artificial markers, and hence do not require hardware installation in the environment. However, markers need to be installed and calibrated in advance. There are also (partial) occlusion problems of the markers, which may result in tracking failure.

2.2 Use of Unwieldy Head-Worn Displays (HWD/HMD)

In AR applications, video see-through displays are preferred to optical see-through displays for higher registration accuracy. However, video see-through displays are often unwieldy and fatiguing, hindering user's natural view of and interaction with the real environment. Thanks to recent technical advances, AR has been successfully ported on hand-held devices such as PDA's and mobile phones [6][7][8], demonstrating the potential of producing practical applications. Hand-held AR systems may be used in many applications including collaboration [5] and navigation [13].

2.3 Lack of Stand-Alone Systems

Because AR integrates many advanced technologies, such as tracking, display, video, and computation technologies, it has been difficult to produce a stand-alone (or all-in-one type) AR system. For tracking systems, many technologies require installation of sourcing devices, on which tracking devices physically depend. Although vision-based tracking systems do not require sourcing devices, they rely on pre-installed markers [4][14]. Inertial trackers work as a stand-alone tracking system, but the tracking information they provide cannot be used to construct geometrical relations between the real and the virtual environment, which is required for image overlays. GPS and digital compass also do not depend on other devices, but because of low accuracy, they are not useful in many AR applications other than navigation and guidance. To summarize, existing AR systems are dependent on tracking infrastructures or accessories such as markers. For non-experts, a plug-and-play stand-alone AR system is desired.

To produce practical applications including E-commerce applications, portable, marker-free, easy-to-use, and stand-alone AR system is desirable. Such an AR system can be used in everyday E-Commerce life of untrained users.

In this paper, we introduce a stand-alone, plug-and-play type AR Pointer system to be used for Augmented E-Commerce applications. The proposed AR system is easy to use and marker-free, and hence more general-purpose in applications. Instead of traditional tracking systems that require laborious installations, a small laser and a video camera are used as a tracking unit in our system.

3 AR Pointer System

Diffractive optical elements (DOE's) transform a single laser beam into various structured light patterns as shown in Fig. 1. These patterns, projected on a planar structure (wall, table, floor, etc.), change their shapes as the distance and the orientation between the laser and the plane change. Through calculating the geometrical relation (distance and orientation) between the plane and the laser, the laser patterns can be used in place of markers that are widely used in vision-based tracking systems. In other words, a projected DOE pattern may play a role of a marker to provide tracking information.

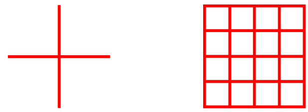


Fig. 1. Laser light patterns

3.1 Use of Laser Devices

Laser pointer has been often used in Human Computer Interaction (HCI) applications in order to support interactions among computer systems, visual environments, and human. It has been used as a 2D pointing device in conferences or presentations in place of traditional pointing devices such as mice [9][10]. Laser pointer has also been used as a travel aid device for blind people [11]. In this system, a stereo camera was used to calculate the depth to the pointed surface. A red-pass filter was also used for robustness of image analysis. In collaborative AR environments, lasers have been used as an interaction device to select, move, and rotate visual elements [12]. However, to the best of our knowledge, lasers have not been used as a real-time tracking device up to present.

3.2 AR Pointer System Components

AR Pointer system is composed of a laser with a DOE, a video camera, and an optional LCD monitor. A laser and a video camera are combined into one unit to be used as a tracking and video capture device. An optional LCD monitor can be used as a display unit, to compose a hand-held AR system together with laser-camera unit. For registration information calculation and virtual object overlay, the laser-camera unit can be connected to any type of computing systems (Fig. 2). Depending on the computing system, AR Pointer system could be constructed as a desktop system (Fig. 3) or a mobile system (notebook PC / tablet PC / PDA / mobile phone). As a mobile unit, AR Pointer can be used also as a hand-held AR system as in TransVision[5] or NaviCam[13] (Fig. 4).

AR Pointer system is distinguished from the previous AR systems, showing many advantages. Firstly, AR Pointer is a stand-alone system: there is no requirement of laborious installation process, bulky and unwieldy tracking devices, or marker installations and calibrations. Secondly, it is also highly mobile and easy-to-use as in plug-and-play peripheral devices. Thirdly, pointing with the laser patterns, AR Pointer system can overlay virtual products on any planar surface of user's real environment. These advantages enable AR Pointer system to be used in everyday E-commerce life of untrained users.

