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Peripheral View Calculation in Virtual Reality Applications

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Abstract

We present an application based on a general peripheral view calculation model which extends previous work on attention-based user interfaces that use eye gaze. An intuitive, two dimensional visibility measure based on the concept of solid angle is developed. We determine to which extent an object of interest, observed by a user, intersects with each region of the underlying visual field model. The results are weighted (thereby considering the visual acuity in each visual field) to determine the total visibility of the object. As a proof of concept, we exemplify the proposed model in a virtual reality application which incorporates a head-mounted display with integrated eye tracking functionality. In this context, we implement several proactive system behaviors including contextual information presentation with an adaptive level of detail and attention guidance; the latter is implemented by detecting visual acuity limitations or attention drifts.

Author Keywords

Human peripheral vision; solid angle; eye tracking; gaze-based interactive technology; proactive systems

ACM Classification Keywords

H.1.2 [User/Machine Systems]: Human information processing; I.2.10 [Vision and Scene Understanding]: 3D/stereo scene analysis

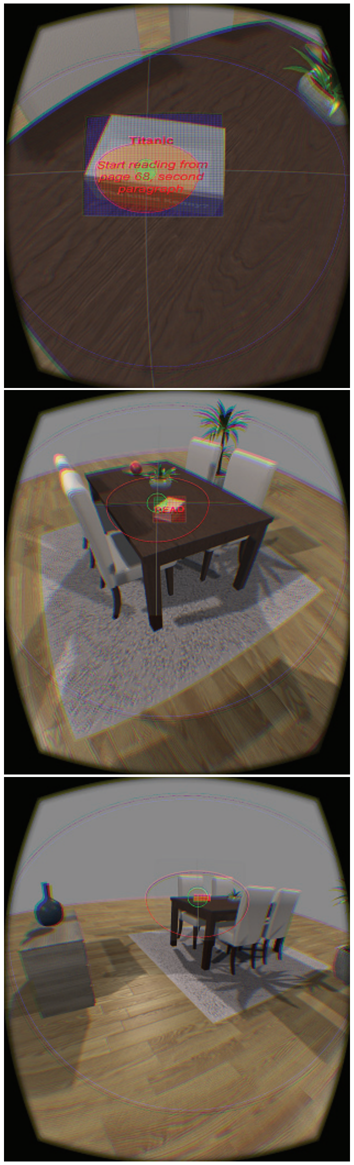

Figure 1: Decrease of visibility through increased Cartesian distance to the observer.

Introduction

Gaze input plays an important role in novel user interfaces. Examples include a wide range of applications, such as systems which use the eye gaze to enable severely disabled individuals to control electronic devices [7], responsive texts which provide interaction possibilities [2], or systems that use an eye tracking interface to store pieces of forgotten information and present them back to the user later [6]. Eye gaze is also used in virtual environments, for instance to improve a player's performance in games [5], or as active input modality [4]. As a matter of fact, many of these applications are limited to line of sight, since they restrict themselves to information available in the very center of gaze while excluding visual stimuli in peripheral regions. According to Barfield et al. [1], the human visual field (HVF) spans a cone-like structure in 3D space with horizontal and vertical opening angles of 190 and 135 degrees, respectively.

As a person observes the environment, he or she receives visual information included in all parts of the mentioned frustum. However, outside the center of gaze, human vision has different limitations that are distributed unevenly over peripheral areas while introducing several forms of imprecision. Depending on the resulting effects of the limitations in the HVF, numerous models have been proposed to categorize different peripheral regions. Based on these formal representations, it is possible to map perceived objects in the environment to defined regions in the HVF in order to find out which of the mentioned limitations affect the visual perception of the object. Results of these peripheral view calculations can then be used by gaze-based user interfaces for integrating additional knowledge about peripheral perception while extending their functionality based on centric gaze information.

