Design and Implementation of IOT Based Non-invasive Blood Pressure Monitoring

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ABSTRACT: Hypertension is commonly known as high blood pressure. The hypertensive patient must commute to the hospital visiting their physician Regularly for blood pressure (BP) monitoring using a cuff-based device. The Patient may feel uncomfortable and pain when the device inflates the cuff and tightens around the arm for a BP measurement. Hence, to overcome this problem, this project proposes a novel sensing system for non-invasive and continuous estimation of blood pressure (BP), which is based on a custom designed wearable radar sensor. There is a possibility for the proposed radar-based BP estimation technique to be employed inside and outside the clinic, such as applications in the vast internet-of-things (IoT) and in-home health monitoring. Doctors can easily monitor the blood pressure of the patient using IOT.

Keywords: Radar, Bloodpressure,IOT

I. INTRODUCTION

As an indicator of cardiovascular system function, blood pressure is one of the important physiological signatures to be measured in the clinic. The digital sphygmomanometer with upper arm cuff is now the most popular device for blood pressure monitoring. However, the cuff-style monitor is flawed, for it does not support a real-time continuous blood pressure detection, and its inflating process causes discomfort. Sleeveless methods that use distal pulses, pulse transit time (PTT), and pulse wave velocity (PWV) to measure continuous blood pressure are increasingly being applied in home healthcare monitoring. Many studies believe that the PTT and PWV are potential substitutes for BP, because there is a short-term correlation between the three factors . One of the most trending sleeveless BP measuring approach using distal pulses is based on Photoplethysmography (PPG),which utilize the change in light absorption to detect pulse volume change waveform, but the approach may be interference by tattoos and sweats .IOT Device ESP32 is used by doctors to monitor the patients blood pressure level. Radar sensor not only increases the detection precision, but also has a small size.

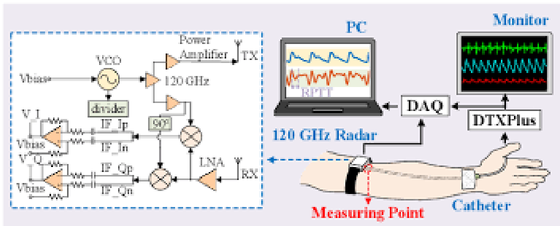

Fig.1.Schematic diagram of the proposed blood pressure estimation technique in clinical trials.

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II. SYSTEM AND THEORY

Experiments were carried out in the operating room with permission, patients Fig. 1 shows the schematic diagram of the proposed blood pressure estimation technique in clinical trials. Patients keep their arms straight with palms facing upward, and a transducer set for medical invasive blood pressure measurement called DTX Plus is set up. DTX Plus has one end connected to a monitor, and the other end connected to the arterial catheter that reaches the brachial artery. The blood pressure signals for reference standard are collected by a data acquisition card(DAQ) from the transmission wire between DTXPlus an monitor. Meanwhile, the radar sensor with concentrated energy and high frequency is used to obtain the pulse wave signals from the brachial artery at the elbow which is almost the same place detected by both invasive and non-invasive methods. The radar sensor continuously transmits electromagnetic signals to the human body, and the throb of the artery modulates the electromagnetic waves in the phase and the backscattered signals return to the radar receiver. For comparison later, the radar outputs are acquired by the DAQ in synchronization with the blood pressure signals. With displacements of micrometre-level, the distal pulse are so weak to be accurately detected that it calls for high sensitivity which can be achieved with millimetre-wave frequencies.

Therefore, the interferometric radar sensor system is custom designed to work at radar sensor, whose wavelength is only 2.5 mm, so the sensor system is available to antennas-in-package (AiP), greatly reducing the system size. The block diagram inserted in Fig. 1 shows the composition of the radar sensor system, mainly including a radar front end and an intermediate frequency (IF) amplifier circuit. The distal pulse is a low-frequency motion of less than 3Hz that modulates the radar signal in phase. Therefore , accurate demodulation of the phase information is the essence to extract the pulse signal. The modified differential and cross multiply (MDACM) algorithm is applied to linearly demodulate the phase information so as to extract the body motions in this paper.

As long as the displacement of the body motion is obtained ,the distal pulse waveform can be reconstructed. The pulse waveform is a combination of a forward wave and a reflected wave, and RPTT can be acquired by extracting the time interval of the first and the second peak in one cycle of the pulse signal. Since RPPT is found linearly related to PTT BP can be estimated as follows, replacing PTT with RPTT.

