

# 사람 시각 특성을 활용한 가상현실 브라우저에서의 시각적 피로도 절감 기술

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## Reducing Visual Discomfort for VR Browser based on Visual Perception Characteristics

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### Abstract

VR browser is one of the most popular applications for VR(Virtual Reality) environment. However, because most of the web contents are not designed considering the VR environment, scrolling the web pages in the VR browser causes much visual discomfort. We found it's because the angular velocity of the eye movement during scrolling increased because the viewing distance got closer compared with legacy devices. So we have developed a technology that regulates the scrolling to reduce the visual discomfort in the VR browser, in reference of the visual perception characteristics of the human visual system.

### 1. INTRODUCTION

Recently, the development of Head Mounted Displays (HMDs) has made it easy for many people to experience the Virtual Reality (VR) environment. One of the most popular VR applications is a browser application, which allows users to find millions of 3D / 360 videos and webVR contents on the web and enjoy them in an immersive environment.

However, most of these contents that users touch with the browser are 2D web pages that prepared not for the VR environment but for existing PC or mobile environments. Generally, in order to show them without hurting the usability of the legacy browsers, a virtual 2D viewport plane should set in the VR environment, and long pages should be scrolled in the viewport through the scrolling operation in accordance with the existing usage.

However, in HDM devices, the viewing distance (the distance between the human eye and the display device) is very close compared with that of other devices such as PC, tablet and mobile.

When the viewing distance is suddenly got closed, it can induce viewing discomfort in various aspects such as brightness, motion, speed, and depth in the content, compared with the normal situation.

Therefore, it is necessary to study the visual perception characteristics of Human Visual System (HVS) in the VR environment to reduce discomfort.

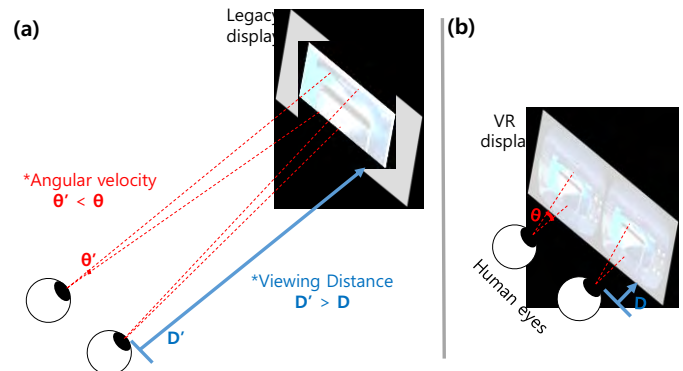


Figure 1 The viewing distance from the VR display (b) is far smaller than the viewing distance from the Legacy display (a), such as PC, mobile and tablet. So, the angular velocity of moving objects is much larger in VR display.

### 2. PROBLEM DIFINITION

When you navigate 2D web pages in the VR environment, the scrolling could be used to see the hidden area of the page for the same usability as the existing environments. However, in the VR display with a short viewing distance, even if the same pixels are moved, the angular velocity of the movement is much larger than that of a normal display. Therefore, even with the scrolling speed that is not a problem at displays such as general PCs or smartphones, you could feel the viewing discomfort at the VR displays.

Therefore, we need to detect the scrolling that the human eyes are not able to catch up with. Then, we need to perform additional processing such as speed limitation, natural blur, and the like.

### 3. PROPOSED SYSTEM

#### 3.1 Viewing geometry of VR display

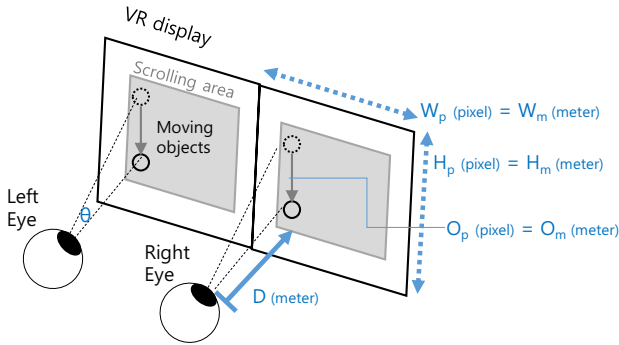


Figure 2 Viewing geometry of the VR display The moving objects are moving with a speed of  $O_p$  in scrolling area in the VR display  $W_p \times H_p$

First, we define variables for a screen size, a viewing distance, a moving speed and so on. Next, we define the scrolling speed of the browser with them. Then, we set the viewing geometry of the VR display as Figure 2.

