Early detection of preeclampsia using ambulatory blood pressure monitoring using wearable devices and Long Short Term Memory Networks (LSTM-NN) on the edge.

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Abstract

The Sustainable Development Goal (SDG) 3 aims to reduce the global maternal mortality ratio to less than 70 per 100,000 live births. These deaths are caused by among other things the emergence of conditions such as pre-eclampsia during pregnancy. If undetected the condition can lead to the loss of both the mother and child, and often times persists even beyond the delivery of the baby. This study is seeking to explore the use of wearable devices for ambulatory blood pressure data collection for use in blood pressure prediction using Long Short Term Memory (LSTM) recurrent neural networks on mobile devices. It is expected that such a solution will be of great benefit in the detection and management of general blood pressure conditions and not just preeclampsia.

Keywords: pre-eclampsia, maternal, ambulatory blood pressure monitoring, artificial intelligence

Introduction

Preeclampsia is a pregnancy complication characterized by persistent high blood pressure. It usually begins after 20 weeks of pregnancy in women whose blood pressure (BP) has been normal. If left untreated it will progress to eclampsia that is often fatal to both mother and baby. (Macdonald-Wallis, C *et al* 2015). Preeclampsia is often diagnosed when a mother goes to the health care facility for routine check where BP measurement is taken. The first sign of preeclampsia is a BP reading exceeding 140/90 in two or more occasions, at least four hours apart at 20 or more week's gestation. Most pregnant mothers in Low and Middle Income Countries do not have personal BP machines to take regular BP readings thus they depend on BP reading during the antenatal clinic visits, which are 4-5 for the entire pregnancy. Early detection of preeclampsia is often missed during these visits because the BP measurement is often taken once unless otherwise indicated during the visit.

The detection and management of preeclampsia in out of clinic settings has however become much easier in the recent past through the development of smart blood pressure monitors. These devices that are now readily available on the market use a variety of non intrusive methods such as a cuff that inflates slightly to measure systolic and diastolic pressure via the oscillometric method as is the case with the Omron Smart watch (Omron 2019) and using a combination of optical sensors and clinically validated software algorithms as is the case with a number of smartwatches such as the one developed by Aktiia (2018) and Bpro by MedTach Inc (2018). These devices are not only able to take readings and generate alarms but are also capable of transmitting this data to other devices such as mobile phones for use in further analysis using techniques such as machine learning.

The use of machine learning techniques for blood pressure analysis, or more specifically, prediction is a practice that is steadily growing using techniques such as Artifical Neural Networks (Hao *et al*, 2015), as well as classification and regression trees (Zhang *et al*, 2018). Additionally Long Short Term Memory (LSTM) networks are increasingly being considered in studies such as the ones by Su *el al* (2017), Zhao *et al* (2019), Lo *et al* (2017) and Radha *et al* (2019). A majority of these techniques, current studies and solutions are developed and deployed on devices with significant computing and storage power such as servers and super computers which presents a major challenge overall in the potential utility of machine learning for individuals who increasingly prefer to access services, content and solutions on their mobile devices.

Purpose of the study.

This study is therefore seeking to explore ways in which an LSTM solution for preeclampsia monitoring and prediction can be accessed from a mobile device.

Study hypothesis

H_o: Long Short Term Memory Networks (LSTM-NN) deployed on mobile devices is not accurate in predicting 48-hour blood pressure levels among expectant mothers.
H_a: Long Short Term Memory Networks (LSTM-NN) deployed on mobile devices is accurate in predicting 48-hour blood pressure levels among expectant mothers.

Study Justification

The use of artificial intelligence embedded in mobile applications is now a common practice and there are a great number of approaches for scaling down models to allow them to work in these resource constrained computing environments. In addition Long Short Term Memory Networks (LSTM-NN) have successfully used for predicting blood pressure in the past.