Most tracking systems are exocentric in terms of tracking coordinate systems (the origin of the coordinate system is located outside the tracking unit). It is because tracking is dependent on external tracking devices or installed artificial markers. However, AR Pointer is egocentric because the sourcing device (laser) and sensing device (video camera) are of one unit. AR Pointer system can be used to "Point a spot & Register an object", which is an intuitive interaction approach. In other words, a

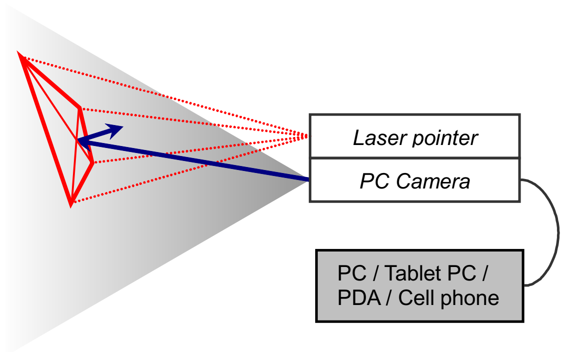


Fig. 2. AR Pointer system components

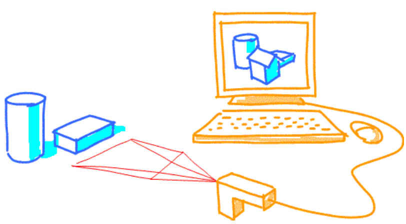


Fig. 3. Desktop AR Pointer system

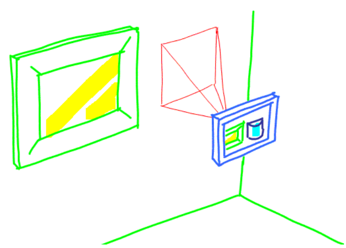


Fig. 4. Mobile AR Pointer system

virtual object can be placed in the user-specified position just by pointing at using the laser: AR Pointer system is an AR pointing device.

AR Pointer system is similar to vision-based tracking systems in that it is also based on "seeing" visual elements. However, AR pointer system does not require marker installations and calibrations. Therefore, AR Pointer can be used to overlay on the environments where marker installation is difficult or impossible. All the more, AR Pointer system can be used on the other side of a glass window or a showcase: it is capable of performing non-contact and/or intrusive operations.

4 Pose Computation and Transformations

There are three major coordinate systems in AR Pointer system (Fig. 5). The laser coordinate system (L) is used to describe DOE pattern feature positions. The tabletop coordinate system (T) is used to represent the position and orientation of the laser patterns projected on the planar surface. Lastly, the camera coordinate system (C) is used to represent image coordinates of measurements (the laser patterns) and to overlay the virtual products in augmented views.

There are two important coordinate transformations, each of which should be calculated on-line or off-line.

T_{CL}: from the laser coordinate to the camera coordinate transformation

T_{CT}: from the tabletop coordinate to the camera coordinate transformation

Parameters of laser coordinate system are the laser DOE starting point (O_L) and the DOE pattern features (Xi). Parameters of camera coordinate system are the focal point (Oc), field of view (FOV: horizontal(θh) and vertical(θv)), and image resolution (Sx, Sy). These parameters can be calculated off-line except for the image resolution (user may specify the image resolution in run-time).

4.1 Coordinate Transformation Calculation

In order to correctly superimpose visual overlays on the tabletop, it is necessary to determine the coordinate transformation from the camera to the tabletop coordinate system (or the inverse) The input measurements are the coordinates of laser pattern features on the camera image. To determine the tabletop coordinate system, in our approach we calculated the feature 3D positions of the laser patterns projected on the tabletop.

