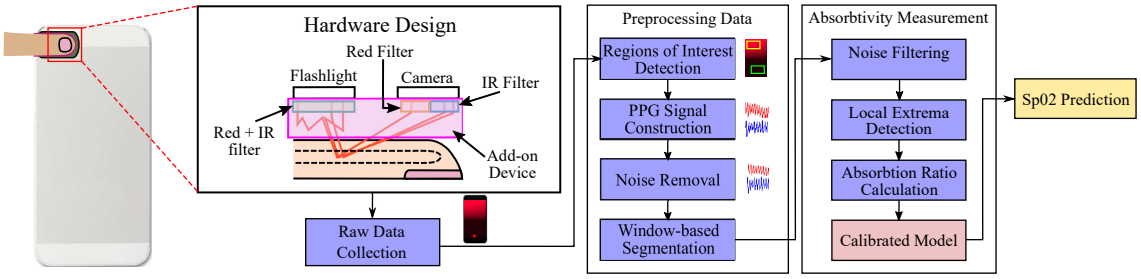

Figure 2: Overall system design and architecture of measuring Sp02 with dual filters.

(difference of max and min value) and mean of each ppg signal. After that, we can receive the absorptivity ratio using

$$R = \frac{AC(s_r)/DC(s_r)}{AC(s_{ir})/DC(s_{ir})}$$

(5) The intensity of light can be referred to the number of photon perceived per a unit area. Theoretically, it should be dependent on wavelength, but, due to the Quantumn Efficiency which defines the percentage of photons can be successfully converted. Specifically, lights penetrates differently on the depletion layer of Charges Couple Device (CCD) or Complementary Metal Oxide Semiconductor (CMOS) according to their wavelength. Therefore, a calibration procedure is needed to compensate the degradation. In practice, the coefficients are non-linear calibrated with ground truth data to suit with different camera models.

3 IMPLEMENTATION AND RESULTS

We build a 3D printed add-on with specific features that are suitable for most of the common models. Solid Work is applicable to persuade our work for different pre-sketched phone models. We then manipulate the form of our device so that it can capture a clean pulsatile waveform by introducing a light-guiding component to improve the beam focus and reduce scattering. Secondly, user-targeting ease of usage and diversity is another issue that our design should take care off. Basically, the thickness of that add-on should be qualified enough to leave space for lights to bound off from our finger and lands on the camera lenses but still be pocketable. 3D printers now become popular in terms of giving a quick overview of actual model and detailing small items such as our add-on module. With that benefits, our first prototype is produced and is illustrated in Figure 3 for evaluation.

Three types of filters are utilized into our design for different purposes. The red component from the white light is extracted by the dark color red film filter. On the other side, the negative film is integrated to cancel out all the visible components and only let the IR go through [2]. The third component is an optical glass filter to gather the light from only a certain range of wavelength (less than 1200 nm). We perform the evaluation of our device using Matlab version 2013 equipped with Image and Signal Processing toolbox.

Subject for evaluation is assisted to deliver a set of recording sequences using four Samsung Galaxy S4. The time stamp between the ground truth obtained from qualified pulse oximeter and our devices is monitored and matched according to the information

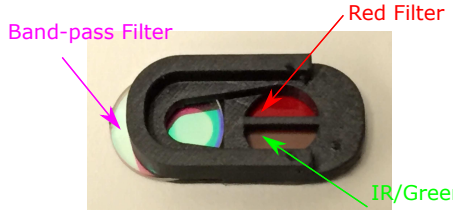

Figure 3: A 3D print add-on for Samsung Galaxy S4.

from a hand-held digital camera. In specific, ground truths are collected from the Accumed pulse oximeter - NELLCOR PM10N at the same time of recording mobile devices. We maximize the exposure level to obtain the information of IR channel. The subject need hold their breath to reduce the oxygen level while recording. Figure 4 demonstrates our system performance by predicting the

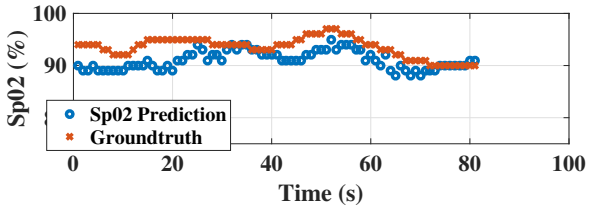

Figure 4: Prediction of oxygen level comparing with the ground truth.

level of oxygen with the mean of error rate is 4%.

4 APPLICATIONS AND DISCUSSION

Motivated by the limitation of current system regarding wavelength selections and light guiding, we introduce a spatial divider as an add-on. We present end-to-end system structure with a preliminary result. We are working on deploying the system on smart phone for real-time processing instead of using Matlab.

REFERENCES

[1] W. Karlen, J. Lim, J. M. Ansermino, G. Dumont, and C. Scheffer. 2012. Design challenges for camera oximetry on a mobile phone. (2012), 2448–2451.
[2] Public Lab. 2016. IR filter Spectrum. https://publiclab.org/wiki/ndvi-plots-ir-kit. (2016).
[3] L. M. Po, X. Xu, L. Feng, Y. Li, K. W. Cheung, and C. H. Cheung. 2015. Frame adaptive ROI for photoplethysmography signal extraction from fingertip video captured by smartphone. (2015), 1634–1637.
[4] Edward Jay Wang, William Li, Doug Hawkins, Terry Gernsheimer, Colette Norby-Slycord, and Shwetak N. Patel. 2016. HemaApp: Noninvasive Blood Screening of Hemoglobin Using Smartphone Cameras. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '16)*. 3320–3338.