Project: Understanding the feasibility of using a mouse for health sensing

RISHIRAJ ADHIKARY, Indian Institute of Technology, Gandhinagar, India

In this project, I investigated the possibility of detecting an individual's pulse/heart-rate using a computer optical mouse. Prior research supports the notion that the change in coordinate pixels of the image sensor of the mouse can be used as a proxy for heart rate. I underlined the challenges that need to be addressed while using a mouse as a health sensing device. Finally, I also used an external sensor retrofitted on the mouse to derive the heart rate of three participants with a mean absolute error of 5.6

ACM Reference Format:
Rishiraj Adhikary. 2021. Project: Understanding the feasibility of using a mouse for health sensing. In . ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/1122445.1122456

1 INTRODUCTION

The importance of heartbeat rate measurement is well known as an indicator of various heart-related diseases. The Global Burden of Disease study results states an age-standardized Cardio Vascular Disease (CVD) death rate of 272 per 100000 population in India, which is much higher than that of the global average of 235 [2]. Non-invasive heart rate measurements provide reduced medical expenses, offer comfort to patients, and are suitable for clinics and home care photoplethysmography or PPG being the most famous example. A PPG is often obtained by illuminating the skin and measuring changes in light absorption. There are two modes of operation of PPG, transmittance mode and reflectance mode. In transmission mode, the tissue sample is placed between the source light and the photodetector, while, in reflection mode, the LED and photodetectors are placed side-by-side as shown in Figure 1. In this project, I explored using a standard computer optical mouse to perform reflective PPG to derive heart rate. I discussed the proposed approach followed by challenges in implementing them. Finally, I end with a workaround approach that uses an external sensor in the optical mouse to measure the heart rate.

2 PROPOSED APPROACH AND BACKGROUND

My objective was to use the mouse as a health sensing device without using any external sensor. In this section, I will first explain how a mouse works and how it can be used to monitor heart rate.

The internal structure of the mouse: As seen in Figure 2, an optical mouse consists mainly of a Light Emitting Diode (LED), a lens and a complementary metal-oxide-semiconductor (CMOS) optical camera integrated into the Integrated Circuit (IC). The laser beam from the LED passes through the convex lens to illuminate a small (about micrometre in size) surface underneath the computer mouse. The light bounces off the surface and hits the image sensor. The image sensor consists of about 1600 pixels (40 pixels in width and height, respectively.). The image sensor can capture topographically and texturally complex landscapes. The image sensor takes about 17000 images of the surface every second. Therefore, even during the slightest movement of the mouse, the image

Ubicomp Class '21, Semester 1, 2021, Gandhinagar, India

ACM ISBN 978-x-xxxx-xxxx-x/YY/MM…$15.00
https://doi.org/10.1145/1122445.1122456

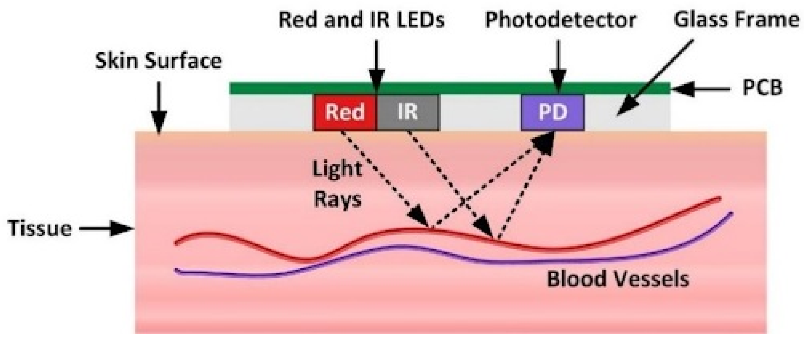

Fig. 1. A representative image showing how reflective PPG works [3]

sensor captures as many images as to estimate the change in position of the mouse. The mouse that I used for this study had a similar internal structure (Figure 3).

