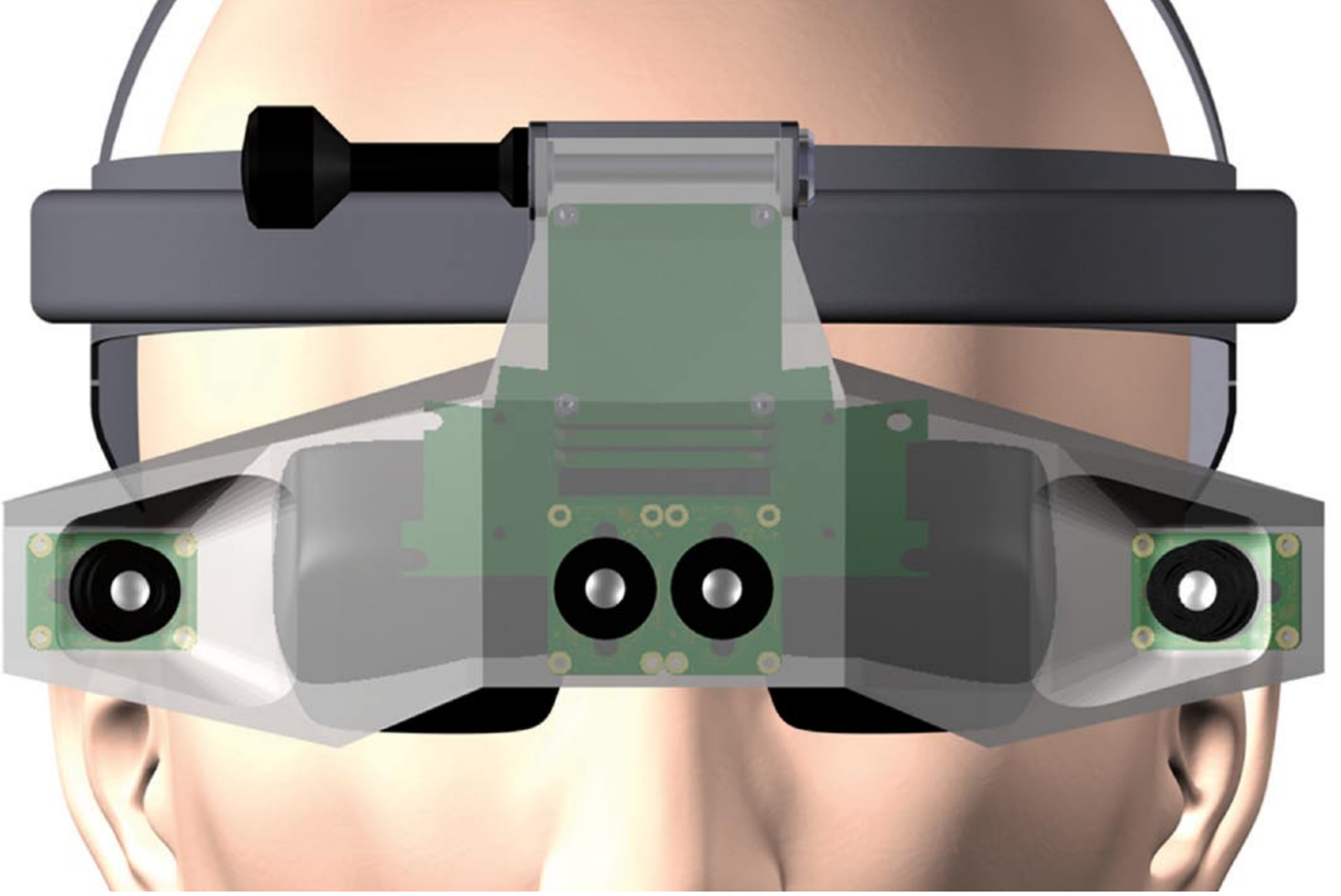
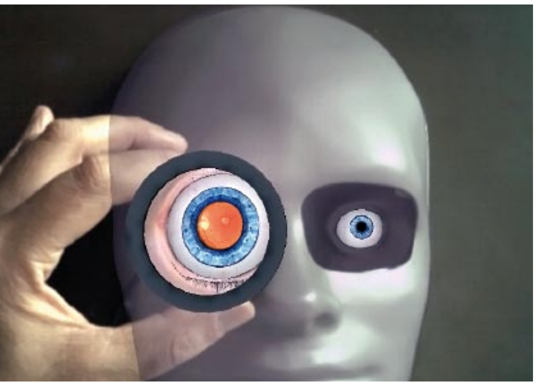


Augmented Reality Instead of Eye Drops

Optical Tracking for Data Eyeglasses of Medical Training Simulator

„Look up. Look up and to the left. Look to the left." … The ophthalmologist wears a light source and a binocular on a headband and looks through the pupil with a magnifying lens in order to examine the fundus of the eye. Anyone who has ever visited an eye-care practitioner will be familiar with this examination. Frequently, the pupil is artificially dilated with drops. As a result, the eyes will be uncomfortably sensitive to light for hours afterwards.

Ophthalmoscopy is a routine examination for registered ophthalmologists. Examination of the fundus is also used for diagnosis by general medical practitioners, e.g. in order to detect high blood pressure. For this reason, all students of medicine have to learn how to perform ophthalmoscopy. Handling of the ophthalmoscope and correct positioning of the magnifying lens require a good deal of practice. The ophthalmologist must first find the correct line of sight with respect to the pupil and must then position the magnifying lens at the correct distance between himself and the patient. To make matters more difficult, the image produced is upside down and inverted, so that the magnifier has to be moved contra-intuitively.



