Feasibility of a Wearable Based Motion Tracking System

Miss. Mayuri Gulhane **Mr. Harshdeep Bongirwar** **Mr. Nakul Jainekar**

Abstract — **The objective was to develop and evaluate the feasibility of a wearable, sensor-based motion tracking system that provides an economical and quantitative means of recording upper limb motion for physical rehabilitation. The tracking system is comprised of a wirelessly connected network of inertial measurement units (IMU), each containing a gyroscope and an accelerometer. Two IMUs were rigidly attached to each subject's forearm and upper arm. A trajectorizing algorithm was developed to estimates the three dimensional upper limb motion based on the measurements of the IMUs. A major advantage of the algorithm is that it allows the IMUs to be attached with arbitrary orientation to each limb and no manuals anthropomorphic measurements needs to be performed. By recording specific known motion the sensors can be calibrated with respect to their orientation in space and with respect to their orientation relative to their respective body segments. During the experiment, healthy subjects performed elbow flexion –extension motion that were recorded using IMUs. To validate the system including the accuracy of record the same motion.**

I. Introduction

National health care is spending in the United States is estimated to reach $ 4.8 trillion in 2021, which will consumed nearly 20% of GDP .The main application of wireless wearable sensors is to reduce the heath care costs and grant users flexibility and the health domain. Typical hardware devices are used in these systems employ the use of computers, mobile devices, and a wide range of sensors (i.e) heart rate monitor, blood pleasure, body temperature, electrocardiogram (ECG), electromyogram (EMG), respiration monitor, gyroscope, etc .Most of the health care systems are designed for different types of patients based on age, diseases type, biological signals measured and other factor etc

Avoid this wearable sensor based motion tracking system is used. This paper tells the feasibility of capturing the dynamic shape of garment with only body-worn, time -of-flight sensor's i. e without assistances from surrounding environment. In the past decades, there has been a rising interest in wearable sensor based monitoring system within the healthcare domain. Various publications have investigated health care system focusing on monitoring physiological activities and motions. Typical hardware devices used in these system employs the use of computers, mobile phones, and a wide range of sensors.

Motion tracking system techniques are applied in many fields ranging from animation to the clinical application. Current sensor based motion tracking system uses a variety of sensors aimed to monitor the motion patterns of a patient.

Generally gyroscope and accelerometer data are combined to determine the pose of tracked body segments, modeled as a rigid body. Aside from the extra power consumed from continuously sampling multiple sensors, using an accelerometer can produce a extra sources of errors, primarily because the accuracy of the measured acceleration is highly sensitive to the accuracy of measured rotation. It was also necessary to correctly measure the location of the sensors on the body. In this report we have explained about feasibility, the wearable devices, features, uses. In the next section the experimental set up is given and the procedure is provided how to use the tracking..

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II. What is Wearable Devices?

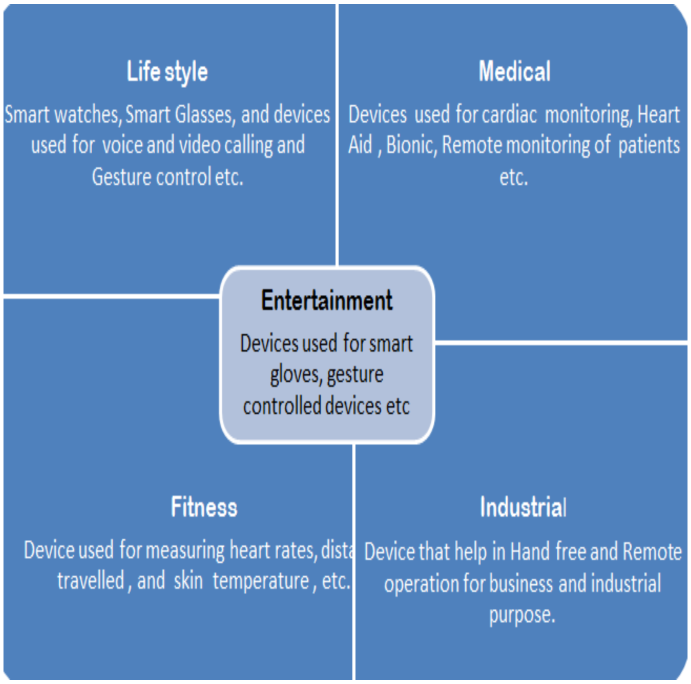
- Lifestyle:

Our developers design social media application for lifestyle wearable technology platform.It includes LED smart clothing design, Bluetooth headsets, and smart glasses and watches. It also includes personal video recording and camera functions etc.

