重力加速度センサーとデジタルコンパスを用いた自動補正携帯プロジェクタ
Using Tilt Sensor and Digital Compass in Auto-calibration Handheld Projector

Dao Vinh Ninh† 細井一弘† 杉本雅則†
東京大学大学院 新領域創成科学研究科
{dao,hosoi,sugi}@itl.t.u-tokyo.ac.jp

1. Introduction

In February 2006 a British company has introduced a matchbox-sized projector for image and video projection, which start-ups a bright future of an in-phone projector [1].
The miniaturization of projector has brought to great development of projector's using and researching. The variation of projector using situation also rises up the need of creating a more flexible projector. When a projector is used everywhere, we can not always use the projector in a sweet position, and usually the projector will create a keystone distortion, which distorts the view of original images.
The research of projector calibration, helps to correct keystone distortion, has archived much development and is applied to practical use.
Nowadays, some types of projector are mounted with auto calibration function, which helps the projectors to auto calibrate vertical keystone distortion for the projection on a vertical screen by using a tilt sensor. A horizontal distortion is practically manual-calibrated by user.
A full auto-calibration method is on researching. Some researchers utilize a camera to correct the distortion. But, the approach of using image processing technique is environment illumination dependent, time consumed and error prone.

Here, we propose a full auto-calibration method by combining the usage of a tilt sensor and a terrestrial magnetic sensor without any presumed knowledge of display screen's position or direction. This method utilized only self-contained information. It is robust to environment illumination, simple to configure, speedy and can apply to any projection screen at any direction and inclination.

2. Related Work

A traditional method of calibrate a projector by using a camera is described by Rahul S. et al. [2]. The system consists of a camera and a projector. The system required the camera to be able to recognize the display screen, which has a known dimension ratio. This system also uses image processing technique for the recognition of projector's projection area. But it is not always possible to recognize a screen, because we do not always use an edged screen for projection.
The using of screen recognition can be replaced by the using of markers on the display area or on portable device.
Instead of using marker on the display screen, Sugimoto† M. et al [3] approached the calibration of projector by using an outside camera to watch the mobile projector, which is mounted with LED markers for detecting its direction.
These approaches require attaching markers to the space beforehand, or using device in an information space, thus are not feasible for ubiquitous use in arbitrary environment.

Raskar R. et al. [4], introduce a self-contained system, which contains a camera, a projector and a tilt sensor. In this system, the camera and the projector form a stereo-pair. By analyzing the dual images, this system can figure out the position and inclination of the screen, which then help the projector to calibrate its projection.
This system is self-contained, but it requires analyzing the dual images, which is not always possible because the camera need to be able to recognize the projection area, the operation that depends very much on background illumination condition. This method is also error prone because when the projector become smaller and smaller, the camera comes closer to the projector, which results in the fact that, the camera's view of projection image becomes similarly to the projector's image and the analysis of dual-views becomes extremely difficult.

3. Proposed Calibration Method

To calibrate a projection, we propose a method of using a tilt sensor and a digital compass.
A three-dimension acceleration sensor is used as a tilt sensor to retrieve a projector's inclination to vertical axis and its rotation around horizontal axis. The sensor looses a degree of freedom by constraint of gravity acceleration when it is used as a tilt sensor. Thus, a tilt sensor is enough to calibrate a projection on a horizontal plane, which is symmetric to vertical axis.

The technique of utilizing a tilt sensor to calibrate a projection on a level surface was applied at CoGAME system [5], an interactive game that players use projectors to lead a turtle-like robot. CoGAME is an application that was exhibited at "International Virtual Reality Competition in 2006", held at Tokyo, and received the "Technical Price" with the over all evaluation ranked 3rd in the competition.
The using of a compass gives a complete recognition of projector's direction, which means the projector looses its last degree of freedom.
The using of a projector, mounted with a tilt sensor and a digital compass, to calibrate a projection on an arbitrary plane needs a one-step-configuration.

3.1 One Step Configuration

To calibrate a distorted projection, we need to know the relative inclination and rotation of the projector to the display screen. We can get the projector's direction, inclination and rotation from sensors' information; therefore, we can calibrate the projection if we know the display surface's direction and inclination. We need only two parameters to define a plane because a plane itself is symmetric to its axis.
To measure a display screen's parameters, all what we need to do is choosing a projector's temporary direction, so that under an un-calibrated condition the projector displays an undistorted image. By pressing a button (which is now represented by a button on computer) on the projector, we can remember the projector's direction and inclination for that figure. The projector's parameters at undistorted projection represent