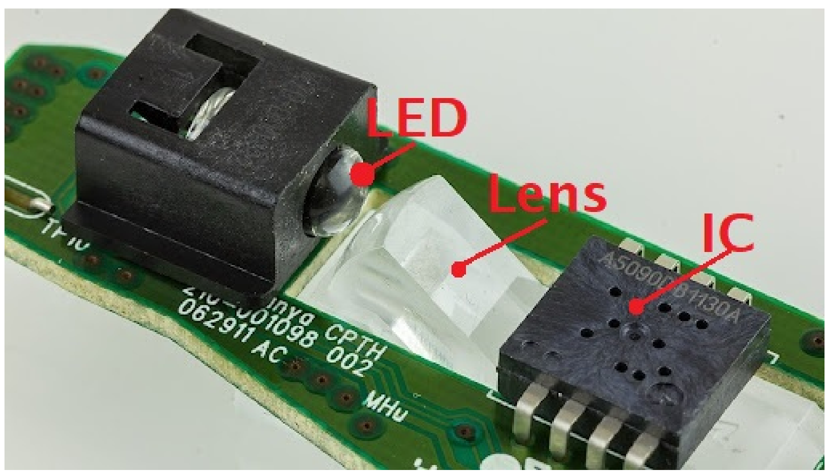

Fig. 2. The internal structure of the mouse showing the illumination source, the lens and the optical camera

Computing the X and Y direction change: The mouse does not store any of these images but compares the latest image with the one taken 59 microseconds earlier. The mouse's digital signal processor (DSP) uses the difference between the two images to compute the X and Y direction change using a cross-correlation algorithm. Each image is composed of 40 X 40 pixels. The DSP takes the first image then overlays the second image on top of it. The DSP subtracts all the values of the second image's pixels from the first to compose a new resulting image. The processor then shifts the second image around while leaving the first stationery and continues to calculate the differences between the two images until a position is found where the resulting image's pixels are at the minimum difference. The amount of shift in position to reach a minimum resultant image tells us exactly how far the mouse moved between two successive images to derive the X and Y direction change measured in pixel count. The cross-correlation algorithm is executed 59 microseconds later when a new image becomes available.

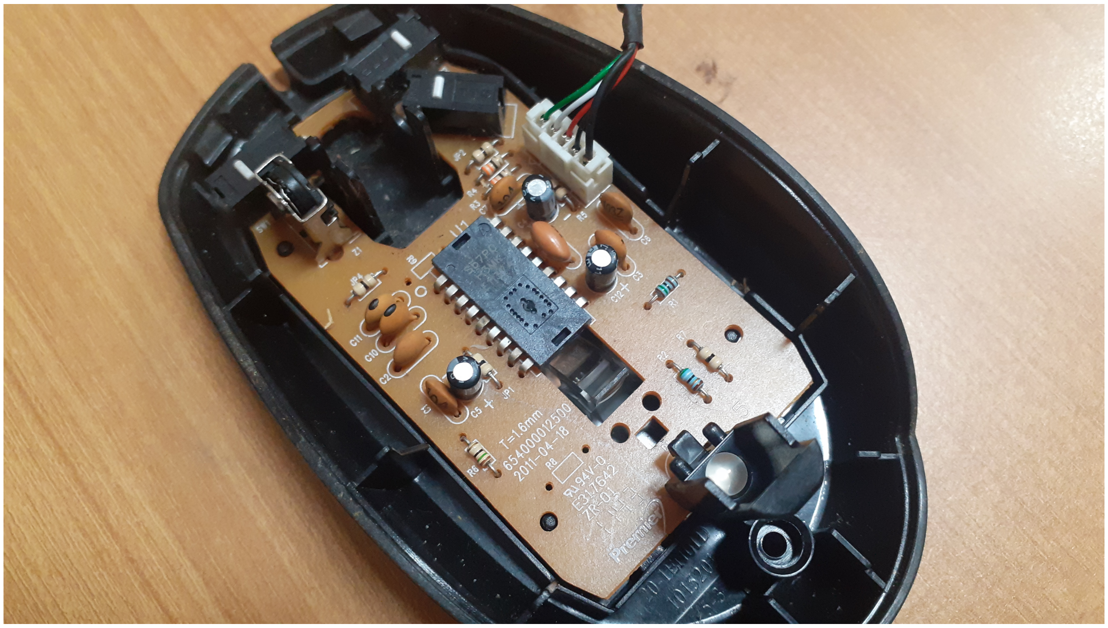

Fig. 3. The internal structure of the USB optical mouse that I used. Note that the LED was lifted to face top and is not pointing towards the lens.