The augmented reality images for left and right eye are output to two separately controlled OLEDs

In cooperation with the Eye Clinic of the University of Frankfurt and the Department of Computer Science of the University of Heidelberg, the Mannheim-based company VRmagic has now developed an augmented reality simulator that allows medical trainees to practice both handling the ophthalmoscope as well as diagnosis of retinal diseases. Augmented reality means that computer-generated images are incorporated into real scenes in real time. For the user, the difference between the real and the virtual image levels is hardly perceptible.

The simulator developed by VRmagic consists of data eyeglasses – the so-called head-mounted display –, a patient model head, a freely movable magnifying lens and a PC with touch screen for system control. The user sees the genuine real-time video image with the model head and hand-guided lens through the head-mounted display. In addition, the virtual images of the visible part of the inside of the eye are displayed on the lens. "The handling and visualization of the simulator should be as close as possible to that of a real ophthalmoscope," says Clemens Wagner, Head of Virtual Reality Development at VRmagic. "A particular challenge of the technical realization was tracking freely moving objects. The magnifying effect of the lens resulted in very high demands for precision."

Multi-sensor Camera for Optical Tracking

Various conditions must be met so that the fundus area visible depending on the

Using a head-mounted display and a model head, physicians can train retinal examination procedures in the same way as with a real ophthalmoscope

position of the magnifier can be simulated in real time and so that the viewing person obtains an effect where the real and virtual image levels appear to merge. A basic prerequisite is optical tracking of the freely guided lens, which must be extremely precise on the one hand and also function robustly under different light conditions on the other. Powerful ray tracing algorithms and high-resolution stereo displays are required for image reproduction. The overall system must be capable of processing the complex data volume with a latency of significantly less than a hundred milliseconds so that users cannot detect the difference between the real environment and the simulation which then leads to the so-called immersion effect.

For the technical realization of this system, VRmagic developed a multi-sensor FPGA camera with four pixel-synchronous sensors, each with a resolution of 752 x 480 pixels (W-VGA). Two image processing paths are combined in this camera: 3D object tracking by two sensors, which track the position of the lens and model head, and a stereo see-through video camera. Only one USB signal is output. "Integration of the four sensors in one camera permits realization of a more compact design, better synchronization of the components and minimization of latency," explains Wagner.

FPGA Tracking Cameras

The two tracking cameras are located as far apart as possible so that robust 3D reconstruction can take place from the 2D camera images. Infrared LEDs are used as tracking markers: There are three LEDS on the hand-held magnifying lens, which allow reconstruction of the position and orientation. Several markers are used on the model head to compensate for shadows. The LED markers are synchronized with the cameras via the strobe output. An IR low-pass filter is used so that the cameras record only the low frequencies of the IR markers. Preprocessing of the image data already takes place on the FPGA chip of the cameras. This includes binarization, removal of interference by an erosion filter and lossless data compression by run length encoding (RLE). The resultant significantly compressed data stream is forwarded to the PC. Blob segmentation, marker matching, triangulation and object reconstruction then take place here.

See-through Stereo Camera

The see-through stereo camera consists of two simple color sensors that forward the recorded image to a PC, where it is rendered into the augmented reality image as background texture. IR cut filters remove the infrared component in the environment and the tracking markers from the image to guarantee clean color representation. Since the tracking cameras require a short exposure time and the see-through cameras a long exposure time, an internal trigger ensures that the start of exposure is clock-synchronous for all cameras. Coordination of the image data takes place on the FPGA of the smart cameras. A 256 MB ring buffer is available for this purpose.

Real-time Ray-Tracing

The multi-sensor camera evaluates a new image every 16 milliseconds at the latest. In "low latency" mode, only packets of four images at a time are accepted at once in order to minimize the latency of the camera system. If a so-called frame drop occurs for a sensor, i.e. an image is missing, the images of the other three sensors are also discarded and processing continues only with the next complete four-image packet. The video images of the stereo see-through camera are incorporated as background texture in an OpenGL graphic image. In a second step, an image of the model head and lens is inserted. Finally, the simulated image of the visible eye area is rendered on the lens. Since it is necessary to simulate several optical refractions at the same time caused by the magnifying lens, cornea and crystalline lens, VRmagic developed their own real-time ray tracing method for the computer graphics. Rendering takes place on the graphics card. The refresh rate currently achieved is 35 Hz and it is planned to increase this to 60 Hz in the future.

Visualization

The calculated augmented reality images for the left and right eyes are output to two separately controlled micro displays in the head-mounted display. OLEDs from eMagin are used with a resolution of 800 x 600 pixels each (S-VGA). A prism optical system magnifies the image. In this way, medical specialists obtain the three-dimensional image impression that they are familiar with from a real ophthalmoscope. "The immersion effect is fascinating," says Wagner, underlining his satisfaction with the end product. "The blend of real and virtual images is so convincing that our sensory system has absolutely no reservations!"

The augmented reality interface developed by VRmagic is a technology platform that is suitable for an extremely wide variety of applications in industry and science. The multi-sensor FPGA camera is also available as an OEM component. This camera is capable of producing pixel-synchronous images from several positions, as required for 3D reconstructions of moving objects, for example.

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