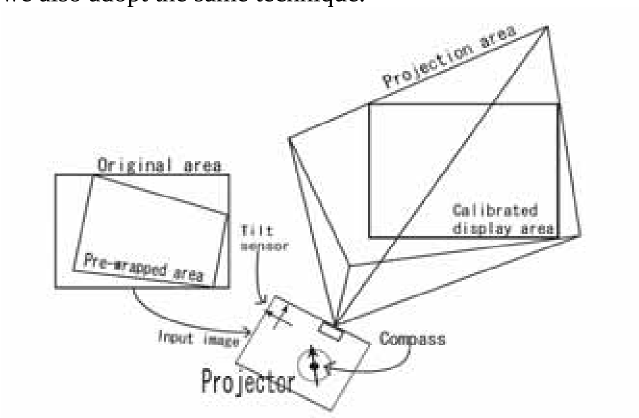
---
† 東京大学大学院 新領域創成科学研究科
Graduate School of Frontier Sciences, The University of Tokyo

plane’s parameters.

By comparing projector’s real time parameters with the standard parameters archived from the configuration, we are able to do a full auto-calibration to the previously unknown display screen.

4. Homography Transformation and Rendering

After retrieving projector’s relative direction to the display screen, we can calibrate the distorted projection by several methods. A general method is to pre-wrap the displayed images so the distortion will be counterbalance. This method creates a lost of image quality but it is flexible.
Another method to calibrate a distorted projection is the method of using a shift-lens projector. By changing the direction of projector’s lens at the direction inverse to the direction of the distortion, a projector can display undistorted images.
In a hand-held projector, the rendering method, which does not contain a mechanical moving part, is preferred. In this system, we also adopt the same technique.



Picture 1: A projector with tilt sensor and a compass uses image pre-wrapping method for calibration.

To render a counter-distorted image, we calculate the projection transformation from the projector to the display screen, and then select a suitable display area inside the projector’s cover area, called expected display area, so that the projection will not cause any distortion. By re-converting the expected display area into the projector’s source image, we archive the pre-wrapped image needed for the calibration.
The pre-wrap image is created by rendering the original image using the homography transformation between the original display area and the counter-distortion area.

5. Implementation and Evaluation

The system was implemented by using a Toshiba’s portable LED projector (TDP-FF1), a Sunhayato’s acceleration sensor (MM-2860) as a tilt sensor, and a Garmin’s GPS receiver (Geko 301) with digital compass function.
A VAIO type-U is used for information processing and images rendering.

Utilize this technique as a backbone; a camera is freed from auto-calibration technique. The camera can come very close to the projector, projector’s projection area becomes unchanged in camera view. This, in return, brings the interaction of camera-projector system into a new way. Because, the projector’s images are calibrated, users from different positions can display images on the same image area.
In a camera-projector system, different projectors can independently interact with each others without confusing because a camera view of the projector in the system is unchanged, which help the image recognition without much image processing effort.

Picture 2: System construction

At this step of implementation, the tilt sensor is speedy and reliable; with the output rate up to 350Hz, the calibration relies on tilt sensor’s information is almost at real time (CoGAME).
The GPS receiver is mounted with a two-dimension digital compass and can only give the output rate at 0.5Hz.
To obtain an accurate direction value, when the projector is not horizontal, we have to adjust the compass’s data by the tilt sensor. A compass is also inflected by a strong magnetic environment. Thus, the system can work well under environment without much steel near by.

6. Conclusion

We have introduced a method of calibrating a distorted projection on an arbitrary planar screen by using a tilt sensor and a digital compass. This calibration method is new, reliable and speedy.
The configuration is quick and easy. This method costs less time to analyze the projector’s direction to the screen, so it is suitable for a mobile hand held projector.
By using a high performance HoneyWell’s three- dimension compass, we are implementing a real time calibration projector system.
Calibration a projector by sensors make a camera become free and can come very close to the projector. This brings the visual interaction into new step because image area recognition is no needed to be done by a heavy image processing technique.

Reference

[1]Edward, B., “Light Blue Optics”, In *SID Mobile Displays Conference*, 2006.
[2]Rahul, S., et al., “Smarter Presentations: Exploiting Homography in Camera-Projector Systems”, In *Proc. of ICCV*, 2001.
[3]Sugimoto, M., et al. “Intuitive manipulation techniques for projected displays of mobile devices”. In *Interaction 2005*, pp. 95–96, 2005.
[4]Raskar, R., et al., “ilamps: Geometrically aware and self-configuring projector”, *ACM Transactions on Graphics (TOG)*, Vol.22, No.3, pp.809-818, 2003.
[5]Interaction Technology Laboratory, CoGAME, *http:://www.itl.u-tokyo.ac.jp/cogame* , 2006.