Sensing Heart Rate From Mouse: Prior literature [4–7] has shown that vibrations in the arteries caused by the blood flow modulate the phase of the laser beam illuminating the inspected surface. Interferometry-based configurations can extract the phase of the reflected light and thereby derive the heart rate. By using a digital camera with high sampling rates and a defocused lens, it has become possible to measure minimal vibrations in a precise way. The LED of the mouse can be used to illuminate the skin. The roughness of the human skin, being illuminated by the laser spot, produces the secondary speckle pattern that is backreflected to the sensor as shown in Figure 4. At this point, the CMOS captures the speckle image at a high rate. The DSP unit inside the processing card of the mouse calculates the correlation between every two speckle images. The correlation of each two images is related to the physical vibration of the skin at a certain period. The term speckle refers to a random granular pattern that can be observed, e.g. when a highly coherent light beam (e.g. from a laser) is diffusely reflected at a surface with a complicated (rough) structure, such as a piece of paper, white paint, a display screen, or a metallic surface. Previous research suggests removing the lens of the mouse for health sensing so that the defocused speckles can be produced at the mouse digital sensor plane.

A microcontroller or an operating system can capture the (X,Y) values from the mouse at a specific time period. As a function of time, the plots of X and Y graphs correspond to the pulses produced by the human body heartbeat.

Challenges and Current Approach: I faced two critical challenges in realising the proposed approach. First, a modern optical mouse comes with a USB connector. A microcontroller cannot read USB connectors since any USB device requires a USB host. Therefore, it was impossible to retrieve the mouse's raw pixel change in the X and Y direction. The same would have been possible had the connector been a six-pin PS/2 port. In the future, I plan to use a USB host microcontroller to read the raw data from the optical mouse. Secondly, it would have been possible to read the DSP processor on the mouse by using alligator clip connectors. But it appears that there was

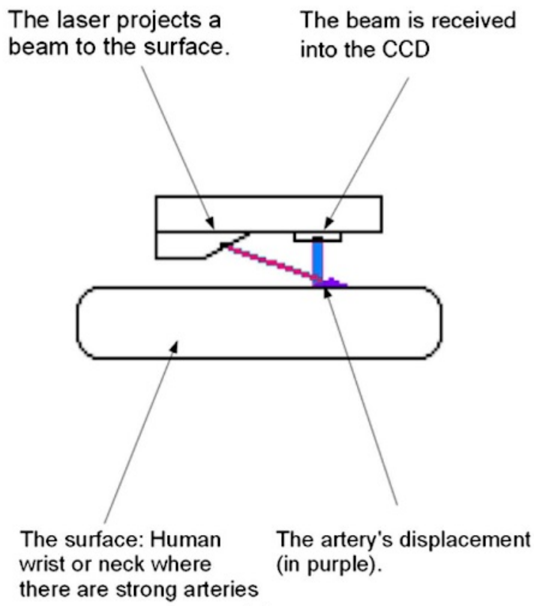

Fig. 4. Representative image showing how the optical sensor inside the an optical mouse can be used to derive heart rate [1]

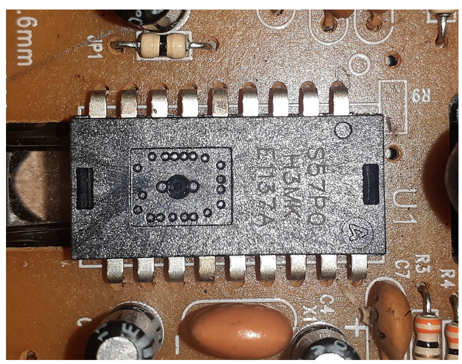

Fig. 5. The mouse I used had a non-standard 18-pin DIP microprocessor. No datasheet is available for this microprocessor making it difficult to reverse engineer this IC.

an unknown 18 pin processor (Figure 5) in the mouse that I was using. The standard mouse DSP popular in the makers and research community is the 16 pin ADNS[1] sensor, as shown in Figure 6. Given the challenges, my current approach was to use a simple pulse sensor composed of a green LED as a transmitter and a photodiode as a receiver and implement reflective PPG, as shown in Figure 7

[1]http://bdml.stanford.edu/twiki/pub/Rise/OpticalDisplacementSensor/ADNS2051.pdf

