Leveraging Wearable IoT Solutions and AI for Improved Orthopaedic Care in Kenya

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Abstract

This work combines wearable IoT devices and Artificial Intelligence (AI) to enhance clinicians' monitoring of orthopedic patients' recovery after a clinical procedure, aiming for improved outcomes. The objective is to advance techniques used in measuring joint flexion angles, which have several drawbacks such as relying heavily on the clinician for accuracy while also being invasive as they require physical contact between the patient and orthopedic specialist. This short paper details the progress achieved in developing two methods of approximating the human joint flexion angles as well as a comparative analysis of the two implementations. Ongoing work involves enhancing the implementation for actual deployment for the first round of testing of the feasibility of the solution in a clinical setting. This work can have a significant impact on the accessibility and affordability of innovative healthcare monitoring technologies in Kenya where the need for quality orthopedic care is much greater than can be met by the available personnel.

1 Introduction

The knee is an important load-bearing joint of the human frame that plays a major role in supporting the upper body when standing or in motion [1]. The forces acting on this joint range between 2 to 3 times the body weight, exposing the joint to a variety of load conditions that make it one of the most vulnerable to injury or trauma. Obesity, lifestyle diseases, and aging are also among some of the causes of wear and tear on the joints [2,3].

In Kenya, the number of orthopedic surgeons is estimated at around 100 but those registered and accredited by the Medical Practitioners and Dentists Board are less than half that number, with most of them practicing in urban cities and hospitals. This means that the ratio of the Kenyan population to the number of orthopedic surgeons(1.1 million to one) is way below the WHO-accepted figure of 100,000 to one [4]. Total Knee Replacement (TKR) is an effective treatment procedure for knee conditions such as osteoarthritis[5]. However, after the procedure, restricted postoperative knee flexion is the most frequent complication and also the main cause of patient dissatisfaction due to the limited range of motion of the joint [6].

Currently, orthopedic specialists use goniometers [7] and estimated passive observation to measure a joint's angle of flexion within its Range of Motion (ROM). Goniometers have some shortcomings associated with their use, among them being highly prone to human judgment and errors when measuring the flexion angle of a joint. They are also more invasive, as the specialist has to come into physical contact with the patient when using the goniometer to extract readings from it. On the other hand, modern technologies have been proposed for use in gait analysis, and joint flexion measurements, but present a heavy budget for orthopedic clinics in rural Kenya.

As such, this work aims to develop a cost-friendly, less invasive, and accurate solution for measuring and recording human joint flexion angles. We develop software and hardware for a wearable IoT device[8] and design a computer vision-based human pose model to simultaneously estimate the joint flexion angles from real-time video input. We also conduct a comparative study of both methodologies. The work on implementation, testing, and a comparative result analysis of the wearable and human pose model has been presented at IST-Africa 2023 conference[9]. The ongoing work involves packaging the device to allow successful deployment and testing in a clinic.

2 Methodology

The project implementation involves the development of the wearable device and the human pose model to work simultaneously in determining the flexion angle. Figure 1 depicts the overall system architecture from receiving input to storing the data in a database and producing a graphical output of angle measurements. The hardware setup shows the components we put together to have the NVidia Jetson Nano running. With the subject's knee in the knee brace holding the wearable device, connected to NVidia Jetson Nano via Bluetooth, and within the webcam's view, we can measure the knee flexion angle. The measured angles are stored in a time series database, InfluxDB, and simultaneously queried in a real-time fashion to feed a gauge plot dashboard. Both the doctor and patient can monitor the changes in the knee position and its flexion angle through the dashboard.

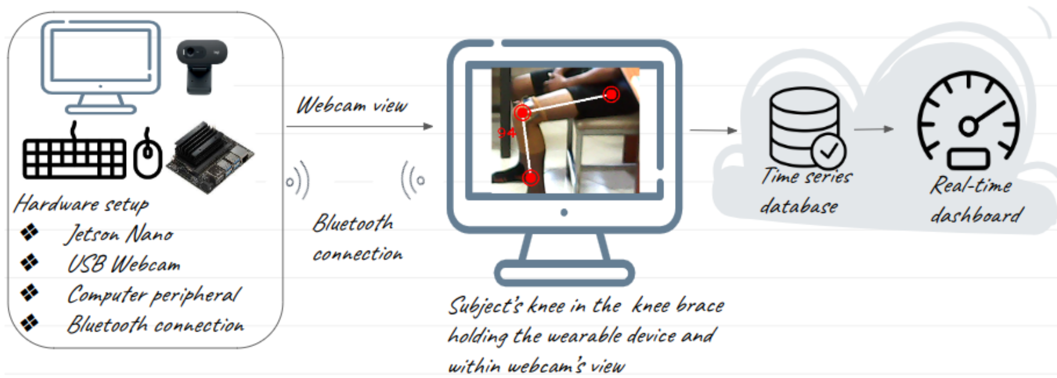

Figure 1. The system architecture of the wearable device and the human pose model