Conceptual framework

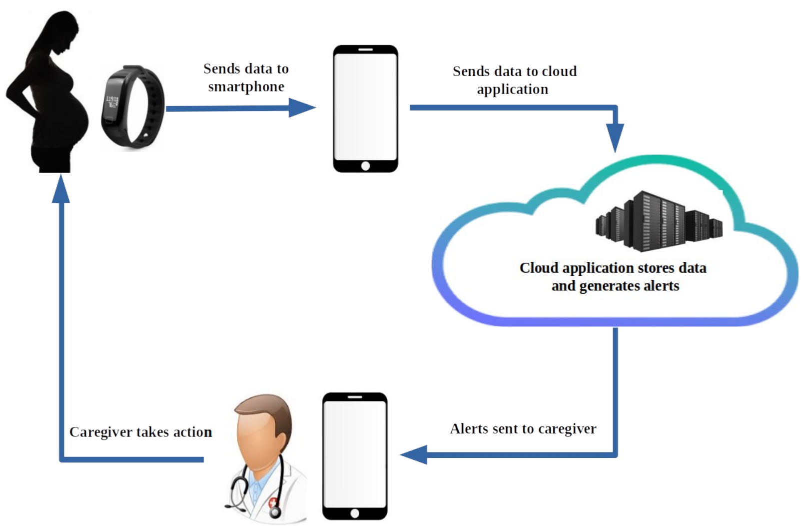

Figure 1: System model integrating a smartwatch, mobile application and cloud application for blood pressure measurement and analysis adopted from Mueni, Thiga and Muchiri (2018)

A wearable wristband smart watch will be used to measure BP. The BP reading will be transmitted to a mobile phone application via bluetooth. The application will analyze the data and alert the mother when the BP reading is abnormal. The mother will be asked to record the activity that she was involved in during the abnormal BP reading (health behaviors, social and work related events). The mother will be asked to identify future events from a calendar and in combination with the BP data predict 48-hour BP levels using Long Short Term Memory Networks (LSTM-NN) deployed on the mobile device – Edge AI. This prediction will aid in early detection of pregnant mothers who are at risk of developing preeclampsia therefore instituting early measures to prevent this occurrence. This approach is possible in resource-constrained areas because artificial intelligence (AI) embedded in mobile phone application can be scaled down. While LSTM-NN has been used for blood pressure prediction its use has not been considered in a scenario that uses less data and on a mobile device.

Methodology

Time series experimental design will be used in this study. A total of 352 pregnancy mothers(Sample size calculated using General Linear Multivariate Power and Sample Size (GLIMMPSE)) at 20-week gestation will be included in this study. The mothers should have not had hypertension before pregnancy. The mothers will be provided with wristband smart watch that will measure the BP and relay it to the mobile phone for analysis. The baseline measurement will be taken at 20 weeks gestation. Abnormal BP will be recorded through out the 20 weeks period. Mothers will be shown how to enter their activity when the abnormal BP is recorded. Using the abnormal BP and the activity entered, the app will predict future BP reading that will be compared with actual reading at 25th, 30th, 35th and 40th week gestation. Paired sample T test will be used to determine the difference between the predicted and actual BP reading at the different time points. Twelve research assistants will be trained who will in turn train the participants on the use of the devices.

Expected Outcomes

The work will develop an integrated solution comprising a smartwatch to take and transmit BP readings to a mobile application via Bluetooth. On the mobile application the BP readings will be analyzed to generate an alert if the reading is above or below normal levels. . The users will also be prompted to indicate the kind of activities they are engaged in when the abnormal BP levels are detected. A LSTM-NN machine-learning algorithm will be trained, tested and validated for blood pressure prediction. The algorithm will be deployed on the mobile application to learn from the individual's BP and activity data. For predictions the user will be prompted to indicate future activities on the mobile application . The indicated future activities and previous learning will be used to predict the users future BP. The predictions will be compared with the actual BP readings on the future indicated date to ascertain if the predictions are accurate.

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