Pursuits: Eye-Based Interaction with Moving Targets

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Figure 1: A user is interested in listening to a music album. She walks up to the in-store display, locates the album on the screen and follows its movement with her eyes. A sample of the music starts to play automatically.

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Abstract
Eye-based interaction has commonly been based on estimation of eye gaze direction, to locate objects for interaction. We introduce *Pursuits*, a novel and very different eye tracking method that instead is based on following the trajectory of eye movement and comparing this with trajectories of objects in the field of view. Because the eyes naturally follow the trajectory of moving objects of interest, our method is able to detect what the user is looking at, by matching eye movement and object movement. We illustrate Pursuits with three applications that demonstrate how the method facilitates natural interaction with moving targets.

Author Keywords
Natural user interface; Eye gaze; Smooth pursuit eye movement

ACM Classification Keywords
H.5.2 [**Information Interfaces and Presentation: User Interfaces**]: Input devices and strategies.

General Terms
Design; Human Factors

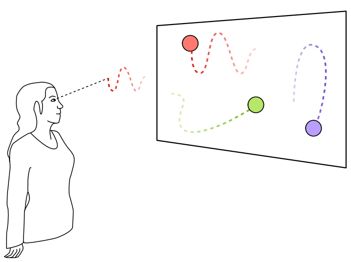

Figure 2: When a user follows a moving object on the screen, her eyes perform the same trajectory as the followed object's.

Introduction

Our eyes are an appealing modality for human-computer interaction as their movements indicate what we are interested in [3]. Consequently, there is a large body of work that has embraced eye gaze for interaction, based on accurate estimation of gaze direction and mapping of gaze to screen coordinates [2]. We introduce a novel eye tracking method, *Pursuits*, that is designed for natural interaction with moving objects.

Unlike existing methods, Pursuits does not estimate gaze direction, but follows the trajectory of eye movement, and matches this against the trajectory of objects in the user's field of vision. Figure 1 shows an application of the method: a user is looking at one of several moving objects on a display, and because her eyes naturally follow the movement of the object, our method is able to detect which of the objects she is looking at. Figure 2 illustrates the matching of eye movement with object movement, which can be performed without knowledge of the actual gaze direction. Pursuits can therefore be used more spontaneously and flexibly than conventional eye-tracking interfaces, as users can start to interact as soon as their eyes are detected by the tracking system, without need for further calibration.

The movements our eyes perform when following a moving object are called *smooth pursuits*, from which we derived the name of our method. Smooth pursuits are distinct from other eye movements, such as fixations that occur when we look at a static point of interest, or saccades that occur when we move our eyes quickly from one fixation to another [5]. Smooth pursuits are very common in our everyday visual behaviour, but have not previously been leveraged for human-computer interaction. In our method, they are used for selection of objects for interaction, contrasting conventional eye-based interaction where objects are selected by fixation. This is significant, because we naturally dwell on an object that moves, whereas longer dwell time on a static object for selection-by-fixation (necessary to avoid the "Midas touch" unintended activations) can feel unnatural and tiring.

The Pursuits method enables novel ways of engaging with movement in user interfaces. With common modalities, targeting moving objects is more difficult than targeting static objects. With our eyes, it is actually the other way around: they are naturally attracted to movement, and we can move them more quickly toward a target than a physical pointing device [4]. This is because our eyes are fast and extremely good at judging speed of moving stimuli [1]. Pursuits is therefore not only natural for interaction with dynamic interfaces and content that moves, but also highly effective for fast and accurate selection of moving targets.

Figure 1 illustrates the user experience of Pursuits. A user is interested to interact with the information on a public display, in this example showing album covers that slowly move around the screen. She walks up to face the screen, and as soon as the system is able to capture her gaze, it starts to compare her eye movements with the movement of the displayed album covers. When the users looks at one of the album covers, her eyes will smoothly follow the object. The system will immediately detect the correlation of eye and object movement, and be able to trigger an associated action, in this case playing a sample of the selected music. The interaction appears seamless and pleasing to the user, as following the movement an object of interest is natural and effortless.

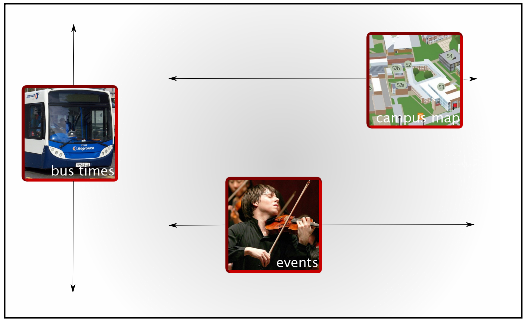

Figure 3: The university display.