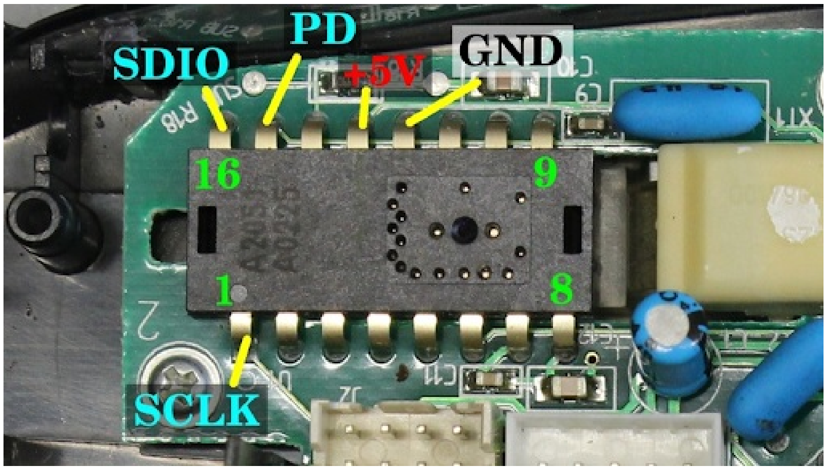

Fig. 6. A standard DIP16 IC inside a optical mouse.

Fig. 7. I retrofitted an external PPG sensor in a location where the thumbs rest for non-invasive monitoring of heart rate.

3 EVALUATION

To evaluate the current approach, I designed a Windows application that computes the heart rate from the fundamental frequency of the PPG waveform. The application also shows the interbeat interval (IBI). It lets the user control the window size of the real-time signal on which the fast Fourier transformation (FFT) needs to be applied. I found that a window size of 0.73 seconds works best in estimating the heart rate. Three participants participated in testing the system. I used an Omron oximeter[2] and placed it in the index finger of the left hand of participants. Their right hand was holding the mouse, such as the thumb covering the PPG sensor. The heart rate was observed at the end of a minute after both the systems were placed. Table 1 shows the result with a mean absolute error of 5.6 between the Omron device and my system. It is worth noting that a person can feel her heart pulse in an environment where ambient noise is very low. I asked participants to count their pulse rate by showing a cue. The self-counted pulse rate differed both from the one estimated from a commercial oximeter and my system.

[2]https://www.flipkart.com/omron-cms50n-pulse-oximeter/p/itm00c56c2bf8c7f

ID, Sex	Estimated Pulse Rate	Omron Pulse Rate	Self Count Pulse Rate
1, Male	78	64	72
2, Male	67	66	70
3, Male	68	70	76

Table 1. My system had an MAE of 5.6 when compared with a commercial off the shelf oximeter. It is not clear why a disagreement occurs between self reported (self counted) pulse rate and other system. This disagreement could be attributed to a different time at which each participant starts monitoring her pulse rate compared to the system time.

REFERENCES

[1] Yevgeny Beiderman, Roy Talyosef, Daniel Yeori, Javier Garcia, Vicente Mico, and Zeev Zalevsky. 2012. Use of PC mouse components for continuous measuring of human heartbeat. *Applied optics* 51, 16 (2012), 3323–3328.

[2] A Sreeniwas Kumar and Nakul Sinha. 2020. Cardiovascular disease in India: A 360 degree overview. *Medical Journal, Armed Forces India* 76, 1 (2020), 1.

[3] Sanjeev Kumar, John L Buckley, John Barton, Melusine Pigeon, Robert Newberry, Matthew Rodencal, Adhurim Hajzeraj, Tim Hannon, Ken Rogers, Declan Casey, et al. 2020. A wristwatch-based wireless sensor platform for IoT health monitoring applications. *Sensors* 20, 6 (2020), 1675.

[4] Tuck Wah Ng. 2003. The optical mouse as a two-dimensional displacement sensor. *Sensors and Actuators A: Physical* 107, 1 (2003), 21–25.

[5] Tuck Wah Ng and KT Ang. 2004. The optical mouse for vibratory motion sensing. *Sensors and Actuators A: Physical* 116, 2 (2004), 205–208.

[6] Tuck Wah Ng and M Carne. 2007. Optical mouse digital speckle correlation. *Optics Communications* 280, 2 (2007), 435–437.

[7] J Palacin, I Valganon, and R Pernia. 2006. The optical mouse for indoor mobile robot odometry measurement. *Sensors and Actuators A: Physical* 126, 1 (2006), 141–147.