III. EXPERIMENT AND RESULTS

Experiments were carried out in the operating room with permission, patients with cardiovascular diseases were tested for several minutes after operations. The experimental set up, in which the invasive system DTX Plus and the arterial catheter were already set by surgeons for intraoperative observation, and the radar was placed at the patient’s elbow. The radar signals and pressure signals were collected for about 2 minutes in every trial.

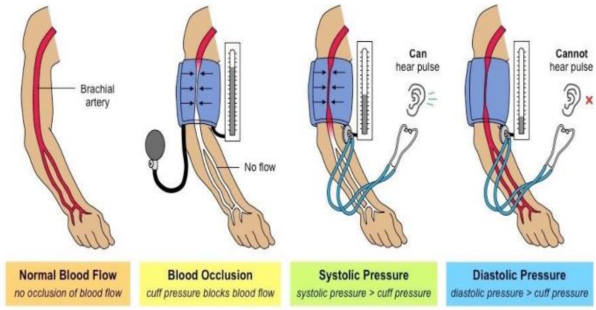


Fig2.Spygmomanometerblood pressure measurement

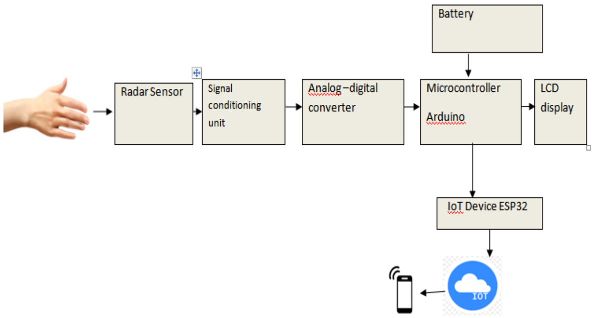
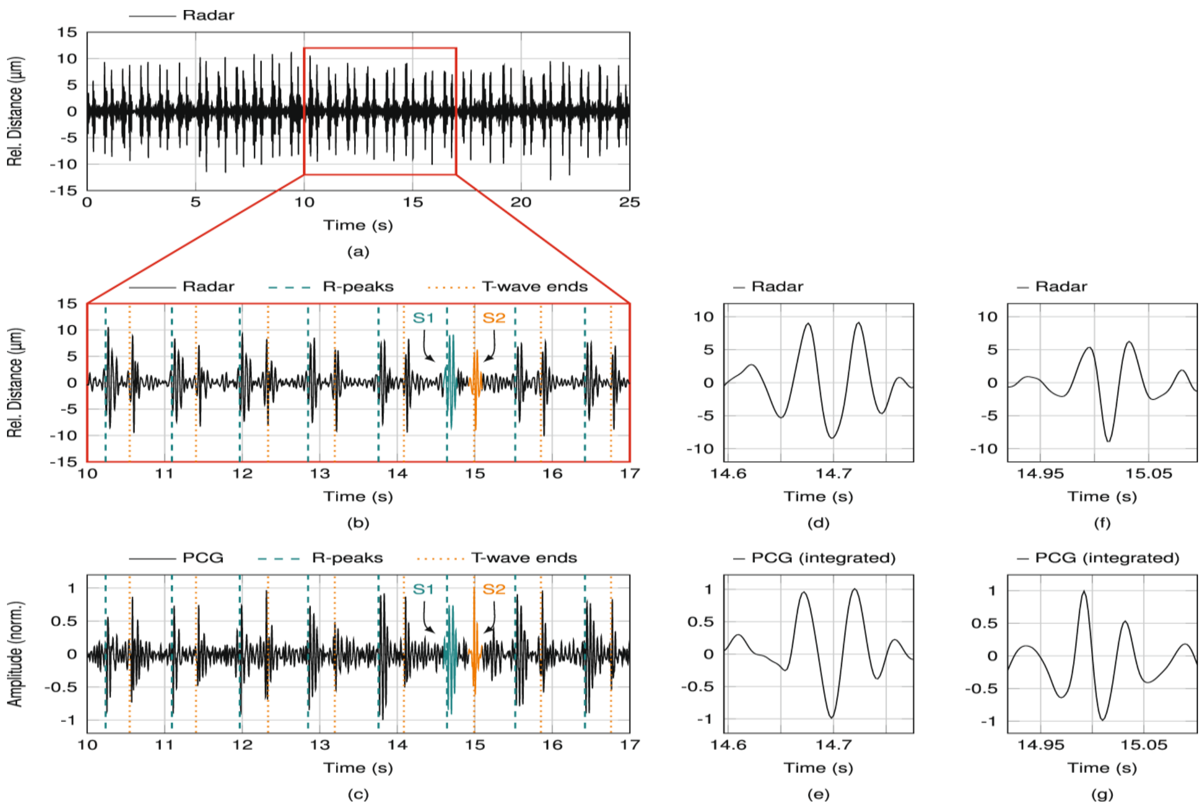


