Automatic Projector Calibration for Mobile Projection on Planar Surfaces.

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***Abstract*—**
The projector is a popular device for larger-scale display. Then projectors are used as a mobile device. The mobile projection has been increased its utilization and projector made a display for the temporal classroom, outdoor events, entertainment events, and mobile augmented reality application. It can generate a display on the desired area with casual projector arrangement. Projector display is bizarre when projection is dis-convergent from non-orthogonal position. However, there is no proper fully automatic calibration methodology for mobile projectors.

Projector displays need distortion-free rectified imagery, which helps users to make contents legible. As a result of causes such as devices needing a fully automated real-time solution for distortion correction, knowledge of the pose of the projector and relative placement of the display surface to the projector is needed.

A common limitation of existing techniques is using visual inputs to identify distortion of the display. Visual input (projector-camera pair [5]) needs pre-calibration phases[2][4][8][10] and high processing power (SURF, SIFT) [4][6][7]with loop-feed mechanisms[14][11] to compute a distortion. In the correction mechanism, fiducial [2] and screen marking boards[12] are damaged by the user's immersive feeling and scenery.

This research proposed a novel hardware and software framework for continuous automatic projector calibration. Distortion correction is achieved by using input data from Inertial Measurement Unit (IMU), while minimizing processing power without using visual inputs. For that, we proposed small scale hardware apparatus: “Beam Adjustment Technology” (BAT). We used very inexpensive low power distance sensor and gyroscope to compute the projector relative pose to the screen. Proposed equations for estimate distortion based on perspective transformation. Processing unit distort a image according estimations and send to the projector. This approach is fully automatic continuous calibration mechanism.it has potential to enable any scalable projector and fault-tolerant display solutions.

***Keywords*—** Distortion, Projector display, calibration

I. INTRODUCTION

Projectors are generate big screens for presentations, but in most of the scenery, distorted display on screen. Distorted display are damage to user immersive feelings and make wrong interpretation about scenery figure 1 and figure 2. In this paper present fully automatic projector calibration system for planar display surface.

Projectors are used in two different ways: as a static projector or as a portable projector. When used as static device, it is fixed to the ceiling using highly complex wall mounters. In a fixed projector setup, screen configurations become difficult and time-consuming to change. The orientation of the projector and screen may change over time as a result of inadvertent physical perturbation reasons, such as human activity, cooling and heating, and even gravity. One can imagine a situation in which a user decides to change the projector or display configuration deliberately, because of physical perturbation, to change the field of view or because of space restrictions. The projector is not a smart device that can’t adapt to such environmental changes automatically. Thus, it needs manual calibrations to maintain its display quality over time. This recalibration is costly; the projector mounted to the ceiling is a commercial system, which means maintenance must be done on-site by specially-trained professionals. Static projectors are used in classrooms, conference rooms, theatre, power walls, and CAVE.

The projector is used as a portable device. It is placed in a non-orthogonal position (projector is inclined with respect to the ground surface and planar screen surface) and projects on a desired planer surface. It generates a distorted display, as depicted in figure 1. To project a distortion-free display, users need to calibrate the projector manually to remove these factors [12], but it is an ad-hoc, tedious, time-consuming process. Where projector pose or the screen configuration is likely to change, it is highly essential to engage in manual calibration frequently. Portable projectors are used in Entertainment events (where pyramids are used as display surfaces), huddle-free group experiences, living rooms, classrooms and gaming.

A projector is placed casually (Non-orthogonal position) and projection on desired area on planar surface, generate a bizarre trapezoid distorted display. Because of the following factors or any combination of them.

1. The projector has been elevated in the horizontal direction in the world's coordinate system .
2. The projector has been tilted horizontally in the world's coordinate system
3. The projector's optical axis is not perpendicular to the planar display surface

Due to this reasons projector light beam propagation has been change in 3D geometry. In this paper proposed hardware and software mechanism to calm this kind of distortion on display. Using sensor inputs in hardware apparatus, identified projector light beam propagation. Proposed algorithm compute a distortion in display and apply a distortion on projecting imagery to correct a projector beam propagation. The proposed mechanism can apply to projector, which is attached to the unmanned aerial vehicles (UAV) is controlled by remote and automated lighting system on such device.

