Virtual Retinal Display – A Novel Technology for Creating Visual Images

Y.Rajeshwari\textsuperscript{1}, T.Srilatha\textsuperscript{2}
Professor, GNITS Engg.College\textsuperscript{1}
Assistant Professor, GNITS Engg.College\textsuperscript{2}

\textbf{ABSTRACT}

The virtual retinal display (VRD) is a display technology which scans modulated laser light on the retina of viewer's eye to create an image. The viewer has perception of standing just in front of high resolution screen or projector but in reality image is on the retina of his eye and not on the screen. The VRD is a device that scans an image, one pixel at a time just like ordinary CRT. The VRD takes video signals from a graphics card or video camera as an input, than these signals are used to modulate light according to the intensity of pixel from light source which can be laser diode, gas lasers or Light emitting diodes. The output is an image with excellent quality in means of high resolution with no flickering.

\textbf{Keywords:} Visual Images, Computer Graphics, Retina, CRT monitor, Display device, Resolution.

\textbf{I. INTRODUCTION}

The Virtual Retinal Display (VRD) is a new technology for creating visual images. It was developed at the Human Interface Technology Laboratory (HIT Lab) by Dr. Thomas A. Furness III.

The VRD creates images by scanning low power laser light directly onto the retina. This special method results in images that are bright, high contrast and high resolution. The VRD scans light directly onto the viewer's retina. The viewer perceives a wide field of view image. Because the VRD scans light directly on the retina, the VRD is not a screen based technology. There are no liquid crystal displays or cathode ray tubes (CRTs) in the system.

The Human Interface Technology Laboratory (HITL) of the Washington Technology Center at the University of Washington is developing a novel display device in which a coherent light source is utilized to scan an image directly on the retina of the viewer's eye.

The technologies of virtual reality (VR) and augmented reality (AR) are the new paradigm for visual interaction with graphical environments. The features of VR are interactivity and immersion. To achieve these features, a visual display that is high resolution and wide field of view is necessary. For AR a visual display that allows ready viewing of the real world, with superimposition of the computer graphics is necessary.

Current display technologies require compromises that prevent full implementation of VR and AR. A new display technology called the Virtual Retinal Display (VRD) has been created.
The VRD is a visual display device that uses scanned light beams. Instead of viewing a screen, the user has the image scanned directly into the eye. A very small spot is focused onto the retina and is swept over it in a raster pattern. The VRD uses very low power and yet can be very bright. The technology has been developed such that the scanning element will cost only a few dollars in mass production. Low cost light sources, optics and controllers will make up the rest of the system. Ultimately, the overall device should be very inexpensive yet it will be small enough to mount on a spectacle frame.

II. DESCRIPTION

A. Necessity of virtual retinal display

The Virtual Retinal Display (VRD) is developed to overcome and solve many of the limitations of image quality, weight, and cost problems associated with current head-mounted display technology. The VRD is a major advancement of the Scanning Laser Ophthalmoscope (SLO) technology i.e. scanning modulated laser light directly onto the viewer's retina to create flicker free high-resolution images. The clear advantages of VRD over other available HMD are higher resolution, increased luminance and potentially wider field-of-view.

B. System description

The VRD uses video signals from a graphics board or a video camera to modulate low power coherent light from red, green and blue photon sources such as gas lasers, laser diodes and/or light emitting diodes. The modulated light is then combined and piped through a single mode optical fiber.

![Fig 1: Block Diagram of VRD](image)

A mechanical resonant scanner and galvanometer mirror then scan the photon stream from the fiber in two dimensions through reflective elements and semitransparent combiner such that a raster of light is imaged on the retina. The pixels produced on the retina have no persistence, yet they create the perception of a brilliant full color, and flicker free virtual image. The VRD exploits the visual property of human vision system to generate the perception of image.

Unlike CRT monitors, the VRD has no phosphorus persistence but, depends on the light-gathering properties of the photoreceptors and the temporal integration properties of the visual system. The time
each pixel is projected onto the retina is very small (30-40ns)(40ns exactly). The pixel information is transmitted to the brain in form of electric signals by the photoreceptors.

It is brain which collects all the information about each pixel of image in form of electric signals from the photoreceptor and generates the perception of a image. And because of this property, there is no flickering present in VRD based displays. Furthermore, the VRD has one more important property that it consumes very little amount of energy with ability of producing images with sufficient brightness for outdoor usage by providing a wider field of view.

