Paper Summary

This paper presents a novel continuous blood pressure (BP) monitoring wearable of an eyeglass form factor. It assesses some non-traditional sensing modalities for its BP estimation. The wearable constitutes of 3 sites to measure PPG via optical sensors, IMUs anda processing and storage unit. The paper has a central hypothesis, continuous measurement of pulse transit time (PTT) is a proxy for systolic BP variation. By measuring PTT on a beat-by-beat basis short term responses to posture changes, rest, drinking etc. can be captured.

On the hardware below operations are carried out,
Heart rate extraction
PTT estimation
Storing raw IMU data

Common approaches to measure BP continuously use the below surrogates,
Pulse Arrival Time (PAT) : This is the time between the ECG's R-peak and the valley of PPG. However, this phase is referred as a pre-ejection period where the heart depolarises and is inherently noisy and non-deterministic. Hence, even though this phenomena is independent of BP, it introduces variability within the ECG-PPG time thus not an accurate method to estimate BP.
Pulse transit Time : This is the time taken by a pulse wave to travel from one point of an artery to another. Typically, it is measured at two different locations of the same artery whose distance is empirically known. This is the approach being used in this paper using 3 sites to extract two PTTs.

The data processing steps include

1. Filtering
2. FFT to derive HR
3. Peak detection of the PPG by transforming it into acceleration PPG
4. Signal Quality Metric – If IMU magnitude s beyond a threshold discard the PTT
5. Derive PTTs and evaluate BP

The mechanical design of the wearable is extensively tested for user comfort and fit (if the glasses are not snug the PPG will not be captured).

In the wild evaluation methodology: Users were prompted to measure radial BP 3 times an hour. Glabella prototype continuously logged user data, and commercial cuff-based BP monitor readings were uploaded in the custom app. Results indicate superiority of the site for superficial temporal artery over the occipital artery for BP measurement.

Things I liked about the paper

The paper was insightful wrt systems design from a functional and wearable point of view. The evolution of the prototype shown in Fig.3. from arduino based proof-of-concept to custom FPCB was well illustrated. It would have been even better if there were more details on the optical sensor design they used since PPG capture is the core of their signal acquisition here.

Areas that can use improvement

The ground truth collected in this experiment is only valid for a small period of time. As argued in the paper, the BP is prone to short-term fluctuations due to various activities. More details on how they construct the Bland-Altman plots with the corresponding window of BP measurement from Glabella would be helpful. Do they use only simultaneous measurement between the two devices or a representative measurement (like mean of BP over a small window prior to the ground truth measurement)?