- Medical:

Wearable health technology facilitates every day monitoring and historical data application integrated with blood pressure, vital signs and glucose monitoring

.It also include insulin pump that can be administer both basal and bolus insulin.



- Fitness:

Wearable devices includes application for heart rate, sleep and stress monitoring. It also develop healthy dieting dash boards with data archiving modules for diet tracking. They develop fitness and wellness technology software for smart clothing for body cooling and heating.

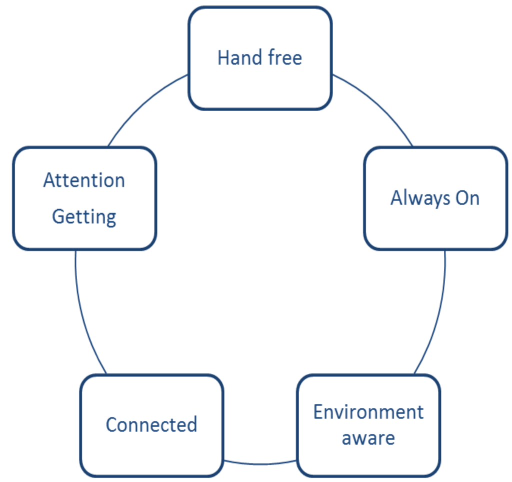
- Entertainment:

Entertainment is defined as providing amusement or pleasure to the user including digital media playing capabilities i.e. playing music, or video on a devices.

- Industrial:

Industrial is defined as functional tools designed to improve workplace safety, productivity and efficiency for companies of the industrial sector.

III. Features of Wearable Devices



- Hand Free:
- Always On:
- Environmental aware:
- Connect:
- Attention Getting:

- Hand free:

Wearable devices are hand free devices that means they can be easily control by our gesture or by our voice. This devices detect the voice or gesture with the help of sensor and thus the device is easily controlled.

- Always On:

This devices are always on because it consumes low power. It is always working in background and is always alert and wakes instantly.

- Environment aware:

This devices are aware to the surrounding environment so it uses Microphones, GPS , Cameras as other sensors.

- Connect:

This devices are connected to Wi-Fi, 3G/4G speed , Bluetooth, and Near Field Communication.

- Attention Getting:

This devices get less distracted while receiving any messages or remainders or alerts.

IV. Development Of Wearable Motion Tracking System

We developed an upper limb motion tracking system using three low-cost Sensor Tag wireless sensor units from Texas instruments. The on board IMU s were used to track the upper arm and forearm transmitting the sampled data via the devices Bluetooth modules. The sensors tag uses the IMU-3000 gyroscope. Each gyroscope was set to a range of ±250 degree/sec with sampling frequency of 50Hz which is sufficient to track a system with high accuracy. Each accelerometer has it's range set to ±4G and sampling rate set to 5Hz. It uses Velcro suit to which 36 retro reflective markers are attached.

The marker were tracked by 12 specialized cameras with infrared LED's. With this set-up, it is possible to use a Bluetooth enabled laptop to connect to and gather data from multiple sensor Tags simultaneously. Motion tracking is the process of recording the movement of objects or people.It is used in military, entertainment, sports, medical applications, and for validation of computer vision and robotics. In motion capture sessions, movements of one or more subjects are sampled many times per second. Whereas early techniques used images from multiple cameras to calculate 3D position, often the purpose of motion capture is to record only movements of the subject and not their visual appearance.