Variables	Description
$W_p$	The horizontal resolution of the VR display for one eye (pixel)
$W_m$	The horizontal width of the VR display for one eye (meter)
$H_p$	The vertical resolution of the VR display (pixel)
$H_m$	The vertical height of the VR display (meter)
$D$	The viewing distance (meter)
$O_p$	The speed of moving objects = The scrolling speed (pixel/sec)
$O_m$	The speed of moving objects = The scrolling speed (meter/sec)
$\theta$	The angular velocity of moving objects (degree/sec)

Table 1 The variables used in the Viewing geometry of VR display

As outlined in the Table 1, we first define variables for the horizontal and vertical resolution, and the actual length of the VR display. Next, we also define the viewing distance, which is the distance between the eyes and the VR display. Then, we define the speed of the objects to be moved by scrolling. Through this defined viewing structure, it is possible to convert the scrolling speed in a pixel unit to an angular velocity as shown in the following equation:

$$\tan\left(\frac{\theta}{2}\right) = \frac{O_m}{2D} \quad (1)$$

$$\theta = 2 \arctan\left(\frac{O_m}{2D}\right), \text{ where } O_m = \frac{H_m}{H_p} O_p \quad (2)$$

$$\theta = 2 \arctan\left(\frac{H_m O_p}{2D H_p}\right) \quad (3)$$

So, an angular velocity ( $\theta$ ; deg/sec) of the objects can be calculated from a pixel speed ( $O_p$ ; pixel/sec) that is a

scrolling speed.

#### 3.2 Angular Velocity Regulation based on a Human Visual System

There has been a significant amount of research on the topic of eye-movements as a function of object motion [1]–[4]. Human eye movements related to visual attention can be classified into four main types [4]:

- 1) Vestibular eye movement allows the image to be constantly focused on the retina of the eye as the head moves
- 2) Smooth pursuit eye movement allows a moving object to be tracked so that it is uniformly formed on the retina
- 3) Saccade eye movement allows the object to be focused on the retina when the eye moves to the object of interest
- 4) Vergence eye movement allows one object to be concurrently in the retina of both eyes

The human visual tracking function is based on the Smooth Pursuit characteristic, and the speed that human can track is medically defined as follows [1]:

- Perfect tracking speed: 20 ~ 30 deg / sec
- Maximum track-able speed: 80 deg / sec

If movements of an object with a speed that cannot be tracked by a person are constantly exposed to the entire eyeball, unconsciously, the tracking motions of the eyeball are repeated continuously, causing irritation to the eye and causing the visual discomfort.

The VR browser's webview (scrolling area) covers most of the human vision, so you can limit the scrolling speed based on the visual characteristics of people as shown below.

$$\begin{cases} V_{out} = V_{in} & \text{if } V_{in} \leq V_{th} \\ V_{out} = V_{th} & \text{otherwise} \end{cases}$$

The  $V_{out}$  means the actual angular velocity of the scrolling in the VR browser, and the  $V_{in}$  means the angular velocity calculated from the scrolling speed that user entered.

The  $V_{th}$  is a threshold of an angular velocity based on a person's visual characteristics, and can be set to a value of about 20 ~ 30 (deg / sec), which is a speed that users can track perfectly. Further, it could be optimized through subjective assessment experiments.

Finally, we can get the  $V_{scroll}$  (pixel / sec) with reversed process of the (3).

The Figure 3 describes overall operations of our system:

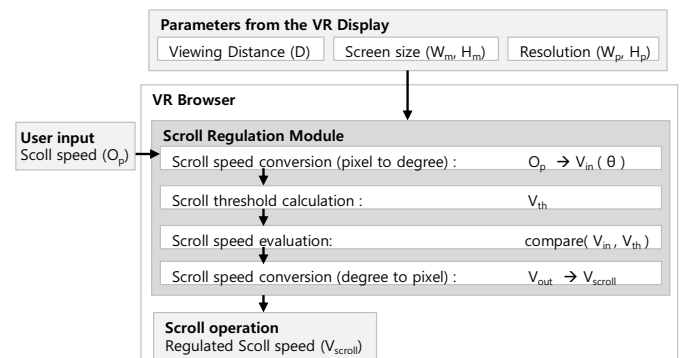


Figure 3 Overall operation of Scrolling speed regulation

#### 4. CONCLUSION

We have developed a technology to regulate the scrolling to reduce the visual discomfort in the VR browser in reference of the visual perception characteristics in HVS.

We can add additional UX to prevent users from feeling frustrated by the regulated scrolling speed. That's possible because we could utilize the "virtual" environment unlike the existing PC environments that the movement of the scroll bar should be matched with the scrolling speed of the contents or the mobile environments that the movement by the touch should be matched with the panning speed.

With our research, users can perform various operations using the VR browser with reduced visual discomfort, then users can perform more effective work with longer usage time. So, the active users of VR browser and the usage rate of VR device can be increased.

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