Treating Knee Complications using Neural Networks

Abstract
Knee pain and complications are one of the most common anomalies that affect people of all ages. It requires the patients to undergo intensive treatment for a long time. Knee pain may be the result of an injury, such as a ruptured ligament or torn cartilage. Medical conditions including arthritis, gout, and infections also can cause knee pain. The present state of society in both developing and developed countries though due to dissimilar reasons are foreshadowing a rise in knee complications. The treatment process involves some recurrent measurement in order to assess progress such as goniometry. It may be neglected by the patients as the equipment are complex and takes more time. Medical professionals use flexion angle as a yardstick to assess the angle of motion of the knee.Flexion angle of a knee is the angle measured between 3 points,the center of the leg,center of the knee and center of the thigh as shown in figures 0.1 and 0.2 given below. A deep learning approach is presented using a synthetic dataset to measure the flexion angle of the knee.

Keyword : Goniometry, flexion angle

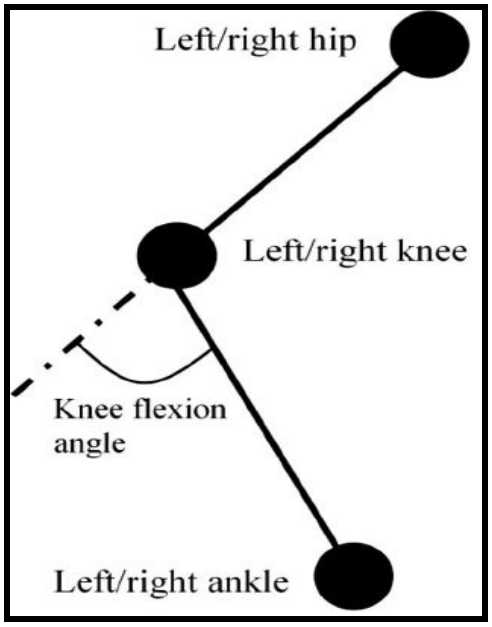


Figure 0.1

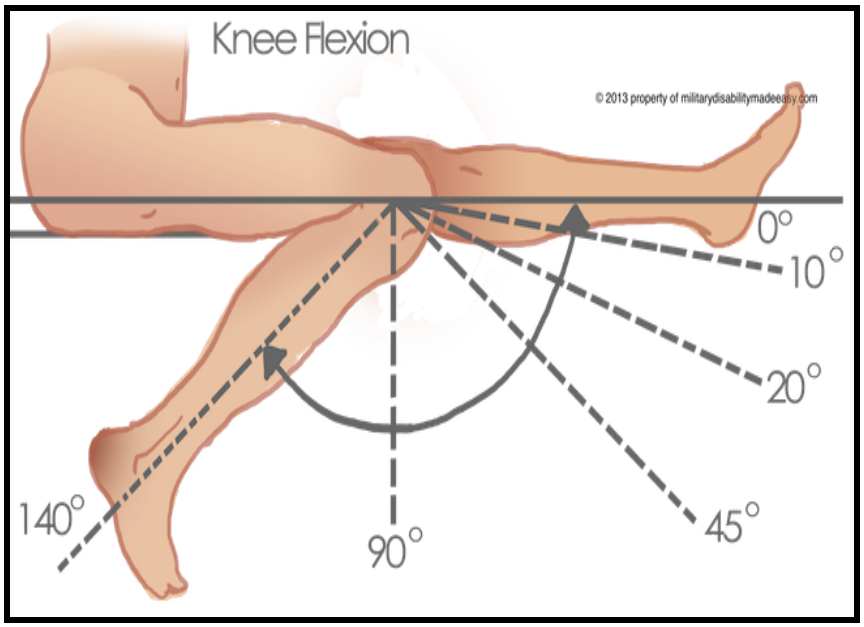


Figure 0.2

1. Problem Identification

1.1 Obesity and increase in knee problems

Urbanisation is on a rise in developing nations and as seen by figures and census, the rise in urbanization leads to an increase in obesity. Obesity is the most prominent causes of knee problems.Urbanization leads to new, more sedentary types of jobs, as more people start slinging expense reports instead of hay bales. And as more women move into white-collar work, they have less time for cooking and rely more heavily on prepared food. Children, too, don't play outdoors as much and spend more time sitting. All the preceding aspects lead to obesity and weaker bones, thus increasing the number of people with knee problems. The current statistics justify the preceding norms as seen in Figure 1.1. According to a report by Urbanet, urban population will increase from 3.968 billion in 2015 to 6.419 billion in 2050 and if the current trends are to be followed, the number of obese people will increase from 1.19 billion to around 2 billion and thus a surge in knee complications.