Camera movements can also be motion captured or tracked so that a virtual camera in the scene will pan, tilt or dolly around the stages driven by a camera operator while the subject is performing. Motion sensors technology makes rehabilitation possible to accurately identify The data that can be acquired using such devices support the diagnosis and the rehabilitation process by allowing therapists to precisely assess the impact of clinical interventions on the patients everyday life and recovery. Although many publications describes effective body motion data collection systems that rely on various multi-model sensors , most of the proposed hardware devices or tracking system includes sensors interconnection cables, not always flexible, and other components that have to be worn. Because of this, such system are usually not so comfortably or easily wearable and of hamper the patient's movements.

V. System Overflow Flowchart

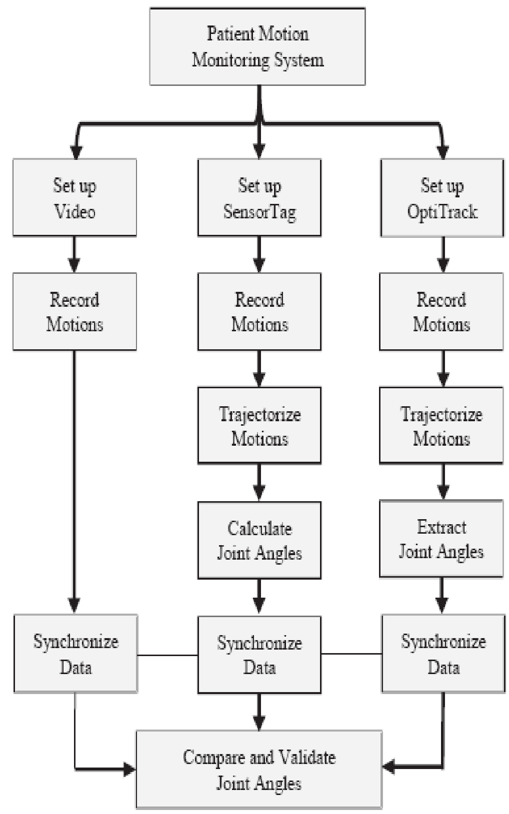


Fig. 1. System overview flowchart.

- Sensor Tag:

This kit includes one of the sensor tag which enclosure the battery . It can be easily removed to access the internal of sensor tag. To use sensor tag a smart phone with Bluetooth 4.0 is required.

- Sensor Set Up Opti Track:

In an optical motion capture system multiple synchronized cameras are installed and 2D images are captured from each cameras .This system the data through detecting emitted or reflected light.

- Trajectories:

The path taken by projectile motion is known as Trajectory .It is the path that a moving object follows through space as a function of time.

- Joint Angles:

It is an angle between the two segments on either side of joint usually measured in degree and often converted to clinical notation. Joint between adjacent segments angle includes the ankle , knee , hip , wrist , elbow , and shoulder. It is also known as Inter segmental angle.

Tracking Algorithm

The human body's posture can be fully described by knowing all of its joint angles. Gyroscope is a device used primarily for navigation and measurement of angular velocity. The data obtained from an IMU's gyroscope represents angular velocity (ώt) given in X,Y,Z rotation components with respect to it's own reference frame. To calculate the sensor's angular displacement these velocity samples can be chained together akin to mathematical integration. Due to high sensitive of accuracy of angular position to sampling error we use Quaternion to represent rotation instead of Euler angle. So by knowing sampling time interval (Δt) we can calculate Quaternion representing angular displacement (i.e.)

$$r_{S_{t-1}}^{S_t} = \cos\left(\frac{\theta_t}{2}\right) + \sin\left(\frac{\theta_t}{2}\right)\,(\omega_{tx} i + \omega_{ty} j + \omega_{tz} k)$$