C. Basic block diagram
The VRD is comprised of six basic parts: video source, control and drive electronics, photon sources, modulation devices, horizontal and vertical beam scanning, and delivery optics as shown in the Figure 2.

![Basic block diagram of VRD](image)

D. Control and Drive Electronics
The control and drive electronics for the VRD store the incoming video signals and controls the acousto-optic modulators that encode the image data into the pulse stream. The color combiner multiplexes the individually modulated red, green, and blue beams to produce a serial stream of pixels, which is launched into a single mode optical fibre to propagate to the scanner assembly. The drive electronics receive and process an incoming video signal, provide image compensation, and control image display. In addition, the drive and control electronics control the phasing of the image, and overall system timing.

E. Light source
The light sources in the VRD are typically lasers though it is possible to use LEDs in limited applications. A single red laser diode having wavelength of 650nm is used to provide a monochrome display. A blue argon laser (488nm), which produces blue lines and a helium-neon green laser (488nm) are used for the creation of a full color display.

Generally, the energy levels are on the order of nanowatts to milliwatts, depending on display requirements. The Control and Drive electronics directly modulate the laser diode. The argon gas laser cannot be directly modulated at video rates. Therefore, an external acousto-optic modulator (AOM) performs the modulation for each of the argon's colors. For the full color system the modulated light from all lasers is combined into a single beam and injected into an optical fiber, which runs to the scanner assembly.
F. **Beam Scanning**

The modulated beam received from optical fiber is then scanned to place each image pixel at the proper position on the retina. To draw the raster, a horizontal scanner moves the beam to draw a row of pixels. A vertical scanner then moves the beam to the next line where another row of pixels is drawn. The scan rate can be determined by multiplying the number of lines in the display by the refresh rate of the display. For example a interlaced video which contains 525 lines that are refreshed 30 times per second resulting in a horizontal scanning frequency of 15,750 Hertz. The field-of-view or image size seen by the user is directly related to the angle through which the optical beam is scanned.

The scan angle for the faster horizontal scan is not likely to match the total angular field-of-view desired for the display. An optical system must therefore be used to magnify the scan angle. The most important part of research in VRD was to find a scanner which can scan at high frequencies to provide high resolution and also having the property of wider view of angle.

The vertical scanning is accomplished using a galvanometer with a second mirror. The galvanometer frequency is controlled by the control and drive electronics to match the 60Hz video frame rate. The galvanometer and horizontal scanner are arranged in what is believed to be a novel configuration such that the horizontal scan is multiplied because of increase in the optical scan angle. The scanners are arranged, such that the beam entering the scanner assembly first strikes the horizontal scanner then strikes the vertical scanner and then leaves the scanner assembly and enters into pupil expander.

G. **Delivery optics**

It contains an exit-pupil with which viewer align his eye in order to see the generated image. One important property of VRD is to generate images with the ability to see through i.e image is superimposed on the physical world view thus giving an augmented vision. This property is achieved by controlling the intensity of output image by using a beam-splitter in the viewer optics. The convergent tri-color beams emanating from the scanner pass (partially) through a beam-splitter. The beam splitter is a 2mm thick parallel plate beam-splitter which on one side is coated such that 40% of any light striking it is reflected and 60% is transmitted while on the other side beam-splitter contain anti reflection coating to avoid double reflections. On first pass, 60% of the energy in the scan is transmitted through the beam-splitter to a concave spherical mirror. The mirror also collimates the individual ray bundles which are focused at the focal point of the mirror. The ray bundles now reflect of the mirror onto the beam-splitter and finally reflected to viewer's eye by passing through exit pupil.

III. **ADVANTAGES OF THE VRD**

The VRD is able to provide several major advantages over current display technologies: color range, resolution, luminance and viewing modes, contrast ratio, power consumption and cost.

A. **Color Range**

The range of hues that can be produced by the VRD is significantly greater as compared to those which can be produced by CRTs and FPDs (Flat Panel Displays). CRTs and miniature FPDs are able to reflect only a portion of the total palette of colors visible to the human eye, and are limited in the degree of saturation they can achieve.
B. Resolution
The current VRD can produce 800X600 SVGA resolution (monochrome) images. Its resolution is limited only by diffraction and optical aberrations in the light source.