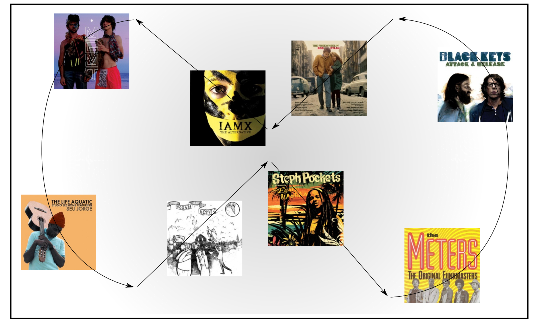

Figure 4: The music shop display.

Demonstrators

We have developed three interactive applications that demonstrate Pursuits. All applications have been implemented on a system composed of a large display (89x50cm, 1920x1080px) and a Tobii X300 remote eye tracker positioned under the display. For interaction with the system, users have to be positioned within range of the eye tracker, which is at about 70cm from the display in our setup.

The first application is an interactive public display providing information, imagined for a university campus. The interface shows three boxes each containing information that a user passing by might be interested in, in our demo bus times, a campus map and upcoming events at the university. The boxes slowly "float" on the screen along three different linear trajectories (one floats up and down, the other two move left and right in opposing directions, see Fig. 3). As soon as the interactive display detects that the user is following one of the boxes, the screen fades out and displays the corresponding information. If the user looks at the "bus times" box, for instance, the screen will fade in to show the departure time and destination of the next five buses.

This first example demonstrates how public information displays can be made interactive in a robust and harmonious way. The movement of the content is slow to provide a pleasing display that is subtle in attracting interest, but the trajectories are very different to ensure robust discrimination.

Our second application takes the scenario of a display in a music shop (see Fig. 1). The display shows the covers of "recommended" albums circulate in a figure-of-eight around the screen (Fig. 4). A potential customer is curious to see what albums are included in the display. As she looks at one of the moving album covers to see who the artist is, the system will detect this based on correlating eye movement, highlight the object with red frame and start to play a sample of the music. Playback will fade out when the user switches her gaze to another album, or leaves the display. This example demonstrates the flexibility of Pursuits: movement does not have to be linear but can follow more complex patterns, and objects can share the same overall trajectory and still be selected based on their local movement. The user experience is "magic": users are drawn to inspect the visual content and are surprised that this triggers related audio playback.

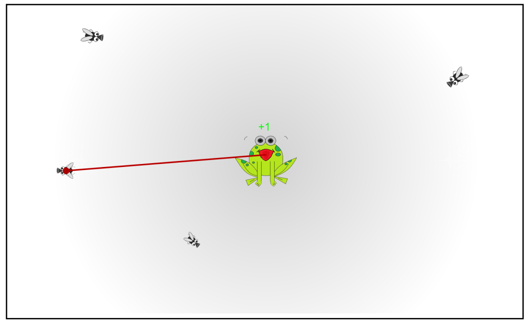

Figure 5: The frog game.

The third application is a game. Once the game has been started (by selecting a moving trigger), the display shows a frog in the centre of the screen and four flies that fly on random trajectories around it (Fig.5). The user's task in the game is to catch as many flies as possible in a given amount of time (30 seconds). They do this by following a fly with their eyes. When they have selected a fly in this way, the frog's tongue shoots out to pick and eat the fly, and the user's score goes up. Flies gradually become faster and smaller, increasing the challenge. At the end of the game, the player's score is shown and they are challenged to give it another go.

This third use case demonstrates further capabilities of Pursuits. It shows that the target size does not matter for the method: the other two applications have relatively large targets while the flies here are very small. The game also demonstrates selection of targets at much faster speeds. In fact, the flies are moving so fast, that users would probably have difficulties to select them with any input device other than their eyes.

Conclusion

We presented Pursuits, a method for natural eye-based interaction with moving objects. The method introduces matching of eye and object movement as a new tracking principle that overcomes the need for accurate calibration of gaze direction.The three applications demonstrated in this work show that the Pursuits method is natural and effective for selection of moving targets, and allows to embrace movement in user interfaces in innovative ways. Pursuits opens up new perspectives on the design and implementation of eye-based interfaces, shifting the emphasis from gaze estimation to movement analysis, from fixations to other activity of our eyes, and from interaction with static interfaces to interaction with dynamic content.

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