Gaze beats mouse: a case study

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Introduction

Eye tracking has become cheaper and more robust over the last years. Soon it will be feasible to deploy eye tracking in the mass market. One application area in which an average consumer might benefit from eye tracking is in computer games, where gaze direction can add another dimension of input. Progress in this direction will also be of high relevance to disabled users who lack the dexterity to control the input modalities traditionally used in computer games. Not only could gaming with gaze be enjoyable in itself, but the virtual world of multi-player games might also be one arena where disabled users could meet non-disableds on an equal footing.

However, for a satisfactory gaming experience, it does not suffice to simply replace the mouse with a gaze cursor; usually, changes to the game play will also have to be made.

In this paper, we will present an open-source game that we adapted so that it can be controlled by either a mouse or by gaze direction. We will show results from a small tournament that indicate that gaze is an equal if not superior input modality for this game.

Breakout

Breakout was one of the first commercially available video games when it was released in 1976 (Kent, 2001). Its game play was based on *Pong*, where the player has to move a paddle horizontally to hit a ball that is reflected at the borders of the game area. *Breakout* now extended this concept by putting *bricks* in the upper part of the game area which dissolved upon contact with the ball; the goal of the game was no longer to keep the ball in the game as long as possible, but to destroy all bricks (see Fig. 1 for a screenshot). This simple, easy-to-understand game play makes *Breakout* still appealing today, more than 30 years after it was first sold. Countless clones have been published for various computer platforms, with better graphics and *extras* that are released on explosion of bricks and need to be collected with the paddle. The one-dimensional nature of paddle control in *Breakout* and *Pong* also makes these games suitable for input modalities other than a joystick or mouse, e.g. brain-computer interfaces (Krepki, Blankertz, Curio, & Müller, 2007) or pitch of voice (the Sony SingStar console game). In the following, we will describe our version of *Breakout* which was adapted to be controlled by gaze.

Figure 1. Screenshot of *LBreakout2*.

Implementation

Our gaze-controlled version of *Breakout* is based on the open-source game *LBreakout2*.[1] *LBreakout2* is published under the GNU General Public License[2] (GPL), so that the game can be freely modified under the condition that the modifications will only be released under the GPL as well.[3] This open-source approach is especially appropriate for such (currently) small markets as that for games geared towards those with severe motor impairments.

LBreakout2 is written in C and uses the *Simple Media Layer*[4] for graphics, sound, and network functionality. We have modified it to work with SensoMotoric Instruments eye trackers, which use an ASCII network protocol sent over a UDP link, so that no additional libraries are required. The major change to the source code was to implement a function that waits on a UDP socket for samples from the eye tracker and decodes them; instead of the paddle position being shifted by mouse movements, it is now set in absolute coordinates to the gaze position of the user.

Strictly speaking, it is not even necessary to calibrate the tracker from inside the game. A first version of the game used an external tool to calibrate the tracker to the screen before the game was started; especially for demonstration purposes, where several players take turns, the constant need to shut down and restart the game led us to implement a calibration procedure that can be started by a keypress from inside the game.

Adaptation of game play

To prevent the ball from going out of play, the paddle needs to be at the same horizontal position as the ball when the ball reaches the lower end of the screen. When the paddle is controlled by gaze, this means that, in principle, the player only needs to look at the position where the ball will meet the paddle. That this is very intuitive might be demonstrated by the following anecdote: During the CeBit trade fair show, we presented our game to a visitor who claimed to have had no experience with computer games at all. After calibration, she started playing and performed very well until, about 2 minutes into the game, she asked when "the whole thing would actually start". Apparently, she had just constantly looked at the ball (and therefore always hit it with the paddle) without even realizing that the paddle followed her gaze!

[1] See http://lgames.sourceforge.net.
[2] See http://www.fsf.org/licensing/licenses/gpl.html.
[3] The source code of our modifications is available on request; we would like to receive feedback and/or incorporate changes made by the community.
[4] See http://www.libsdl.org.

Although playing with gaze is very intuitive, players naturally face other challenges in a gaze-controlled setting. A well-known problem for gaze-based user interfaces is how a user should confirm an action (the equivalent of a mouse click). In *Breakout*, a mouse click normally is needed to start the game and release the ball from the paddle. We solved this problem by releasing the ball automatically after 5 seconds when the game is played with gaze.

Another problem is that even the best eye trackers today still have calibration errors, so that the paddle position might be slightly shifted from the "true" gaze position. This can be highly irritating and must be consciously compensated for by the player, even though there are no fixation targets at the location that needs to be fixated. Also, by carefully adjusting on which side of the paddle the ball is deflected, the player can control the direction in which the ball is sent off again. Due to tracking noise, this is much harder with gaze than with a mouse, but it seems that gaze players get better at this with some training.

