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PURSUITS:

Spontaneous Eye-Based Interaction for Dynamic Interfaces

Although gaze is an attractive modality for pervasive interaction, real-world implementation of eye-based interfaces poses significant challenges. In particular, user calibration is tedious and time consuming. **Pursuits** is an innovative interaction technique that enables truly spontaneous interaction with eye-based interfaces. A user can simply walk up to the screen and readily interact with moving targets. Instead of being based on gaze location, Pursuits correlates eye pursuit movements with objects dynamically moving on the interface.

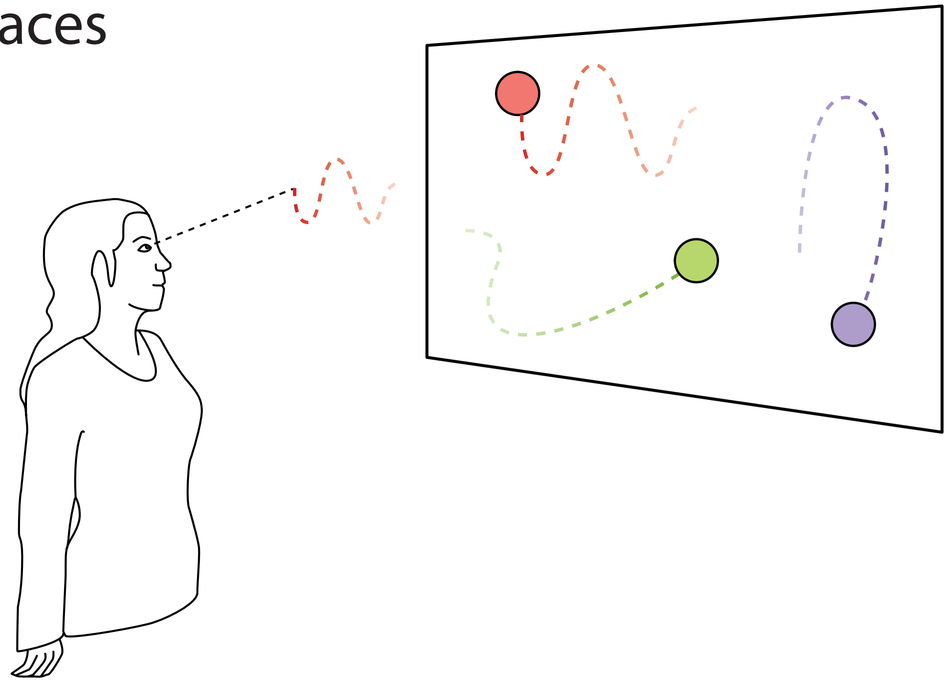

FIGURE 1. Pursuits matches the user's eye movement with the movement of on-screen objects.

EYES FOR INTERACTION

Gaze holds great promise as an input modality because it indicates what our visual attention is directed at. It is particularly promising to interact with the increasing number of out-of-reach displays because our eyes naturally point at what we are interested in. As a result, eye tracking has attracted increasing interest for interaction. For example, Stellmach and Dachselt researched the use of the eyes to pan and zoom on maps [4] and Turner et al. looked into using the eyes to select out-of-reach content on a display and move the content to a personal handheld device [5].

However, the real-world implementation of eye-based interfaces poses significant challenges. Most current interfaces require to calibrate the eye-tracker for each user to know where their gaze is located. The calibration calculates a mapping between the user's eye position and corresponding 2D positions in the user's visual scene, e.g. on a screen.

During calibration the user should stand still and fixate on several points on the screen. This process can be cumbersome and straining for the eyes and makes spontaneous eye-based interaction in everyday environments challenging. This is especially the case for public settings, in which passersby may not be willing to spend time calibrating the eye tracker before being able to use the interface.

The method we developed, Pursuits, enables users to walk up to a display and immediately interact with it in an engaging way. It gets rid of the calibration procedure and is based on natural eye movements, which means users do not need to learn how to use it – the interaction feels instant and seamless.

EYE MOVEMENT, NOT EYE LOCATION

To achieve this, we took a radically different approach to eye tracking. Instead of trying to locate where the user's gaze is on the screen, we observe the movements of their eyes over time. This is similar to Fekete et al. which raised the idea of driver movement mimicking for interface control [2] and that of Drewes et al. which introduced eye-based gestures for desktop control [1].

Eye gestures, just like our method, are based on the movement of the eye rather

WE [HAVE TAKEN] A RADICALLY DIFFERENT APPROACH TO EYE TRACKING.

than its location. By getting rid of the need to know where the eyes look, but instead studying how they move, we can get rid of the calibration procedure.