In this paper, we present an application which relies on an implementation of a binocular model of the HVF based on two angular dimensions. With this parametrization, our task of mapping arbitrary objects in the environment to characteristic regions of the visual field constitutes a 3D problem. In this context, we opt for the concept of solid angle as 2D angular measure in 3D space in order to determine the fractions an object occupies in different regions of the visual field from the observer's gaze direction and the position of the object. Obtained fractions are weighted considering the visual acuity in each region of the visual field to determine the total visibility of the object. In order to prove the feasibility of our visibility measure for different analysis and interaction purposes in intelligent user interfaces, we deploy our concepts to a virtual reality (VR) application where said information is used to decide how to choose the best strategy to convey a message to the user in terms of visual overlays with adapted level of detail. For this purpose we have implemented our algorithms in a VR setup with integrated eye tracking in which the user has the possibility to look at the target object from different angles and distances.

VR Application

Our use case can be described as similar to the one explained in [8].This study explores the mixed reality realm for helping dementia patients. As a point of the user's engagement with the environment, they use gaze. In other words, for their different algorithms concerning object or face recognition or augmentation they use always the very center of gaze. In our application, we want to build on this and bring the other objects in the user's periphery into the interaction space.

We approach their scenario by simulating daily life scenarios in a controlled virtual environment. Their episodic memory logging and object augmentation is based on the gaze

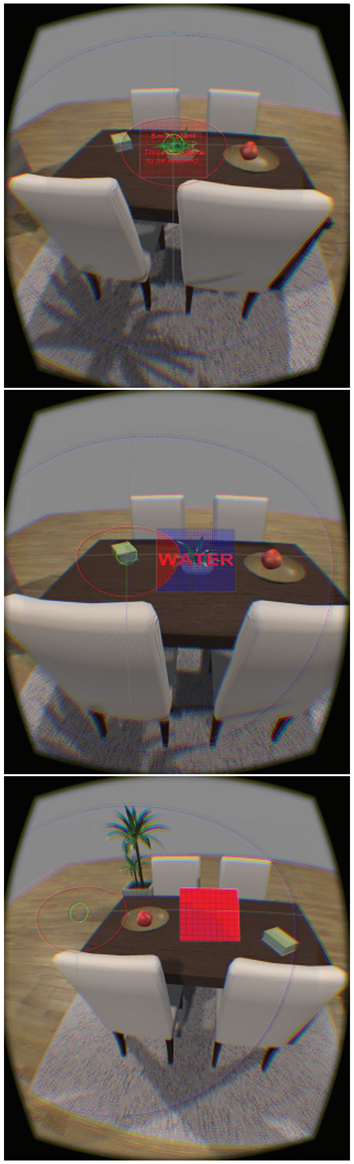

Figure 2: Decrease of visibility through increased horizontal angular distance.

center. We apply our model to perform these actions also in the periphery with complementing information like, for example, visibility of the object. For our application, we use a virtual reality setup with the option of gaze tracking. For this purpose, we use a special integrated eye tracking Oculus Rift DK2 system, which is commercially available[1]. In order to implement our algorithms, we use the Unity Game Engine[2]. In our scenario, the user plays the role of the patient and can freely move within an apartment. Regarding the different objects in the apartment, there are some tasks that the user should accomplish. These tasks should be executed in a definitive order. Our system supports the user by providing contextual information on the target object depending on the visibility of the object to the user. The information is stuck to the object and as the user's gaze moves in the scene, depending on the visibility, we show different messages on the object. These messages are related to the task that should be accomplished by the patient. Examples are eating fruit, reading a book or watering a plant. As the gaze of the user approaches the object and the visibility of the object increases, the message includes more details about the task. We define the following three levels of detail depending on the visibility of the object:

- Low Visibility: The visibility of the object is very low. Some examples for this case are high Cartesian distance between the object and the user or high angular distance between the user's gaze and the object.
- Medium Visibility: Either the object is in the center of gaze and the Cartesian distance of the user to the object is not very small or the user is near the object but he or she is not looking at it.
- High Visibility: The object is in the focus of the user and the user is in the vicinity of the object.