In the *Breakout* version we have adapted, bricks that are destroyed sometimes release "extras" that fall towards the bottom of the screen. Once they are collected with the paddle, they alter the game by, for example, increasing the speed of the ball or making the ball explosive (so that several bricks can be destroyed at once). Some of these extras require a reaction by clicking the mouse, so we removed them from the game using the integrated level editor. Other extras should not be collected by the player because they have a negative impact; carefully avoiding to look at something in a dynamic environment takes a conscious effort and some training by the player. One extra that is particularly enjoyable in gaze-playing mode, though, is the extra ball. Because of the much higher speed at which the eye can travel compared to the hand, it is possible to keep several balls in play simultaneously. Keeping track of a number of dynamic objects while still maintaining fixation on the ball that is going to reach the bottom of the screen next was found to be highly entertaining by our test subjects.

Pitting gaze against mouse

LBreakout2 also offers a multi-player mode with one paddle at the bottom and one at the top of the screen. The goal is to play the balls in such a way that the opponent cannot return them. To make the game more lively, every player can fire up to 3 balls so that up to 6 balls are in the game simultaneously.

To test how well our gaze-based interface fared against the mouse, we set up a little tournament in which pairs of players took turns playing against each other. First one player controlled the game with gaze and the other with the mouse, then the roles changed.

20 undergraduate and graduate students from our department volunteered. 4 had been involved in writing or presenting the game before; the other 16 had had little or no eye-tracking experience and had not played the game before. To ensure a fair game, we also matched pairs by their general computer game experience. Eye movements were recorded with a SensoMotoric Instruments iViewX Hi-Speed tracker running at 240 Hz. We also have successfully played the game with a 50 Hz SMI RED-X remote tracker, which obviously is better suited for gaming because it does not require the player's head to be fixed.

After calibration, the gaze player was able to try out the gaze control for about 15 to 30 seconds. Then, the match started. Each match lasted 5 rounds. For every ball that the opponent could not return with their paddle, a player scored 1 point; a round was won by the first player to win 10 points. Every round was set on a different background, i.e. the layout of ball-deflecting bricks in between the players changed. Such bricks close to the player's baseline are a slight disadvantage for the gaze player because it is easier to aim shots exactly with the mouse (see above). The results are shown in Fig. 2. Clearly,

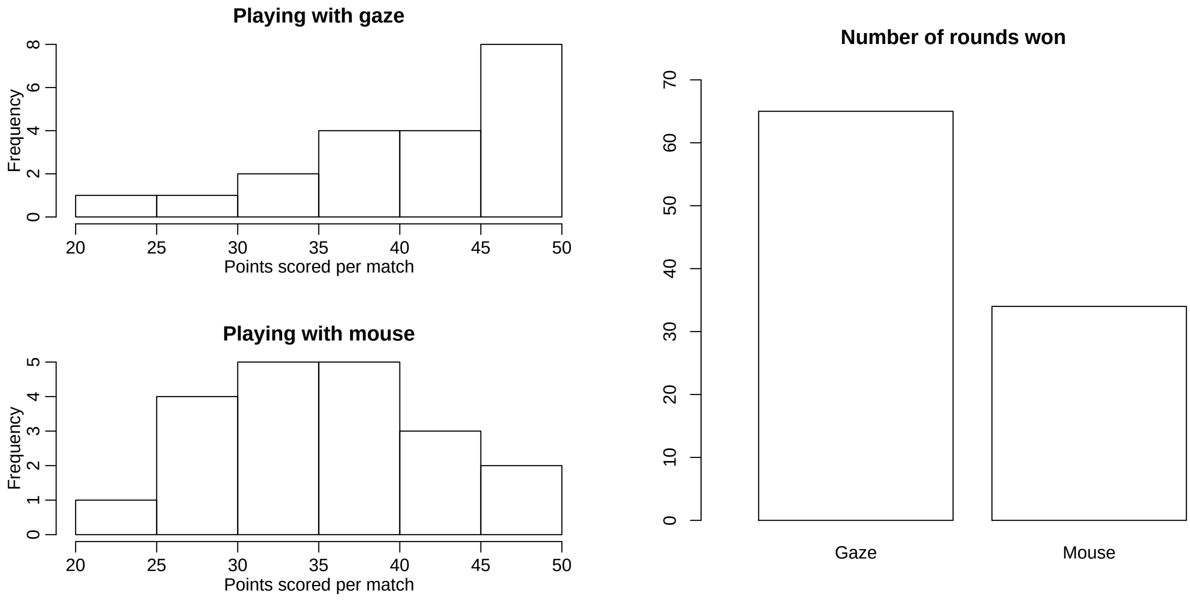

Figure 2. Left: Distribution of scores. Right: Number of rounds won.

playing with gaze yielded a higher score on average (41.95 vs. 36.25). Almost two thirds of all rounds (65 out of 99, one data set had to be discarded because the tracker had lost the pupil temporarily) were won by the gaze player. Gaze control thus was a statistically significant advantage ($p < 0.0015$).

Conclusion

We have presented modifications to the open-source game *LBreakout2* that allow the game to be controlled with gaze. Even though both the graphics and the game play of *LBreakout2* are very simple, our test subjects found "playing with eyes" highly enjoyable. More importantly, we also have presented results that show that gaze-based interfaces can be superior to traditional input modalities even for users that have had no previous training with such interfaces.

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