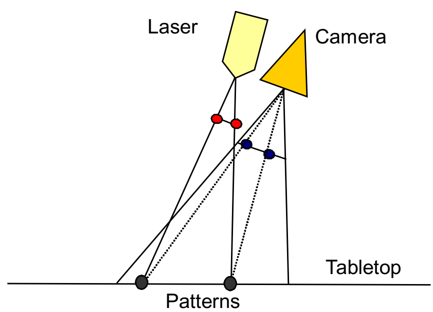


Fig. 5. AR pointer Coordinate Systems

As can be seen in Fig. 5, these 3D positions are the intersections of the rays from the laser DOE starting point to the DOE pattern features, and the rays from the camera focal point to the image features [14]. To calculate the intersection (more precisely, the closest point between the rays), the rays should be represented in a common coordinate system (in our implementation, camera coordinate system was used). To represent rays in a common coordinate system, coordinate transformation between the laser and the camera coordinate systems should be known. This transformation was calculated off-line as explained in the following section. Detailed steps for computing ray intersections are described in the following.

(1) Laser feature patterns are transformed into camera coordinate system as follow.

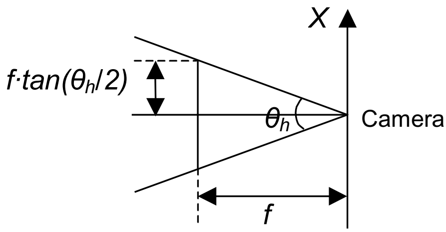
$$X_i^C = T_{CL} \cdot X_i^L \quad \text{(DOE pattern features)}$$

$$O_L^C = T_{CL} \cdot O_L^L \quad \text{(DOE pattern start point)}$$

(2) Ray from laser focal point to the feature points represented in camera coordinate system are obtained (there is no unknown parameter).

$$l_{Li}^C = O_L^C + t_i (X_i^C - O_L^C)$$

(3) Rays from camera focal point to the image feature points are calculated using the camera FOV.



$$f \cdot \tan\frac{\theta_h}{2} : \frac{s_x}{2} = y_i^C.x : y_i.x - \frac{s_x}{2}$$

$$y_i^C.x = \left(y_i.x - \frac{s_x}{2}\right) \cdot \frac{2f \cdot \tan\frac{\theta_h}{2}}{s_x}$$

$$y_i^C.y = \left(y_i.y - \frac{s_y}{2}\right) \cdot \frac{2f \cdot \tan\frac{\theta_v}{2}}{s_y}$$

$$l_{Ci}^C = O_C^C + s_i(y_i^C - O_C^C)$$

(4) The intersections (the closest point between the rays) of the rays are computed.

The intersections of these pairs of rays are the positions of the laser pattern features projected on the tabletop, represented in the camera coordinate system. With three or more non-collinear points, the tabletop coordinate system can be constructed, and the transformation between the camera coordinate system and the tabletop coordinate system can be calculated.

4.2 Laser to Camera Coordinate Transformation

The transformation between the laser coordinate system and the camera coordinate system should be known in order to represent the rays in a common coordinate system. We used an off-line calibration method, which is described in the following.

(1) The laser pattern was aligned perpendicular to a visual marker, and the distance between the laser and the marker was measured (Fig. 6-top).
(2) The camera image of the visual marker was taken with the laser switched off (Fig. 6-bottom).
(3) The 3D visual marker coordinates were measured.
(4) The camera pose was computed using an optimization method based on the 3D marker positions and the 2D image coordinates.

In step (1), the transformation from the laser to the marker coordinate system (T_{ML}) was obtained (simple translation on Z axis). In step (4), the transformation from the marker to the camera coordinate system (T_{CM}) was calculated. Transformation from the laser to the camera coordinate system (T_{CL}) was then calculated using T_{CM} and T_{ML}.

$$T_{CL} = T_{CM} \cdot T_{ML}$$

This calibration process was performed once after system assembly: it does not have to be repeated. The images used for "from the laser coordinate system to the camera coordinate system" transformation calculation are shown in Fig. 6.

4.3 The Prototype of AR Pointer System

Our prototype of AR Pointer system is composed of a laser with a 5x5 grid pattern DOE, an IEEE-1394 video camera, and an LCD monitor (Fig. 7). The laser and the camera were placed parallel and apart. As the distance between the laser and the camera increases, the tracking accuracy might be improved.