C. Luminance and Viewing Modes
The amount of energy incident at the corneal surface can be varied in the range of 60nW to 300nW. This flexibility in the range of intensity allows to produce images in varying environments as compared to conventional electronic displays which do not emit (or transmit) substantial amounts of light energy. As a result, they are primarily used in controlled lighting environments, and it is difficult to see them under bright ambient light conditions such as exist outdoors.

Generally, the VRD can be used in two viewing modes, occluded or augmented. In the occluded mode, the outside environment is not visible and only images generated by the VRD can be seen. In the augmented mode, the VRD can overlay an image on the real world allowing both to be seen at the same time. In the augmented mode, the VRD luminance can be controlled to allow the user to see an image even under outside ambient light conditions.

D. Contrast Ratio
The brightness of the VRD can be increased to very high levels or decreased to minimal levels as already explained. As a result, its contrast ratio is inherently high and far greater than that of standard at panel displays or even conventional CRT monitors. As a result of this greater range, the VRD's contrast ratio is inherently higher.

E. Power Consumption
Conventional displays do not efficiently convert electrical energy into light energy. Both backlit FPDs and CRTs draw substantial power to produce radiant energy. As a result because most of their energy input is wasted their brightness is relatively low. In addition, they are among the biggest battery consumers in portable devices that use them. VRD technology, by contrast, conveys virtually all of its generated light onto the retina, allowing a brighter display with minimum power requirements (based on laser emitting diode).

F. Cost
As already described the basic design of the VRD consists of subsystems that are very simple in their design and largely make use of established optical and electronic technologies, so the VRD devices will be able to mass-produced at very low cost as compared to the other available display technologies of today.

IV. APPLICATIONS
A. Head tracking system
To create an image with the VRD a photon source (such as laser diode) is used to generate a beam of light. In case of a laser diode, the source can be modulated directly with respect to the video input. The resulting modulated beam is then scanned to place each image point, or pixel, at the proper position on the retina. The VRD uses the raster method of scanning an image. This allows the VRD to be driven by standard video sources.
To draw the raster, a horizontal scanner moves the beam to draw each row of pixels, while the vertical scanner moves the scan lines vertically at 60 Hz frame rate. The proposed system extends the VRD capability into the position tracking system. The system is suitable for the augmented vision especially when a high luminance display is needed. The principle of the proposed head tracking system is the shared aperture retinal scanning display and tracking system. Using the scanning aperture of the VRD bi-directionally, we can measure the instantaneous orientation and position of the display image over the outside world.

As shown in Figure (3), our approach is to add an infrared light source to the standard visible light channels of the VRD and, a wavelength selective beam splitter to the existing VRD optical system. The multispectral light can be separated at the beam-splitter. With a custom hot mirror, the IR light is reflected immediately to the outside world, while the visible light passes through the beam splitter and is ultimately focused on the retina as the traditional VRD optical system. The IR light reflects off the beam-splitter is following the same raster scan pattern. The sweep of the IR light over an IR detector placed in the surrounding environment generates a signal that indicates the instant in time when the beam is coincident with the detector.

![Fig: 3 Head tracking system](image)

To summarize our approach in one simple sentence, the infrared beam is used solely for the tracking and the visible beam is used solely for the display system. However, the current experiment setting is slightly different from the figure (3) as shown in the figure (4). The VRD optical projection is removed and the VRD scans directly into the environment. The modification is to make the current system have less optical components, which results in a more convenient calibration procedure.

Thus, the custom beam-splitter is not being used in this demonstration and multispectral light is being scanned into the surroundings. However, the tracking procedure largely remains the same, even though the superimposed image (a red reticle) is being projected into the environment instead of user’s eye.

The detectors are put on the robot arm, a 5 degrees-of-freedom moving stage. The robot arm moves the detectors and the detection circuit in predetermined moving patterns. The purpose of this demonstration is to show that the signal, which is detected by IR detectors, can be used to locate where the detectors are located within the field of view of the display. The predetermined moving patterns were designed to explore the tracking performance in the cases that the detectors are moving horizontally along the horizontal scanned line.
In the future augmented reality applications, the visible reticle would be projected directly to the retina using retinal light scanning of the VRD.

V. CONCLUSION

The VRD is a safe new display technology. The VRD readily creates images that can be easily seen in ambient room light and it can create images that can be seen in ambient daylight. The combination of high brightness and contrast and high resolution make the VRD an ideal candidate in several applications like Head mounted display, surgical display, aerospace, military etc. Further, tests show strong potential for the VRD to be a display technology for patients with low vision.

REFERENCES