Affordable human motion analysis system

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Abstract. An initial prototype of two-dimensional motion analysis system which uses less expensive cameras, markers along with a open-source software for precise tracking of human movements is proposed here to overcome the difficulties faced by the researchers in using the current technology. Gait analysis is normally used to treat the abnormalities in walking or running ability of an individual. The main objective of this work is to build a less expensive gait setup which will be capable of finding out basic gait parameters. Currently available expensive 3D motion analysis system is not accessible to most of the people. This proposed system can be useful to people from all walks of life and especially beneficial to the people undergoing physiotherapy, autism patients, stroke patients and sportspersons etc. This setup is both reliable and portable which makes it quite different from other existing setup. This will open up new areas of biomechanical studies which would pave the way for most of the people to move into this type of research.

1. Introduction

Biomechanical studies deals with the study of motion, posture of the human body and animals. It finds its own applications in many fields including sports, health care rehabilitation etc., Currently, Gait analysis is not accessible to most of the people in different parts of the world just because of its expensiveness. Day-by-day the patients who are in need of physiotherapy, just after the joint surgery is also increasing [1]. There arises a need of economical gait analysis setup which could help people treat their joint pain, injuries in joints thereby correcting their abnormal posture during walking or running [2]. The basic parameters of gait can be found using this setup and the movements of lower extremities is concentrated just because it bears the total mass of the upper extremities [3]. Most of the people face issues in the lower extremity resulting in an unusual gait pattern. The ankle joint is important for motion and it provides the force and energy needed for the forward progression [4]. So, the knee and ankle angle can be found and compared with the angle of the normal patients to improve their walking ability and stability [5, 6]. Different gait measurements are made [7]. The whole components used for the setup is compatible.

2. Literature Review

The 3D motion analysis is the favoured approach for the human movement analysis because of its accuracy and easy accessibility [8, 9]. But the high-priced 3-D motion analysis software force the
clinicians to explore easier ways to carry out the analysis in 2-D. Many low-cost motion analysis system has been developed recently in both kinematics as well as kinetics but in some of the work the convenience in operating those systems and the resultant output are not up to the standard which provides a scope to this work [10]. The usual errors that occur during finding out the basic kinematic parameters in other related work are manually corrected in this work with the help of the open-source software. Different human motion analysis methods are markerless gait capture, kinetics, dynamic electromyography, pressure measurement [11, 12]. Another work which uses wearable inertial measurement units to track the motion is little complicated because of the programming part and the difficulty in compiling the data from the multiple inertial measurement units installed in the different parts of the body for the continuous motion tracking [13]. Such difficulties can be overcome easily and efficiently by using this work which uses markers in the various parts of the body for the accurate tracking of human movements.

3. Method

The schematic representation of the proposed gait setup is shown in the Figure 1. Basic gait parameters to be found are fixed [14]. Four cameras are used. The tripod is adjusted to the required height and the camera is fixed for focusing on the required area of the body. The markers are placed on the desired area. The positioning of the markers is shown below in Figure 2. The markers used here is small sponge balls which is lighter and cheaper. The walk path for the movement analysis is fixed as 5 meters after a base study of the different research papers and according to the given lab space. The Camera is set to 120 fps at 720p. It is controlled by a remote. The patient is commonly instructed to walk at a normal speed (self-selected speed) down a walk path through a 1.75 m zone for acceleration, a central zone of 5 m, and a 1.75 m zone for deceleration. The central 5 m testing zone is bounded by a starting line and a finish line and the assessment of gait speed begins when the patient’s lead leg crosses the starting line and ends when the patient’s lead leg crosses the end line. The video is captured and the USB is connected to the laptop to upload the video. The video is then uploaded on to the Kinovea software for the 2D analysis of the human movement.

![Figure 1. The proposed gait setup.](image)
4. Materials
The hardware components and the open-software used for the human movement analysis setup is as follows.

4.1. Noise Play SE Action Camera
The Noise play SE action camera can record 30fps videos at 4K or 120fps videos at 720p. It has a wireless remote control that helps in capturing videos as well as images. It can capture images and videos with a super-wide angle 170 degree. A battery of 1050 maH comes with the recording time of 150 minutes at 1080p. It also supports sd cards with a memory of upto 64 GB. The average battery life is about 2.5 hours. It has 16MP resolution. Screen size is of 2 inches. It also has a built in wifi support and it comes with a complete kit of 13 accessories. It has USB port for transferring videos and images easily to the laptop.

