Cardiolens: Remote Physiological Monitoring in a Mixed Reality Environment

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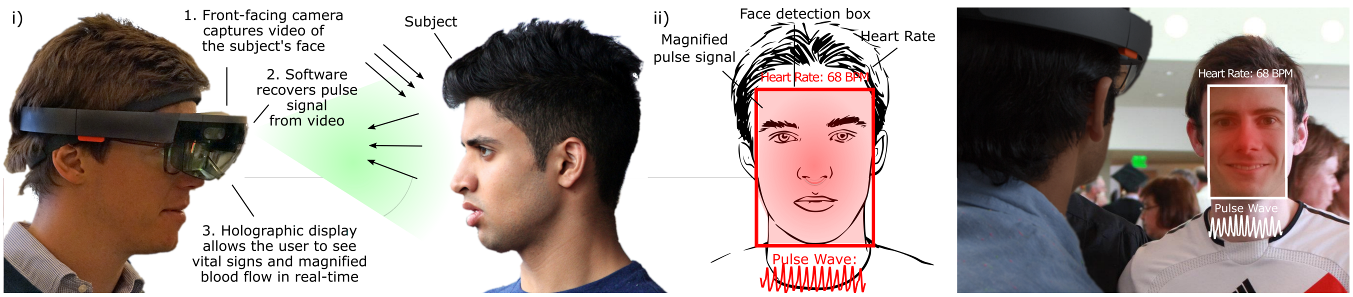

Figure 1: Cardiolens is a physiological measurement tool that allows real-time visualization of vital signs in a mixed reality environment. i) Summary of the Cardiolens system. ii) An example of the experience from the perspective of the wearer.

ABSTRACT

Numerous vital signs can be captured through the measurement of blood flow; however, these signals are not visible to the unaided eye and measurement traditionally requires customized contact sensors. We present *Cardiolens* - a mixed reality application that enables real-time hands-free measurement and visualization of blood flow and vital signs. The system combines a front-facing camera, remote imaging photoplethysmography software and a heads up display allowing users to view the physiological state of a person simply by looking at them. *Cardiolens* provides the wearer with a new way to understand physiology and has applications in health care and affective computing.

CCS CONCEPTS

• **Computing methodologies** → **Computational photography**;

KEYWORDS

Health, Augmented reality, Mixed reality, Non-contact

1 BACKGROUND

Remote imaging photoplethysmography (iPPG) is a set of techniques for measuring the blood volume pulse (BVP) via small variations in light reflected from the skin using ambient light and a digital camera [Verkruysse et al. 2008]. For a survey of the research see McDuff et al. [2015]. In addition to measurement of the BVP signal important vital signs including the pulse rate and breathing rate [Poh et al. 2011] can be subsequently calculated. Heart rate variability can also be measured providing information about nervous system activity and stress. The unaided human eye does not have the acuity to notice these changes. Therefore, methods for post-processing videos to magnify subtle changes resulting from the pulse have been proposed [Wu et al. 2012]. However, video magnification does not provide an intuitive real-time visualization of the signals and requires an individual to look at a screen rather than the person, or body part, of interest. Furthermore, these approaches do not work in real-time. Augmented reality allows us to bring information from remote sensing into the user's perceived real-world experience. New head-mounted wearable devices (e.g., Microsoft Hololens, Meta2) that feature transparent displays allow digital information to be overlaid on the real-world.

Fernando et al. [2015] validated remote heart rate measurement in neonates using a Google Glass device. The camera on the device was used to recover the PPG waveform and infants' heart rate. However, no visualization of this signal was proposed. Google Glass has some limitations including a very constrained field-of-view (FOV) in the heads-up display and limited processing power. We present *Cardiolens*, a novel mobile system that allows users to view "hidden" physiological signals in real-time by simply looking at people around them.

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Figure 2: Screen capture of the Cardiolens visualization through the demo application. The blood flow signal is magnified using a semi-transparent mesh.

2 DESIGN

Cardiolens combines a head-worn forward-facing camera and a heads-up display, see Figure 1i. We use the Microsoft Hololens and implemented the application in C#. All the processing is performed on the device and images captured using the front facing camera. Thus the device does not need to be tethered to a computer, nor does the hardware require any custom adaptation.

Technology. The video signal from the camera is processed using a 15-second moving window. An automated face tracker detects the largest face within each frame and a region of interest (ROI) is segmented. Spatial averages of the luminance (L) and chrominance (U, V) pixel intensities are calculated. Alternatively, the images can be converted into RGB space and the red, green and blue pixel intensities used. Using either method, these form three time-varying signals. We use the method validated by Poh, McDuff and Picard [2011] to recover the blood volume pulse from the resulting camera channel signals. Signal decomposition is performed using independent component analysis (ICA) and band-pass filtering using a Butterworth filter with high and low frequency cut-offs of 0.75 Hz and 3 Hz respectively.

Visualization. Figure 1ii illustrates the experience using *Cardiolens*. The user is given feedback about a detected face via a white box overlaid on their real-world environment that highlights the ROI being analyzed. The heart rate (in beats-per-minute) is displayed next to the box.

We augment the appearance of the subject with the blood flow signal. This process presents the technical challenge of displaying a semi-transparent mask on a moving object to create a mixed reality experience. We developed a holographic overlay which shows the BVP signal superimposed onto the face using a linear image processing pipeline. We segment skin pixels from the Hololens camera by converting each image from NV12 to RGB format and filtering on the resulting three color channels. We modify the red channel values of the skin pixels to magnify the pulse frequency. Finally, we compute the position of the captured frame in the 3D environment. We place this image in the mixed reality space at the average distance of the user from the device (approximately one-meter). We also define a speed vector for this plane, which corresponds to its change of location when the user or subject moves his or her head. This step ensures that the overlaid hologram remains stationary on top of the subject's face from the perspective of the *Cardiolens* user. The resulting experience allows the user to see the pulsating blood flow signal that would otherwise be imperceptible. Finally, the pulse wave for a 15-second window can be displayed below the subject's face (this display option can be controlled via a simple "air tap" gesture). Figure 2 shows a screenshot of the actual visualization through the Hololens, captured using our demo application.

3 INTERACTION

Each user will be able to interact with *Cardiolens*. When they wear the Hololens the user will see a box displayed around the face of the closest person that they look at. After looking at someone for 15 seconds the heart rate and pulse wave will be displayed next to the face box and the magnified pulse signal superimposed onto the skin. The measurements will be updated continuously until the user looks away from the individual. We will have a traditional contact sensor on hand for users to compare the *Cardiolens* heart rate with that from a gold-standard device.

4 APPLICATIONS

The option of remotely monitoring peripheral blood flow and vital signs with a real-time mixed reality visualization has promise for improving many HCI systems in healthcare and affective computing. Visualizing blood flow in different parts of the body in real-time would be useful for surgeons in an operating theatre. Understanding changes in heart rate and heart rate variability would allow a speaker to gain insight on the cognitive load their audience is experiencing. *Cardiolens* is intended to help people understand physiological changes. There are ethical and privacy questions related to a device that can measure and visualize the physiological responses of another person. We hope that this demo also spurs debate about these issues.

5 CONCLUSIONS

We present *Cardiolens* the first mixed reality physiological monitoring tool that allows real-time remote measurement and hands-free visualization of vital signs and blood flow. Employing recent advances in computer vision, the system allows users to view normally imperceptible physiological signals in real-time by simply looking at the people around them.

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