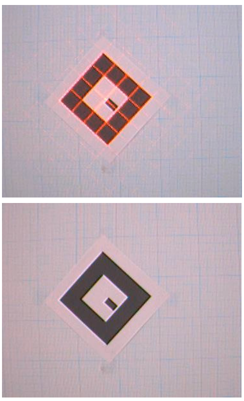


Fig. 6. Images used for laser to camera transformation calculation with laser on (top) and off (bottom)

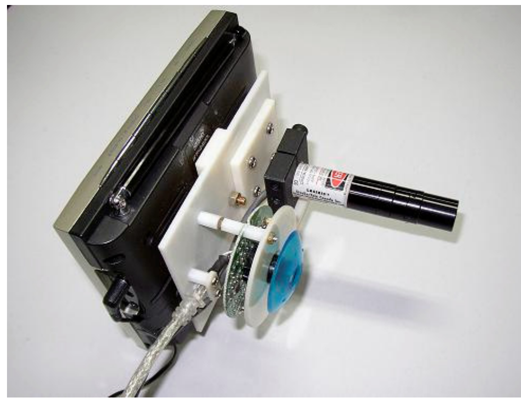


Fig. 7. AR Pointer system hardware configuration

For robust detection of bright laser patterns, the automatic camera exposure control was disabled (manually controlled to obtain dark images). The video images were captured in VGA resolution at about 15fps. The depth range of the system was from 15cm to 4 meters depending on the illumination condition.

5 Prototyping Augmented E-commerce Web Sites

We built an Augmented E-commerce system based on our noble stand-alone AR Pointer system. Fig. 8 shows the Augmented E-commerce prototype embedded to an E-Commerce web site. The scenario is very intuitive. A user searches for a product on-line and drag-and-drops the 3D model of an interesting product onto the AR window. AR Pointer system, then, registers the virtual object on the user pointed spot in the real environment. The user interacts with the virtual objects by moving and rotating in order to estimate the dimension and shape of the product, and to find the matches with the room environment. In other words, users can "Put & feel a product" in reality.

Using Augmented E-commerce system, users' shopping experience can be greatly improved. Users can perceive the products in his/her office or home environment through LCD monitor without wearing unwieldy HMD's or HUD's.

We have performed usability tests of the system. Untrained users could place the virtual products with no difficulty, and perceive the size of the bookshelf visually comparing with papers of A4 size (Fig. 9). In another experiment, users placed a virtual toy truck beside toy robots. Users estimated the size of the truck easily by comparing with other reference objects such as a soda can and a sports watch (Fig. 10). As a stand-alone system, users also could utilize AR pointer to place virtual products on various places (on the wall and on the desktop in our experiments).

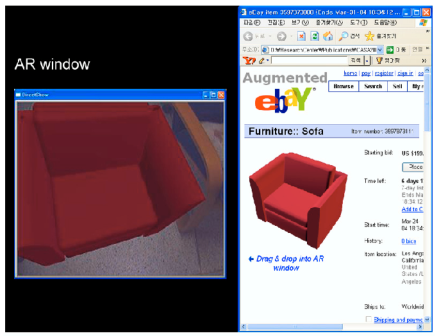


Fig. 8. Augmented E-commerce

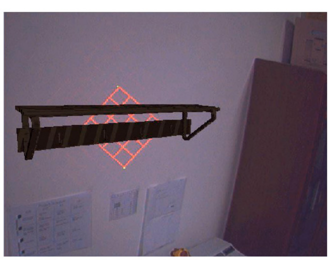


Fig. 9. Augmented view of a shelf

Fig. 10. Augmented view of a toy truck

6 Conclusions

We introduced a laser-projection based AR Pointer system and Augmented E-Commerce prototype that combines web contents and AR technologies. AR Pointer is a stand-alone, marker-free, and easy-to-use AR system that can be used in everyday E-Commerce life of untrained users. AR Pointer can be used to overlay virtual objects on the environments where marker installation is difficult or impossible. Owing to its non-contact and intrusive nature, AR Pointer system can be also used on the other side of a glass window or a showcase. AR Pointer system is less influenced by visual noise because the tracking is based on bright laser patterns: it is less dependent on illumination conditions and less influenced by occlusions.

Inertial trackers can be integrated with AR Pointer system to avoid tracking failures when laser patterns cannot be correctly detected. An inertial sensor can be also used as a control device to rotate the virtual objects in the augmented views. AR Pointer system can be improved by enabling tracking on non-planar surfaces. If executed in real-time, 3D shapes of the surface may be estimated for advanced interaction with the real environments.

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