4.2. Samsung EVO Plus Micro SD Card
Samsung evo plus memory card is a 32 GB SD card. It gives higher speed and perfect for full HD videos. It has a superfast read speed up to 95 MB/s. Memory of 32GB is enough for full HD videos, 6 hours of HD video, or 7,500 photos.

4.3. Syvo 3110 Foldable Tripod
It is a light weight and adjustable tripod and it is also sturdy and endurable. There is a center shaft jacking system to adjust height. It extends up to105 cm available. Easily 180 degree twistable. A level tester is available to achieve the stability. When the ground is not level the level tester helps to adjust the tripod. Tripod’s three way head helps in changing the orientation of the camera.

4.4. Color Marker
The marker used here is of light weight and very inexpensive. Small sponge balls of the required colour is taken for the Gait Analysis. It can be easily fixed to the area of interest.
Figure 3. A graph showing the angular acceleration of the lower extremity of a subject.

4.5. Kinovea Software
This software is a 2D analysis software. Kinovea is related to studying human motion in capture, observation, annotation and measurement. Beta version of the Kinovea software is used here. Because it comes with the added features. The time in Kinovea is shown in various units like total milliseconds, frame number etc., Labelling can be done in the video. The video can be zoomed into increase the accuracy and measurements can be done in figure 3. Frame to Frame the video can be checked. Measurements can be exported as tabular data in CSV format. Speed, distance travelled and angles of knee and ankle can be found easily using semi-automated tracking tool [15]. The angular acceleration of the lower extremity is shown in Figure 3. Two videos can be simultaneously observed using this software. The different gait parameters found using the software is shown below in Table 1 and Table 2.

| Subjects | Left step length(cm) | Left step time(s) | Left step Velocity(cm/s) | Right step Length(cm) | Right step time(s) | Right step Velocity(cm/s) |
|----------|----------------------|------------------|--------------------------|-----------------------|-------------------|--------------------------|
| 1        | 56.87                | 0.54             | 105.4                    | 60.25                 | 0.548             | 109.9                    |
| 2        | 59.97                | 0.55             | 110.36                   | 60.58                 | 0.60              | 101.56                   |

Table 2. A table showing other gait parameters.

| Subjects | Stride length (cm) | Stride time (s) | Stride velocity(cm/s) | Stance time (s) | Swing time (s) | Cadence    |
|----------|--------------------|-----------------|-----------------------|----------------|----------------|------------|
| 1        | 117.125            | 1.08            | 107.7                 | 0.705          | 0.383          | 110.29     |
| 2        | 115.42             | 0.94            | 123.66                | 0.716          | 0.454          | 104.34     |

5. Results and Discussion
The basic parameters of gait such as Step length, Stride length, Stance, Swing and Cadence are found for a subject. The velocity and time of each step and stride of both the legs are calculated. The speed is calculated manually in excel by dividing the distance by time which is shown in kinovea. The marker
tracking tool from the kinovea software is used to find out the knee and ankle angle by going frame by frame to ensure the accuracy of the measured readings and it is done by using the slow motion option in the software. Before the parameters are calculated the length or height of a known object is taken as a reference for calibration and this value helps to find the other parameters accurately. A reference point is needed for the angle measurement. The line tool is used to measure the step and stride length with the help of the markers.

6. Future Aspects
Introducing this inexpensive gait lab would help more people to come and check their gait parameters. In future 3D tracking of the human movement can be easily found using the same setup and by using a different software. More parameters can be found. And proceeding with this setup to take readings of more number of subjects to carry out a detailed study on the gait pattern of different people.

7. Conclusion
The parameters are found by one of the best open-source software available from the internet and the validation of readings are carried out by comparing the measured parameters with the standard ones from the accessible sources. For example the normal average walking cadence of a healthy person is 110-115 steps per minute and the cadence measured for subjects here is approximate to the standard value. This gait setup opens up a platform for people to get easy access to the gait lab for checking out their basic gait parameters and those who are worried about the amount they have to spend to get their few gait parameters checked in the fully fledged gait lab.

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