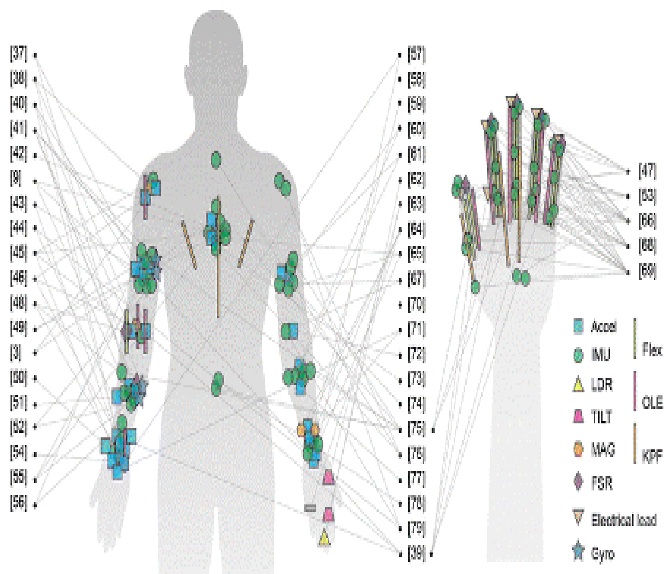
$\theta_t = |\omega_t|\Delta t$ denotes the angle step, S denotes the sensors frame, t is the current time step . i , j, k are the quaternion basic elements .The process of trajectorizing the sensor's orientation can be achieved as follow:

$$r_{S_0}^{S_t} = r_{S_0}^{S_1} \cdot r_{S_1}^{S_2} \cdot \ldots \cdot r_{S_{t-1}}^{S_t}$$

$r_{S_0}^{S_t}$ indicates the orientation of current sensor frame(St)relative to initial sensor frame(So).

- The subject were instructed to hold a neutral stand posture with arm pointing straight down.
- In this posture the sensor tag accelerometer was used to detect the direction of gravity.
- Now the subject are asked to flex their shoulder while keeping the elbow fully extended.
- These motions are sufficient to determine the orientation of arm with respect to world and orientation of IMU with arms.

VI. EXPERIMENTAL SET-UP



VII. METHOD

Requirement:

- Eight healthy adults (i.e.)
- 4 males, 4 females.
- Age(22-28 years)
- Average height should be 169.69cm.

All subject were right handed and none of them should have any previous upper limb injuries.

VIII. Procedure

Set up the video camera and 12 Opti track surrounding the subject area.
Now the 36 retro reflective markers were attached according to marker's guide.
This sensor tags were then fastened to the body as shown in fig..

- One to the fore arm.
- One to the upper arm,
- One to the chest using Velcro fabric suit.

This suits are used to rigidly secure the IMU to their respective body segments.
Now the IMU were powered On and the PC with the Bluetooth host dongle was used to connect with each sensors.
To maintain consistency between two subjects, the motion that each subject has to perform were presented in front of them by demonstrator so that they could simply mirror the motion.

This motion allows for easy identification of the exact frame of highest arm elevation in the IMU and Opti track data. This help to synchronizes in the tracking algorithm. Each recording sessions have 10 such cycles.

IX. Data collection and analysis

During experiment, this process is continue for 10 elbow flexion cycle. The trajectorize algorithm is used to obtain the elbow joint angle.The trajectorize data of IMU is compared with opti track system so as to get the motion tracking system.
CC (correlation coefficient) is used to measured the similarity between system and opti track.
RMSE (Root mean square error) is used to calculate difference of joint angles.
MAD (median absolute deviation) is used to indicate difference in angle of distribution.

Observation

- The CC for joint angle of two system was high (>0.99 degree for all subjects).
- The RMSE were low for all subjects (2.06-5.53degree).
- The MADs were also low for all subjects (2.21-3.47degree).

CONCLUSION

- In this experiment we have studied a wearable sensor based motion tracking system and elbow joint angles of eight subjects were tracked by using IMUs attached to upper arms and forearm.
- A motion trajectories algorithm was developed to calculate the elbow joint angle.
- In this experiment we have used only data from only IMU’s to track the elbow joint angle for simple motion for one arm.

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AUTHOR’S PROFILE

Miss. Mayuri Gulhane
J.D.I.E.T yavatmal
EXTC Final Year
mayurigggg0787@gmail.com

Mr.Harshdeep Bongirwar
J.D.I.E.T yavatmal
EXTC Final Year
Harshdeep26@gmail.com

Mr. Nakul Jainekar
J.D.I.E.T yavatmal
EXTC Final Year
Haxornova1331@gmail.com