1.2 Aging and increase in knee problems

A major concern for developed countries is an aging population as denoted in Figure 1.2 and as people age their bones and muscles weaken and deteriorate, this causes joint pain, mostly in knee joints. United Nations report on world population aging indicates that the global population aged above 60 is projected to reach 2.1 billion people by 2050 that is more than of double the present population over the age of 60. This trend is more dominant in developed nations. With an aging population, a surge in patients with knee complication is inevitable.

1.3 Correlation between Flexion Angle and Knee problems

The preceding points indicate that the surge in knee problems is inevitable in both the developing and developed world. To combat knee problems, physical therapy is predominantly advised by medical professionals. These medical professionals consider flexion angle as the best resource to advise, the type of exercise and treatment patient must follow or undergo respectively for the best outcome and in order to assess the patient's evolution and efficiently conduct the rehabilitation, health professionals (physiatrists and physical therapists) must perform recurrent measurements.

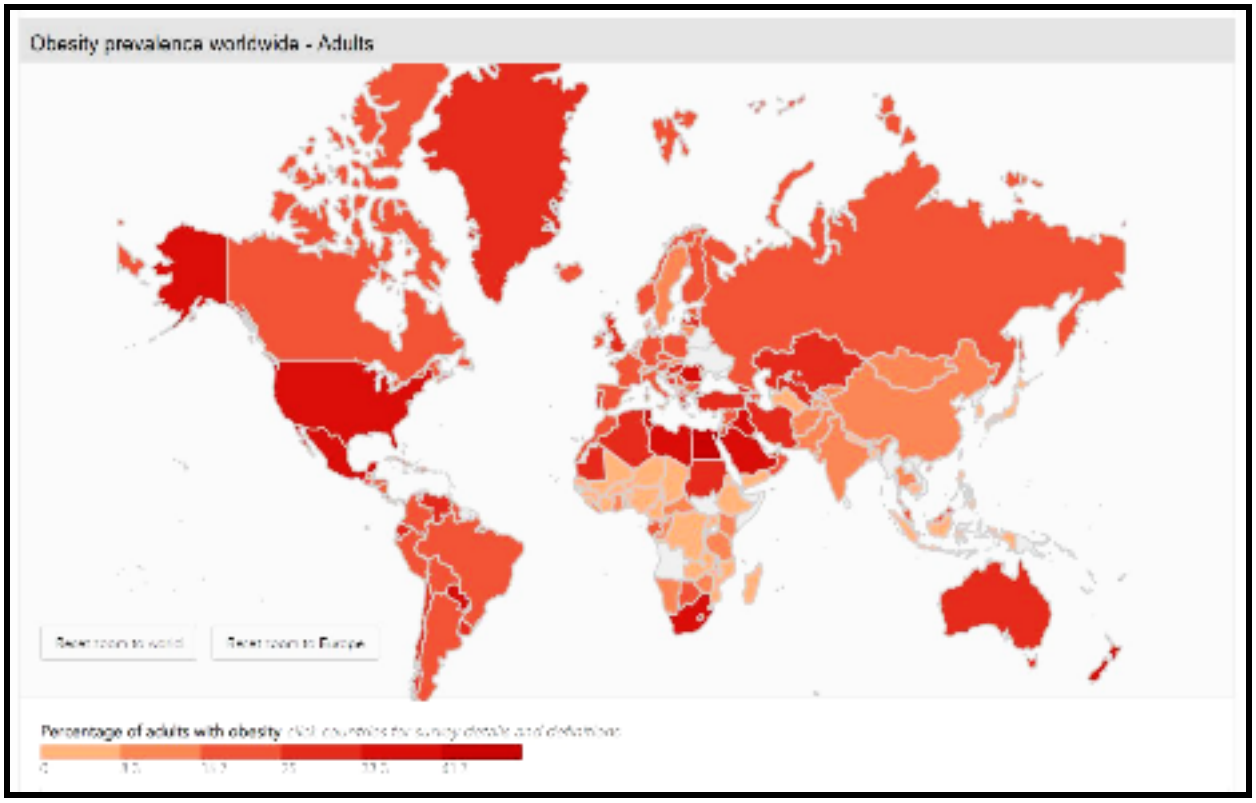


Figure 1.1(Obesity prevalence worldwide-Adults)

