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GazeBall: Leveraging Natural Gaze Behavior for Continuous Re-calibration in Gameplay

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Eye tracking offers opportunities to extend conventional game control with gaze input for multimodal game interaction. Gaze, however, has been found challenging to use as it requires re-calibration over time and for different users, in order to maintain an accurate input. In this work, we propose to leverage the natural gaze behavior that users exhibit during gameplay for implicit and continuous re-calibration. We demonstrate this with *GazeBall*, continually calibrating players' gaze based on their natural ocular pursuit of the game's ball movement. Re-calibration enables the extension of the game with a gaze-based 'power-up'. In the evaluation of GazeBall, we show that our approach is effective in maintaining highly accurate gaze input over time, while re-calibration remains transparent to the player.

Keywords: Eye movement; Gaze; Eye tracking; Smooth Pursuit; Calibration; Gaze interaction; Natural user interfaces; Games

Introduction

Gaze has been shown to be a compelling modality for gameplay. Players' gaze naturally indicates objects and actions of interest, and can be embraced for explicit pointing and selection tasks (Isokoski & Martin, 2006) as well as for implicit gaze-contingent behaviors such as view control (Nacke, Stellmach, Sasse, & Lindley, 2010) and depth-of-field adaptation (Hillaire, Lécuyer, Cozot, & Casiez, 2008). Gaze tracking can support fast input with minimal effort (Isokoski, Joos, Spakov, & Martin, 2009), contribute to the player's sense of presence and immersion (Kondou & Ebisawa, 2008; Vidal, Bismuth, Bulling, & Gellersen, 2015), and afford new mechanics that engage gaze and attention in playful and deliberately challenging ways (Vidal, 2014). As eye trackers are becoming available as commodity device, popular videogame franchises such as *Tom Clancy's* and *Assassins Creed* integrated gaze to expand the user experience (Massive, 2016; Quebec, 2015).

However, players' experience of gaze-based controls and behaviors is dependent on the accuracy of the gaze input, and requires careful calibration to the individual user. Conventional methods for gaze calibration are separate from gameplay (Dorr, Pomarjanschi, & Barth, 2009), of poor usability (Morimoto & Mimica, 2005), and subject to users' movements, often requiring repetition before a sufficiently accurate mapping of gaze to the display space is established (Schnipke & Todd, 2000; Villanueva, Cabeza, & Porta, 2004). Whereas other more natural methods using smooth pursuit eye movements have been introduced to make calibration task more flexible and less tedious (Pfeuffer, Vidal, Turner, Bulling, & Gellersen, 2013), it remains a separate task, breaking the game experience.

Method

We developed *GazeBall*, a 2D retro-inspired videogame based on the popular Arcade game *Breakout* by *Atari, Inc.*. The aim of the game is to control and move the paddle so as to make the moving ball bounce on it in order to hit and break all the bricks situated on top of the game scene. We implemented bricks to contain special "power-ups" to introduce gaze interaction. When a power-up is triggered, players are able to influence the ball's direction by mirroring the angle towards the position they are looking at, based on the natural strategic behavior to first look at the ball and later check the remaining bricks.

Furthermore, there is no need to calibrate the eye-tracker before playing the game as unaware continuous re-calibration is implicitly embedded. The eyes naturally indicate players' point of regard (Jönsson, 2005; Vidal, Bulling, & Gellersen, 2013), they pursue with gaze the ball's movement (Dorr et al., 2009), in order to predict its position to make it bounce on the paddle. Leveraging this natural behavior, we proposed a continuous re-calibration using smooth pursuit eye movements by embedding *Smooth Pursuit Calibration* (Pfeuffer et al., 2013), to detect when the user is following the moving ball, in order to re-estimate gaze position without their awareness.

Pursuit Calibration uses the *Pearson's product-moment correlation* between gaze and the ball positions to determine if it has been followed by player's gaze. Later, matched ball and gaze points are stored and used in a 25 samples window to compute a geometric transformation (homography) using *RANSAC* (Random Sample Consensus) (Fischler & Bolles, 1981) for outliers' removal with a 0.1 projective error threshold. The resultant homography is used to map unfiltered gaze points into estimated calibrated screen coordinates.