Figure 1: A conventional projector with a rectangular shaped display area using orthogonal projection.

Figure 2: An oblique projector makes a bizarre trapezoid distorted display. An oblique projector makes a bizarre trapezoid distorted display.

MAIN CONTRIBUTION

This paper presents a novel method for real-time calibration to improve projector use with portability features. The proposed apparatus can be attached to the conventional projector externally while this unit can also be embedded to a next-generation projector without any dimensional changes. In contrast, the most significant feature in the proposed method is that it is free from visual inputs (cameras) and automatically wipes out the tedious and time-consuming camera pre-calibration process. We used easily augmentable low power sensors like distance sensors and IMU instead of cameras. In the proposed method, the placement of hardware components (developed apparatus) and software (methodology) are totally independent entities, then it no need of pre-calibration stage. To the best of our knowledge, this is the first automatic real-time work , without visual inputs and fiducials.

II. STATE OF ART

The first mechanism has been implemented using cameras by researchers [1], [2], [4], [5]and[10].

There are several manual and automated approaches implemented for calibration followed by previous mechanisms with various scenarios [3, 4, 5, 6]. Customary projectors are mounted so that their optical pivot is opposite to the projection zone. At the point when a projector is sideways with the presentation region, it anticipates a misshaped picture on the showcase region. This twisting is determined to utilize epipolar geometry of a couple of cameras which are connected to the projector[3]. In the pre-alignment process, the predefined picture is anticipated into the planar surface and afterward appraises how the pair of cameras are physically mounted in the projector[5], [6]. At that point, corner pixels are coordinated with the camera pictures to discover the connection between the enlightened showcase region and the normal projection area[1]. Irrespective of the picture is being anticipated, such frameworks constantly repeat through this procedure without concerning the projector shake to refine a continuous estimation for the following imager to be anticipated [7], [8]. This is a noteworthy downside in a camera-based framework.

The proposed framework repays bending continuously for a planar screen with no showcase sensors, the laser focuses or fiducials. Existing frameworks have dreary pre-adjustment step[1], require mounting cameras[1] and info sign originating from sensor which is set far away from the projectors[9], and require manual calibration[10] and manual focal point shifting[10]. As of late created frameworks, which had laser pens and camera with a100 Hz casing rate and human mediation too [10] ,zhaorange Li proposed a strategy for mobile projectors [1] and it just corrected screen.

III. IMPLEMENTATION

The entire development process has been broken into two main components.
They are:

- The hardware component (BAT)
- The software component (Algorithm)

THE HARDWARE COMPONENT (BAT)

Beam Adjustment Technology (BAT) is a hardware apparatus used to measure projector beam propagation in 3D projection regions. Instead of cameras, we propose the off-the-shell sensor apparatus (BAT). BAT consists of two ultrasonic distance sensors with inertial measurement unit (IMU) MPU-6050 as shown in figure 3. All are low-cost, off-the-shelf sensors (less than two dollars). In addition, used a single-board computer (Raspberry Pi) to compute the distortion.

BAT had been designed in smaller scale (25 X 10X 4 cm) Length, Width, Height), enabling it to be attached to an existing projector. On the other hand, BAT will be deployed in a next-generation projector without changing any of its dimensions.

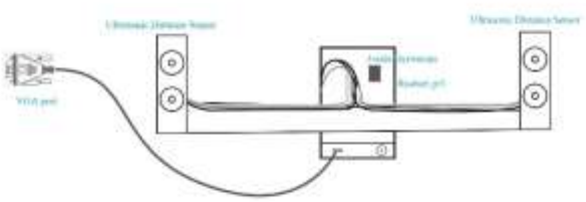

Figure 3: A Smart Projector Units "BAT"

THE SOFTWARE COMPONENT (ALGORITHM)

Proposed geometric image transformation algorithm has 3 steps,

A. Perspective Distortion Corrections
B. Trapezoid Distortion Corrections
C. Tilted Distortion Corrections

One of the correction or any combination of them generate distortion free display.