3 Results

The first author of this paper wore the wearable device and at the same time positioned himself within the webcam's range of view to measure the knee flexion angle simultaneously. The readings from the wearable device and the human pose model show consistency in the three positions we decided to focus on: that is standing, sitting, and squatting. The graphs shown in Figures 3, 4, and 5 were generated from a Juptyer notebook to show a clear visual comparison of the data collected from the readings of this device.

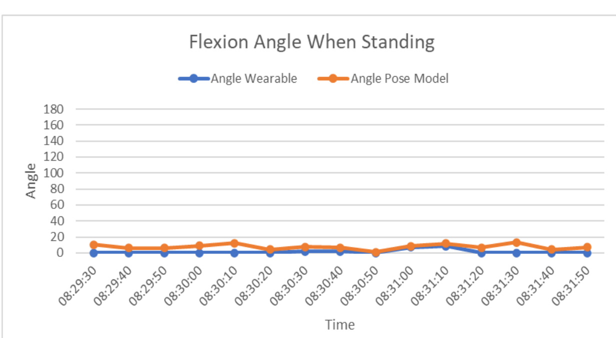

Fig 2. Flexion angle while standing

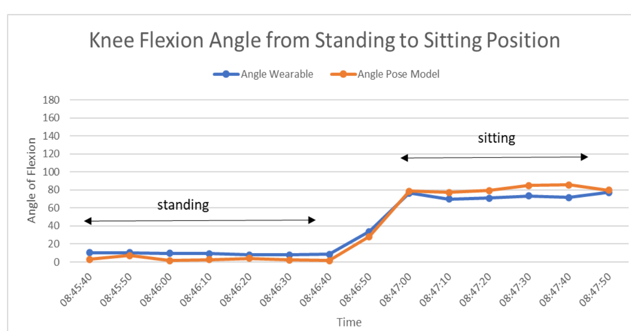

Fig 3. Flexion angle from standing to a sitting position

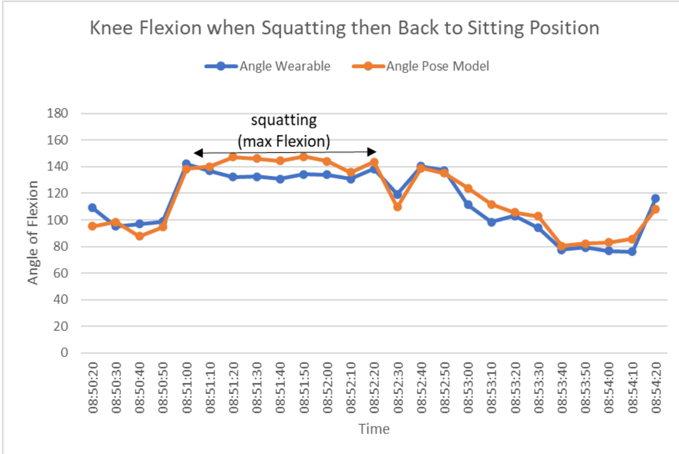

Fig 4. Flexion angle when squatting then back to sitting

4 Discussion and conclusion

The presented results directly compare the knee flexion angles estimated by the wearable device and the human pose model working together in tandem. Figure 2 is a graph showing the comparison of the two readings when the subject is standing upright. As expected, there is near zero flexion from both readings because the flexion of the joint is zero when the leg is fully extended. Figure 3 shows the results of the transition from a standing position to a sitting position while Figure 4 is showing a transition from a sitting position to squatting (maximum flexion) and then back to the sitting position. When seated the expected angle of knee flexion averages between 80° to 90° and when squatting it lies between 130° to 140°.

The results shown in this paper are from testing the prototype internally because the test subjects considered were healthy with no orthopedic complications. Therefore, a broader validation of this solution is necessary, particularly by testing the prototype on recovering orthopedic patients. This constitutes ongoing additional developmental work before we deploy the prototype in a clinical setup.

Acknowledgments

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