[1]http://www.smivision.com/en.html
[2]https://unity3d.com/

Note that for these classifications we neither use Cartesian nor angular distances directly. These categories are set by the thresholds which we select by weighting the solid angle of the visible part of the object with respect to its visual acuity in the according field. This novel approach provides a unique feature to categorize the objects in the environment depending on their visibility and not directly on their position and size. If the object is near to the user but partially occluded by any other surface, we will get the appropriate visibility measure. This value might be the same as when the object is in the periphery of the user. In any case the output of our algorithm in the application is a single visibility value which summarizes its visibility situation to the user.

Depending on the visibility of the object, our system augments it with more or less detailed information. If the object is in the "‘Low Visibility"’ category, the system covers it with a blinking surface to attract the user's attention to it. As Hatada et al. mention, in the induced visual field (which has very low visual acuity), the observer has discriminatory capability to the extent of being able to recognize the existence of a visual stimulus [3]. We use this indication to attract the user to the object, while augmenting a small part of the visual field. Figures 1, 2, and 3 show different screenshots of our VR environment. As it is shown, the three mentioned visibility classes can occur by varying the Cartesian or the angular distances between the object and the user. The two other visibility categories are the "‘Medium Visibility"’ and "‘High Visibility"’. In the case of "‘Medium Visibility"’, some hints about the patient's task will be augmented over the object. This augmentation is performed in short words with big fonts. It should help the patient to recall the corresponding activity without overloading the visual field. If

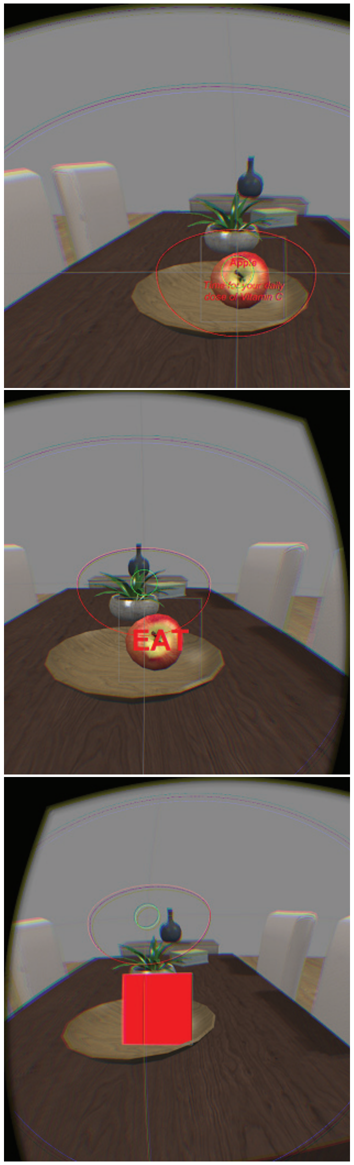

Figure 3: Decrease of visibility through increased vertical angular distance.

the user can not recall the activity, he or she can approach the object and look at it directly. In this case, the state of the object in the application will enter the "'High Visibility"' mode. Thus, the task of the patient will be recalled to him or her in the form of short sentences.

Our augmentation is located on the object itself, disregarding its relative position to the user. Instead, depending on the visibility of the object, we choose the appropriate form for communicating the message to the patient. First by attracting the user towards the object, then by augmenting the task's description step by step. This way, we do not always bring the full information to the user, instead, we assist the patient to recall the task by providing the information gradually and helping her/him to recall. We permanently monitor the visibility of the object to the user so that we can perform an episodic memory logging concerning the peripheral visual field of the patient. This is an added value to the episodic memory logging of Toyama et al. in [9] as it can be effectively used to support an individual user's memory by logging certain types of everyday information that the user perceives in his or her peripheral vision and tries to organise in his or her memory.

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