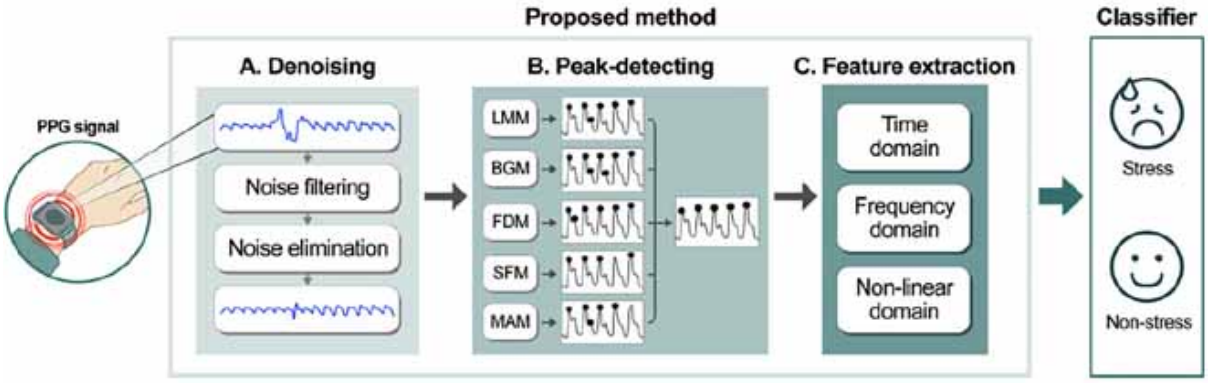
In recent years, we have seen lots of new wearable devices getting equipped with ever more advancing sensors. One of the most commonly used sensors is PPG(Photoplethysmogram). This sensor is capable of Monitoring heart rate and cardiac cycle respiration, blood pressure, and SpO2(saturation of partial pressure oxygen)providing an insightful tool to assess our health. Its small size and versatility makes it invaluable to everyday healthcare. So how does it work?

The process starts with a green LED illuminating the skin. With each heartbeat, the blood volume in the subcutaneous tissue changes, which affects the amount of light absorbed by it. The photodetector then captures variations in light absorption, which are then converted into an electrical signal. This signal is known as the PPG waveform.

Now let's take a look at the various applications. Firstly, we can measure stress with it. In one study using discovered three parameters, the time from pulse onset to peak, the time from the dicrotic notch to pulse end, and the pulse rate significant. Interestingly, measurements at the radial artery may provide superior performance than the brachial or temporal arteries. Another study used a public datasat(wearable stress and affect detection dataset)(WESAD), and measured the performance of the proposed PPG denoising and peak-detecting methods by lightweight multiple classifiers(determinants). The stress-detection performance demonstrated an improved result compared with the existing methods.



Secondly, it could be used to detect cardiovascular diseases. The European Society of Cardiology (ESC) reported that heart rate is an independent risk factor for cardiovascular diseases; as such, any change in the normal heart rate (or blood volume) activity is a significant marker for a possible cardiovascular dysfunction.

The PPG-BP data set contained all the said information. Such data can be evaluated through different machine learning algorithms with different parameters. Supervised machine learning classifiers such as decision tree (DT),

naïve Bayes (NB), support vector machine (SVM), and ensemble classifiers are used to evaluate the proposed model using k-fold cross-validation dd

Cardiovascular, cerebrovascular diseases, diabetes and high blood pressure diseases are at the top 10 major cause of death list in South Korea. 15.8% die from the first two causes alone, which are preventable with everyday health management such as improving lifestyles. This would help us effectively monitor and prevent diseases from getting severe. Being a relatively cheaper and simpler tool, photoplethysmography allows for the easy detection and monitoring of heart diseases without the need for invasive measures.

Photoplethysmography is also viewed in the medical field as a tool for managing cardiovascular diseases post-treatment. Once diagnosed, cardiovascular diseases may become problematic or restrictive for a person, especially in terms of limited dietary options, physical activity, and stress levels; however, PPG is now widely-utilized by physicians as a monitoring tool for the aftercare treatment of cardiovascular diseases.

Lastly, PPG can be used to help monitor aerobic physical exercise, which can be beneficial in mitigating both motor and nonmotor symptoms of Parkinson's Disease(PD). In a recent pilot study on healthy paricipants ,Fitbit Charge 4(wrist-worn) showed comparable accuracy to Polar H10(chest strap). Another study using galaxy watch 3 obtained a conclusion that Blood Pressure(BP) measurement using a smartwatch with a photoplethysmography sensor is an accurate and reliable method in patients with PD. Then what about Alzheimer’s Disease? Radial blood pressure waveform (BPW) and finger photoplethysmography signals were measured noninvasively for 3 minutes. The

5-layer MLP(**multilayer-perceptron**) algorithm employed evaluated the following 40 harmonic pulse indices.The BPW indices differed significantly between the AD patients and control subjects with an accuracy of over 80% and a high specificity. Moreover, Significant intergroup differences were found between mild, moderate, and severe AD (defined by Mini-Mental-State-Examination scores) with an accuracy of around 70%.

The identified differences can be partly attributed to AD-induced changes in vascular elastic properties. This could be used as a noninvasive, rapid, inexpensive, and objective alternative for detecting and monitoring the AD status.

The biggest potential of this sensor lies in telemedicine. Take COVID-19 for example. Not only can it read SPO2, one of the first signs to be checked in ER to decide COVID-19 severity, providing a convenient remote way to monitor patient vital signs, especially COVID-19 patients, with the Recent FDA guidelines and an enforcement policy for noninvasive remote monitoring devices manufacturers, its potential is being recognized amidst the pandemic. Algorithms that can indicate the possibility of infection in the early stages of COVID-19 may be developed. Estimating the quarantine duration for each individual could be a useful way as well. It may be used for initial individuals' temperature evaluation, in high throughput places like airports, shopping malls, and sporting events, effectively slowing down the spread.

Merging the healthcare domain with information technology (IT) is a demanding area to reduce the rehospitalization of CVD patients. In the proposed model, PPG signals from the Internet of things (IoT)-enabled wearable patient monitoring (WPM) devices are used to monitor the heart rate (HR), etc., of the patients remotely. a system that assists physicians during continuous monitoring The proposed system provides cost-effective, efficient, and fully connected monitoring systems for cardiac patients.

So what are its limitations? Currently, the lack of standardization, hindering a proper comparison of the results from different or similar studies, reduces the effectiveness of a study and jeopardizes the overall quality of results. Specifically, many validation studies provide inconclusive evidences for different reasons, such as for the approach in comparing different variables or for methodological issues.

The high sensitivity to various external influencing parameters, both environmental and subject dependent highlights a poor reproducibility and comparability of the results. So what can we do about this?

Firstly, the health status and presence of tattooes of participants must be verified. Secondly, Specific percentages for skin tone, BMI and gender must be included to account for the subject's differences. Thirdly, Report room temperature and ambient lighting; sensor position; characteristic of eventual straps used, and contact pressure measured between skin and sensor. Lastly, the lack of databases should be addressed by research suooirted by governments, since they determine the accuracy of results. These kinds of

methodological rigor in the execution of the tests should be encouraged to prevent ambiguous or incorrect quantifications of the performance of the PPG sensors.

With the wearable healthcare market forecasted to grow about 17~27% YoY, and digital health using AI going mainstream, we can expect this amazing technology to develop even further. So the next time you put on your smart watch, let's take a moment to appreciate the cutting-edge technologies behind that make all the magic happen.