However, eye gestures imply that the user needs to learn in advance which gestures will make the interface react. This is another factor that would prevent spontaneous interaction.

On the contrary, our method harvests the natural behaviour of the eyes and thus, users do not need to learn how to use it.

The key idea of Pursuits is that the eyes perform the same trajectory as the object they are following (see Figure 1). Thus, by correlating a moving object's trajectory with the eyes' trajectory in real time, it is possible to detect which object is being looked at. Because it is based on eye trajectory rather than direct point-of-gaze, it does not matter how that data is translated on the screen or in space: the trajectory of the eyes still resembles that of their moving target.

Pursuits is named after the movement our eyes perform when they latch onto a moving object, called smooth pursuits. Although the dynamics of smooth pursuits are well understood, they have not yet been leveraged for human-computer interaction. In Pursuits, smooth pursuit movements are embraced for the selection of objects for interaction.

We believe this novel method for eye-based interaction is compelling in its simplicity – simply matching eye movement against the trajectories of on-screen objects. Yet it facilitates robust selection of moving objects in ways that are spontaneous and usable for pervasive applications.

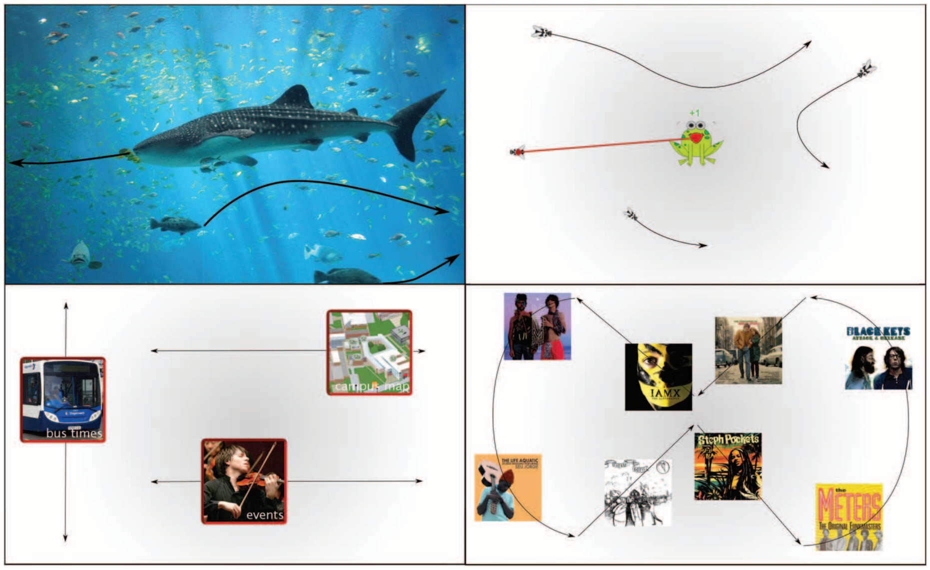

FIGURE 2. An example of the interfaces possible with Pursuits. From left to right and top to bottom: An interactive aquarium screensaver that unlocks upon looking at a specific sequence of fish. A game where a frog eats the flies that the player targets with their eyes. A university information display offering to show bus times, a campus map and upcoming events in harmoniously floating boxes. A music shop display with several moving album covers that play an extract of a song from the album that is looked at.

IT'S ALL ABOUT SPONTANEITY

The use of smooth pursuits movements gives Pursuits several strong advantages over traditional eye-based interaction methods. The eyes are attracted by movements and we naturally dwell on an object that moves, which makes Pursuits a very natural interaction technique. Users do not need to learn to look at a target - their eyes follow it instinctively. In addition, by removing the need for calibration, the technique is user-independent: it enables users to walk up to a Pursuits-enabled screen, use it, and be replaced by another person immediately afterwards.

This can be useful for a wide range of scenarios. It is great for public spaces where passersby do not have time to learn to use an interface. We think this could be used for example in train stations, in museums, as information displays in a crowded area, etc. Pursuits and eye-tracking is especially interesting for applications where the screen might be out-of-reach. Imagine interacting with a screen situated on the other side of a subway track, behind the glass front of a shop, or with an information display in an airport.

Pursuits is based on movements, and so it requires interfaces to be dynamic and display moving objects. This opens up new possibilities for interface design. HCI research has attended to target movement as a problem [3]: it is difficult to select a moving target with a mouse, while our eyes follow movements easily. It is also difficult to select a small target, but since Pursuits is based on trajectory rather than location, the moving targets can be as small as desired – only their trajectory matters.