Define three parameters, β (projector's horizontal projection angle) γ (projector's vertical projection angle) are two intrinsic parameters of projectors. The α represent a projector front panel angle to the relative screen.

A. PERSPECTIVE DISTORTION CORRECTIONS

In this scenario, the projector light beam propagation distance is changed. With this perspective distortion, it produces a trapezoid shape display, as shown in figure 5. A distortion totally depends on the projector's horizontal projection angle β and a projector's front panel angle to the relative screen α .The distortion has been propagating in a vertical direction. According to research findings, the distortion factor for a horizontal image unit is equal to the image height with distortion (H) divided by distorted height (h) . The mathematical combination between H (Image height with distortion) and h (Distorted height) is shown in Equation 1.

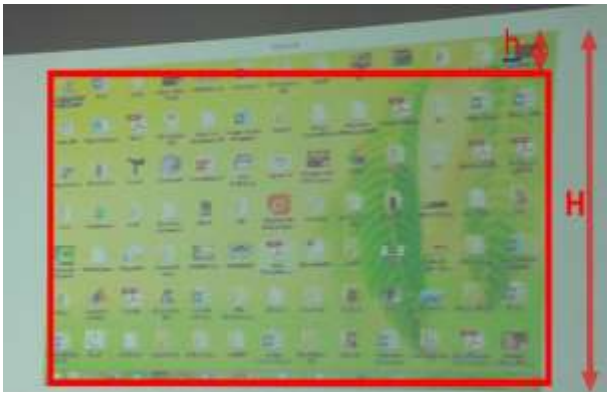

Figure 5:Trapezoid projected by the oblique projector.

$$\frac{h}{H} = \frac{\cos(\alpha - \beta) - \cos(\alpha + \beta)}{\cos(\alpha - \beta)} \qquad (1)$$

B. Trapezoid Distortion Corrections

The projectors were elevated to get a display on the desired planar surface, as depicted in Figure 6. The display area will be larger at the top than at the bottom, as shown in figure 6. A distortion totally depends on the projector's vertical projection angle γ and elevated angle of the projector ϕ. The distortion has been propagating in the horizontal direction. According to research findings, the distortion factor for vertical image units is equal to the image width with distortion (W) divided by the distorted width (w). The mathematical combination between W (Image width with distortion) and w (Distorted width) is shown in Equation 2.

$$\frac{w}{W} = \frac{(\cos\gamma - \cos(\gamma + \phi))}{\cos\gamma} \qquad (2)$$

Figure 6: The trapezoidal image that is caused by the projector being elevated.

C. Tilted Distortion Corrections

A portable projector can casually be placed on any surface but the surface can be tiled (with earths horizontal axis) to the left or right. As a result of the orientation of the projector, it produces an oblique display area as shown in Figure 7. The projector is tilted to the side by an φ angle, scenery on the surface with φ angle. For rectifying the display, before projecting an image, the system will inversely rotate the image by a φ angle. The rotation factor for the x and y axis are shown in equation 3 . The image is rotated inversely by a φ angle through the center of the image. x' and y' are new coordinates of x and y coordinates as illustrated in figure 7. The original image has *n* number of pixels for the vertical direction and *m* number of pixels for the horizontal direction. The scaling factor for the horizontal direction is S_x and for the vertical direction it is S_y.

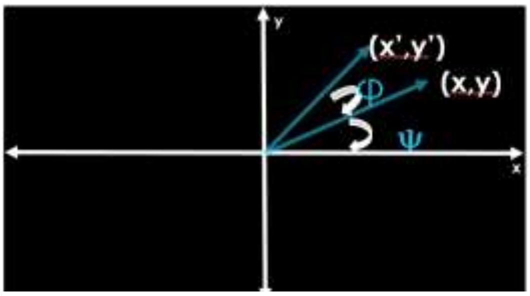

Figure 7 Image rotated inversely by an ' angle through the center of the image.

$$x' = (S_x * x - \frac{m}{2}) * \cos(\psi) - (y - \frac{n}{2}) * sin(\psi) + m/2 \qquad (3)$$

$$y' = (x - \frac{m}{2}) * \sin(\psi) + (S_y * y - \frac{n}{2}) * cos(\psi) + n/2$$