GazeBall was tested in a user study with 12 volunteer participants between 21 and 32 years old (M = 26, SD = 3, 6 female). We used a *Tobii EyeX* remote eye tracker, collecting data at 30Hz for both further research and interaction. Participants were asked to play 6 levels and make a break after 3 of them to move away from the experiment desk and come back to test the robustness of the calibration method. After each level and the pause, they performed a 16 points accuracy test, by looking at the displayed points. No information about gaze calibration or interaction was given and short questionnaires and interviews were used to evaluate the experience.

Results

A total of 7 accuracy tests were recorded during each study, but data from the last one was dismissed as participants showed a lack of attention knowing it was the end of the study. Accuracy is evaluated in degrees of visual angle (1° is generally a good result), and computed by first taking the median distance from all the gaze points to each target position, and later the mean between all targets results.

Results in Figure 1 show the mean accuracy values after each test and the pause, for all users. It reports how the estimated gaze accuracy is subjected to drops over time, especially when participants came back from the break. However, our approach on continuous smooth pursuit re-calibration reports auto-correction of accuracy being able to improve and correct deviations.

Feedback captured during the interviews and questionnaires reported how participants found the gaze interaction enjoyable the more you played, introducing a novel and interesting new dynamic to the game. Furthermore, they also reported that gaze interaction in this game was easy to learn without previous experience or explanation and that the background re-calibration process was unnoticeable.

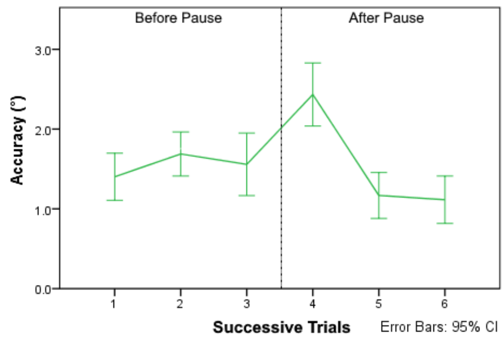

Figure 1. Mean Accuracy tests score (° of visual angle) for Smooth Pursuit re-calibration before and after the pause, reporting for the whole study (M = 1.56°, SD = 0.66°).

Discussion

Our approach introduced the integration of continuous Smooth Pursuit re-calibration in ongoing game dynamics rather than designing a separate calibration task. It enhanced the game experience by considering players natural behavior when playing, to induce them and re-calibrate the system in an unaware way only when looking at the objects in motion.

Results showed how the integrated gaze re-calibration was accurate and unnoticeable. Gaze interaction in the dynamics of the game was reported to be enjoyable, novel and easy to learn, providing a new positive game experience. Furthermore, interaction was reported to be more enjoyable over time, as the re-calibration was continuously correcting gaze estimation, making it more effective. Embedded re-calibration showed improvement after the pause whereas standard one-time-calibration would have the same decreases effect on its accuracy and would not be able to recover without performing an alienated calibration task.

The introduction of gaze influence in the game created an attention dilemma on whether using gaze interaction or continue with normal play. It was presented not to make the game easier or introduce a game advantage, but to enhance the experience by adding new gaze-based mechanics that were able to influence on players' behavior. The more players learn how to use gaze in the game, the more they changed their behavior while playing. They turned from being constantly looking at the ball and quickly looking at bricks into keeping their gaze at targeted bricks so as to benefit from the new challenging dynamic.

Conclusion

With *GazeBall* we successfully demonstrated that the integration of gaze calibration is feasible inside ongoing game dynamics, without creating a gammified task. It leverages the natural behavior of the eyes following the moving ball, to embed unaware continuous gaze re-calibration that enhances the game experience allowing gaze interaction. Gaze integrated re-calibration does not compromise the game experience and it reported good accuracy results. It introduced automatic correction of estimation deviations without the need to stop the experience and perform an external calibration.

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