EMBRACING DYNAMIC INTERFACES

During technical studies, we extensively tested the limitations of the technique [6]. General design guidelines are presented in the side bar.

Although Pursuits requires movement, interfaces with moving objects can be very versatile. Movement is ubiquitous: planets rotate around the sun and can be used for a gaze-enabled museum display; fish swim in different patterns and can be used for an aquarium screensaver that unlocks when certain fish are looked at.

For example, we implemented a game where a frog eats flies that the player targets with their eyes; the more flies are eaten, the smaller and quicker the new ones get (see Figure 2). We envision that short games like this one could be used in waiting areas, such as bus or subway stops. We also created more abstract interfaces, where floating boxes present available information to a potential user. As the user gets closer and stares at one of the moving boxes, the relevant information appears on the screen. We created a similar application for a music shop example where an excerpt of a song plays when a user looks a one of the album covers moving on the screen. Both are illustrated in Figure 2.

We have repeatedly verified how natural and simple to use Pursuits is by getting naïve users to play the frog game, as shown in Figure 3. In one study, we placed the eye tracker and screen with the frog game in the department's lobby area during the open days without attending it. 14 out of 16 people were able to successfully play the game, and occasionally came back to play it again. In another setting, we brought the game to a Girl Guides afternoon during which 50 children aged 5-12 played the game. The interaction was intuitive enough that the children very often came back, brought their friends and told them how to play, without the researcher's help.

Results from our user studies suggest that Pursuits is a versatile and robust technique for interaction with moving objects. It opens up new perspectives on the design and implementation of a new class of gaze-based interfaces that rely on smooth pursuits as input.

A key difference to interfaces that use absolute point of gaze is that smooth pursuit movements require the interface to be dynamic, i.e. with the objects of interest moving with different trajectories and speeds. While this requirement might be problematic for interfaces that follow the traditional WIMP (windows, icons, menus, pointer) paradigm or use static interface elements, Pursuits is predestined for highly dynamic interfaces, such as interactive multimedia installations or games. Beyond such special-purpose interfaces, Pursuits also encourages to break out of conventional thinking with respect to how future gaze-based interfaces might be designed and look like.

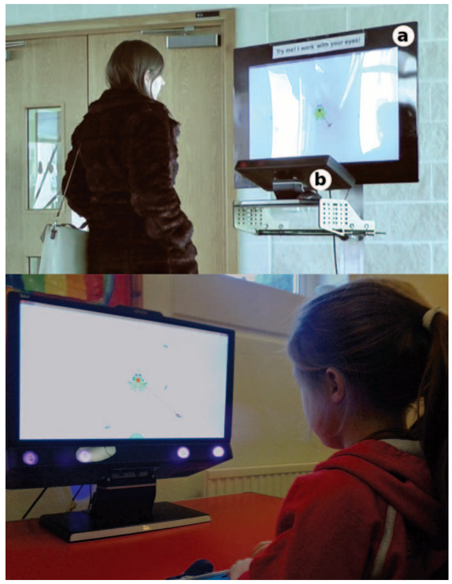

FIGURE 3. Naïve users successfully use Pursuits-enabled interfaces without directions during field experiments (a: display, b: eye tracker).

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HOW TO DESIGN AN INTERFACE USING PURSUITS?

Pursuits is based on Pearson's product-moment correlation method. It takes the horizontal and vertical eye data as an input, together with the horizontal and vertical positions of the moving objects on the screen. The method evaluates the similarity of each object's trajectory with the eyes trajectory and outputs the single object which is likely to be followed. This only happens if the most likely object has a correlation coefficient above a certain threshold; otherwise no object is detected as being looked at.

Pursuits is reliant on the fact that all the trajectories of all the objects are always different. We thus wanted to investigate the influence of the number of objects on the screen (directly linked with how different the trajectories can possibly be) on the performance of the method. We also wished to evaluate the effect of the speed of objects, the amount of data considered for correlation and the correlation threshold.

A technical study brought us the following general guidelines to create robust Pursuits-enabled interfaces. It is best to try to keep the number of objects below 8 if their trajectory is linear, or below 10 if the trajectories are rather circular. Speed itself does not influence the performance (as long as it is not too quick for the human eye to follow) but if two objects have a similar trajectory, a difference in speed between the two objects will increase the robustness of the algorithm.

Finally, if the objects on the screen have to move slowly, a large window size is required for Pursuits to properly differentiate between fixations and smooth pursuits. The window size is a particularly important parameter and should in general be set around 500ms. It is still possible to perform a high detection with a shorter window size but it is more error-prone. This should only be favoured for high speeds and for systems whose reactivity is essential. ■