Three distortions are mutually exclusive, then we can integrate them as equation 4. Then the system generates the final collinetion matrix. It is convoluted on the original image. Now, the system generates the distorted image and it is sent to the projector. It makes a distortion-free display.

$$\begin{pmatrix} x_1' \\ x_2' \\ x_3' \end{pmatrix} = \left\{ \begin{bmatrix} Trapezoid \\ Distortion \\ Corrections \\ Matrix \end{bmatrix} + \begin{bmatrix} Tilted \\ Distortion \\ Corrections \\ Matrix \end{bmatrix} + \begin{bmatrix} Perspective \\ Distortion \\ Corrections \\ Matrix \end{bmatrix} \right\} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} \qquad (4)$$

IV. Experimental Results

To ensure the complete functionality of the final product of the research, the results can be retrieved in two ways. Before and after correcting, its horizontal edge angle with the world coordinate horizontal axis (σ) and its vertical edge angle with the world coordinate vertical axis (μ), as shown in Figure 8 . The system has been developed by three ways of distortion correction. To prove it, we test the system with various projector pose.

Full system functionalities are tested, for that ϕ, φ and α angles are changed simultaneously and σ, μ are measured, distorted and corrected display. Figure 9 image has ϕ= 6˚, φ=8˚ , α= 6˚. Figure 10 shows the respective system output.

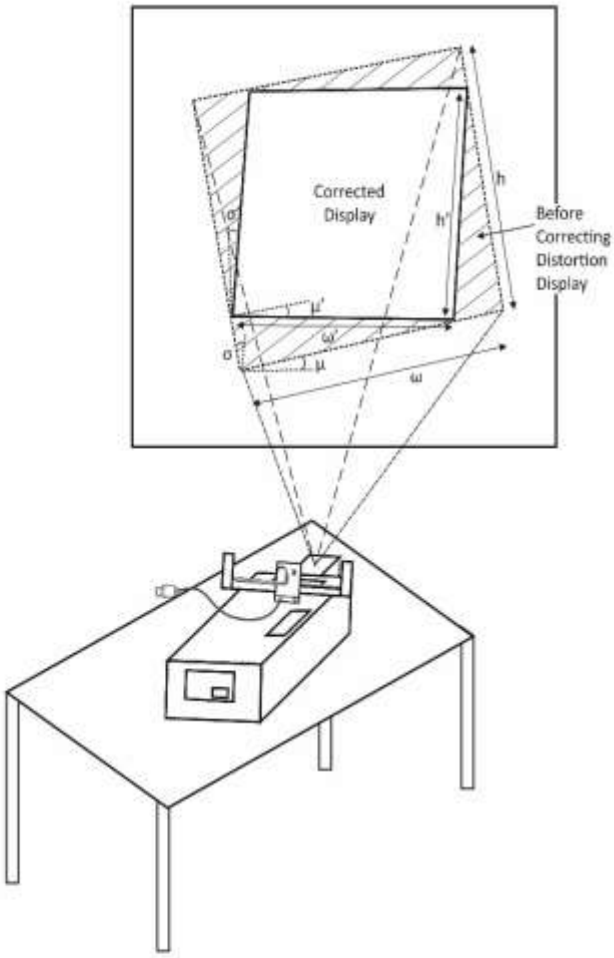

Figure 8: The layout of a two-projector display: before and after distortion corrections.

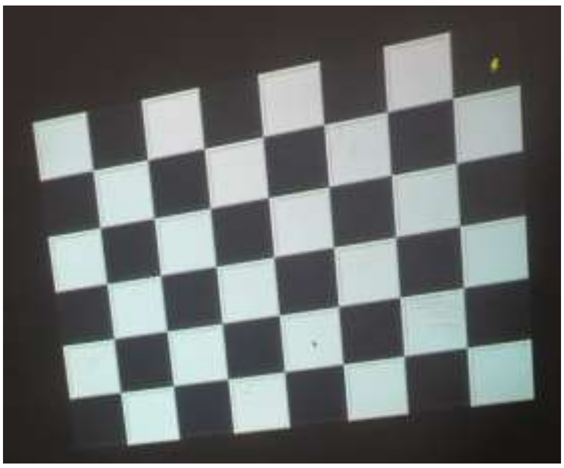

Figure 9 Projected images before correcting the distortion ϕ= 6˚, φ=8˚ , α= 6˚, σ = 3˚, μ = 6˚.