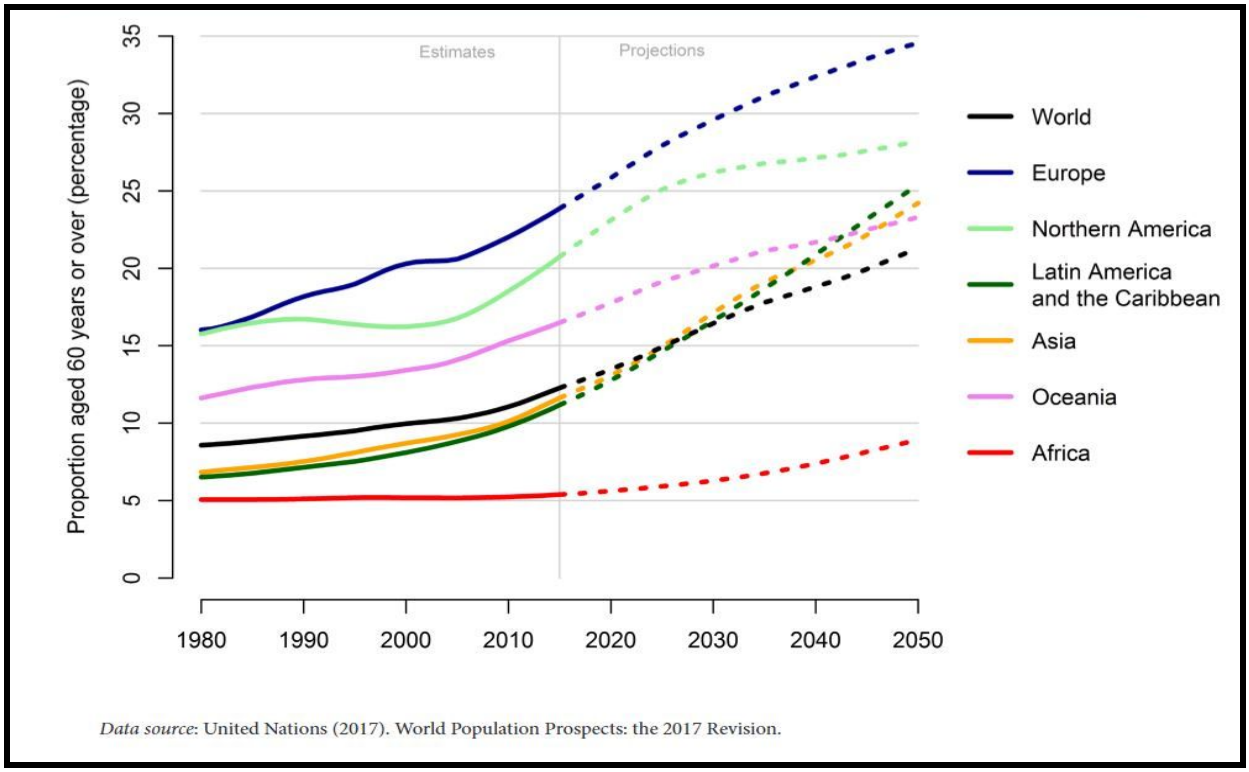


Figure 1.2(Aging population across the world)

2. Existencing Tools and Techniques to determine Flexion angle

This section analyses present instruments that are in use to perform goniometry on the knee joints to determine the flexion angle, in the context of physiotherapy and injury rehabilitation.

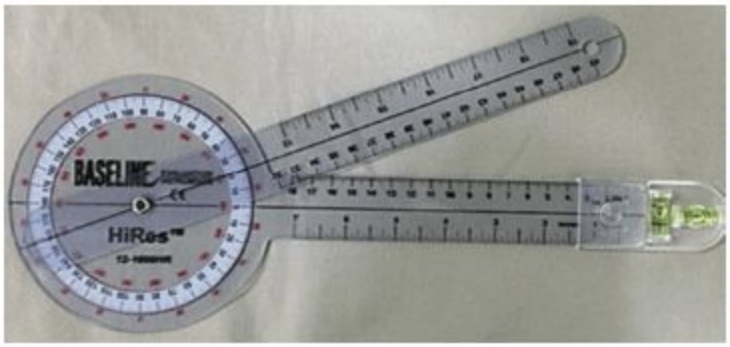
2.1 Conventional Techniques

Though conventional techniques for measurement of flexion angle were often based on simple visual estimation, several tools and techniques have been developed and updated are currently used by many health professionals. Although the developed tools are more precise than a visual estimation, they still require and have certain liabilities.

2.1.1. Radiography: The technique generally accepted as reference consist of direct observation of the bones in a radiograph. However, due to radiation exposure, this method cannot be used frequently.

2.1.2. Universal goniometer:

This is one most commonly used tool for measuring flexion angle. Research indicates that, with more than 30 degrees of knee flexion, there is no significant difference between the results of a goniometer and a radiograph thus a range of error.



Universal Goniometer

While it is considered a reliable solution, it still has some disadvantage.Beside requiring a specific physical tool, it also requires a trained medical professional to manually operate the tool. Another disadvantage is that the leg needs to be stationationary during the measurement of flexion angle by a goniometer.