Fig 3.Block diagram of non-invasive blood pressure Measurement using IOT

DTX Plus, which is the main component as a pressure transducer. The radar sensor system is designed to be a highly compact 4 layer PCB with a size of 15.24 mm × 17.043 mm × 1.6 mm, whose radar front end is designed on the top side of the PCB as shown , while the voltage input and IF amplifier circuit are on the bottom side. The whole radar system is packaged by a small 3D printed box for easy wearing . The monitor screen connected to DTX Plus, simultaneously displaying heart rate (HR), peripheral oxygen saturation (SpO2), and BP, the blood pressure waveform that is obtained by integrating the signals collected form DTX Plus output for reference, and the demodulated radar signal that represents the brachial artery pulse waveform. The result demonstrates the same amplitude trend and period of the two waveforms,indirectly showing the high accuracy of the radar system. Since each pulse corresponds to a RPTT, SBP, and DBP, the real-time continuous BP estimation can be achieved by acquiring every RPTT of pulse waveforms and converting them to SBP and DBP through prediction model. An example that the RPTT, reference SBP and DBP of the first 50 pulses were taken as a training set for linear fitting, thus obtaining γ value for the testing set of the rest 66 pulses to estimate

BP. The testing errors are larger than those in the training set, but all the errors are below 2.6 mmHg. Fig. 4 (a) are results of a patient who has a small blood pressure fluctuation less than 4mmHg. Errors of those who have larger blood pressure fluctuation will increase , however, the mean errors are still below 3 mmHg.



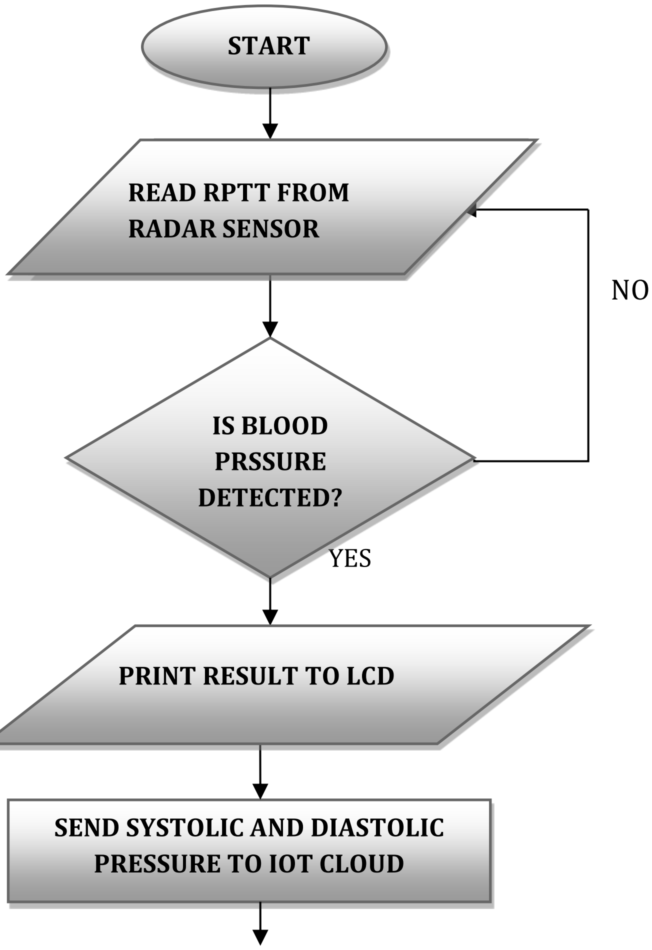


Fig 4.shows the RPTT and flow chart of non-invasive blood pressure measurement

IV. CONCLUSION

There is a strong need for continuous ,non-invasive, and cuff less blood pressure monitoring. A radar-based pulse wave extraction algorithm was presented that allowed pulse wave analysis on the individual pulse waves. In this paper, a non-invasive and continuous blood pressure estimation technique based on a novel miniaturized radar is proposed. RPTT can be extracted from the linearly demodulated radar signals to estimate blood pressure through prediction model. Additionally, a wearable and cuff less device would increase patient comfort and therefore lead to more realistic blood pressure readings that are not distorted due to discomfort. It can therefore be concluded that radar-based blood pressure monitoring is indeed feasible and a promising approach that could be integrated into wearable devices for at-home blood pressure monitoring and screening applications. Since the technique applies to various body regions that have a strong pulse, it is possible for the sensing system to be integrated into different forms for applications inside and outside the clinic.

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