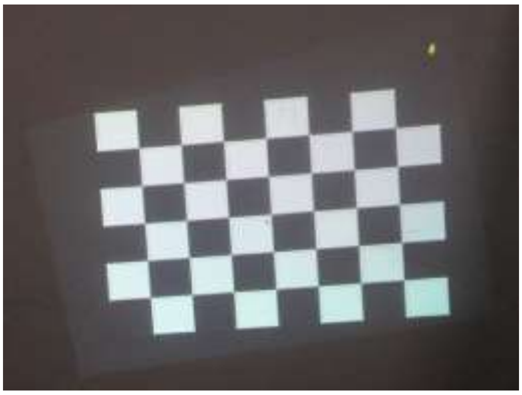

Figure 10: The resulting projected image is rectilinear and non-tilted. It's σ = 0 °, μ = 0 °.

Figure 11 Projected images before correcting the distortion ϕ= 10˚, φ=20˚ , α= 8˚, σ = 22˚, μ = 26˚.

Figure 11: The resulting projected image is rectilinear and non-tilted. It's σ = 2 °, μ = 3 °.

To evaluate the system's performance, the system in run on Raspberry Pi 3 model B .Then the sensor was checked if the values were read properly, whether the images were shown properly without a distortion, and if all components function properly for a given period of time. The test was successful under the following conditions, as seen in Table 1. The system has two phases. In the first phase, the sensor input is read and in the second phase the image is distorted. In this table, we compare the time that is taken by the image distortion phase because the sensor reading time doesn't depend on the processing platform. According to calculations, the sensor reading time = 27.0276154 seconds.

Platform / ϕ, φ ,α	Time on Raspberry pi (Seconds)
8 °,5 °,6 °	40.217618
9 °,6 °,12 °	40.9187818
10 °,20 °,8 °	42.413628

Table 1: Hardware performance evaluation

V. Conclusion

Rapid advances in the field of projector-based visualization has taken place over the last few years. An often cited benchmark that exemplifies this progress is the projector visualization challenge. The "BAT" has been demonstrated as a promising technique for solving distortion in projected displays. Entertainment events, class -rooms, outdoor events, and handheld projectors are such real-world applications uses of "BAT", especially projectors used as portable devices. In that scenario, "BAT" generates a rectilinear, non-tilted display on a planar surface and it also preserves the aspect ratio.

The "BAT" system can estimate the poses of projectors and generate distortion free display accurately(σ =0 °, μ = 0 °). Error in the display (σ , μ) is changed with ϕ, φ ,α , β, γ.

System output is not equal to ideal display (σ =0 °, μ = 0 °), but humans eyes can't detect that kind of small (σ ≈ 0 °, μ ≈ 0 °) distortion, it has been proved our user experiences collective section. The used area of the display decreases, when increase the azimuth angle(α), titled angle (φ), or elevated angle (ϕ) but the distortion correction mechanism is important to users to get the correct interpretation of scenery.

This solution is a requirement for existing projects. In addition, "BAT" with a projector allows us to generate large display areas when required.

VI. References

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Acknowledgement

I would like to convey my gratitude to my supervisors Prof. N.D Kodikara Senior Lecturer of University of Colombo School of Computing for their guidance and encouragement to do this research. The step-by-step guidance you provided helped me to progress steadily during the research. This made all of it look so easy for me – though I was bamboozled at the start, contemplating whether I would be able to pull off this project. Thank you, sirs, for all that you've done unto me, to see the project bear fruits.

Additionally, I would like to convey my heartiest gratitude to Dr. C Keppitiyagama , Senior Lecturer of University of Colombo School of Computing and Dr. K D Sandaruwan and Mr. Prabhash Kumarasinghe, Lecturer of University of Colombo School of Computing as well for the mentorship and the guidance provided.