2.1.3 Digital Protractor:A digital protractor is a type of protractor which measures the angle automatically without the user having to read it from a scale. It can't be used directly to measure the flexion angle but by laying the device on the thigh and lower leg, a flexion angle can be

determined. This process is hectic and thus seldom used in the medical sphere to determine the flexion angle.

2.2 Unconventional Techniques

Inertial Sensor

2.2.1. Inertial sensor:The gyroscope-based smartphone is also an option to determine the flexion angle. The component relies on Earth's gravity to determine the orientation. Thus, a gyroscope-equipped smartphone can provide the same functionality as a digital protractor. Again this technique as digital protractor requires measurement of two inclination for determining knee joint angle or flexion angle. Unsuitable orientations while using gyroscope based smartphones can lead to error in accuracy.

3. Proposed Solution

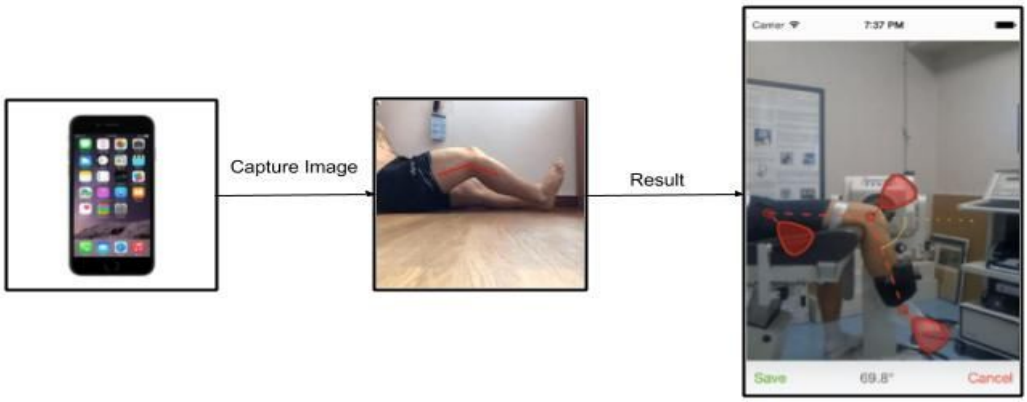


Figure 3.1

The solution that we propose uses deep learning, specifically Convolutional Neural networks to predict the flexion angle of the patient with high accuracy. The Convolutional Neural networks were trained on the synthetic dataset created using Makehuman and Blender as shown in Figure 3.2 as the required dataset was not readily available. The proposed model achieved high accuracy as we could generate varied images for the dataset with the complete range of motion of the knee joint as shown in Figure 3.3.

Figure 3.2

Figure 3.3

The client end is a smartphone application that serves the machine learning model. When the medical professional points the device's camera at the patient's leg, it immediately presents the knee flexion angle estimation on the screen.The estimations are executed in real-time, without requiring photography or any interaction by the professional other than pointing the camera, and the obtained results are promptly presented on the device's screen.
Furthermore, unlike existing solutions that rely on photography, this works not only on previously captured images, but instead, estimations shall be executed in real-time allowing dynamic measurement of the flexion angle.

How does this solution replace the traditional approach?

In order to perform a traditional approach, tools like Goniometer must be used. However, most of these tools are either not available at every physical therapy clinic or even if they are present in a clinic, due to their complex operationality, they can't effectively be operated by an un-trained medical professional. To acquire flexion angle from tools like goniometer, multiple readings are required which makes the task hectic and hence the professional who is

accountable to assess the value of flexion angle tends to evaluate by simple visual estimation which opens up room for errors to creep in. Thus in most cases, the evaluation tends to be mainly an estimate, and frequently imprecise.

The proposed solution is a smartphone app-based solution; thus, it doesn't require any professional knowledge for operating the traditional devices. Since it is an app, it has zero investment and operational cost and it is simple and quick enough to operate, so that physical therapists and psychiatrists, can use it frequently while dealing with the patient during the treatment.

The deep learning model being used in the application has been trained on diverse synthetic data plus the data that will be generated by the users of the application will, in turn, be used to significantly improve the performance of the model. Thus the evaluation tends to be quantitative, qualitative and very precise.

Conclusion

This work proposes a solution to the problem of measuring the motion range of a recovering patient's knee. It is an accurate, easy and quick method to solve the problem. The final step involves the implementation of the solution in the form of a smartphone application. The solution to the problem definition gives a satisfactory result as it uses deep learning method for image recognition. CNN model is used to train the inputs in the form of an image dataset. For future scope, enhancement of automated image can be focused by exploring different strategies.