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I am a Smartwatch and I can Track my User's Arm

The main objective of this paper lies in **tracking a user's arm with the use of a smartwatch**.

The main motivation behind this work revolves around the fact that arm postures are very meaningful and have a wide variety of applications such as in sports analytics, activity detection, stroke rehabilitation, gesture control, virtual reality, smart home, etc.

In order to define the problem, the authors look at two main things :

1. **How** is the arm moving and 2. **What is the meaning** of that movement?

The first part regarding how does the arm move comes under the field called **posture recognition** while the second part regarding what does the movement mean comes under the field called **gesture recognition**.

Some examples for arm posture recognition are natural user interface, sports analytics (basketball), motion gaming, healthcare, etc. There have been prior works that use classification methods for gesture recognition to classify say, a user drinking water from a user running.

The question now is, can arm postures be tracked by using a smartwatch?

The authors begin by describing the sensors inside a smartwatch - IMU :

1. Accelerometer : Measures the acceleration along 3 axes
2. gyroscope : Measures the rotation speed along the 3 axes
3. compass : Measures the projection of the North vector to the 3 axes

In order to model the system, the authors observe that the shoulder is fixed while the variations are dependent on the elbow location (2 DoF), wrist location (2 DoF) and the wrist rotation (1 DoF).

Next, the authors perform a set of experiments in order to figure out about using track arm postures :

1. Dead reckoning (Double integration) : The first step is to find out the wrist orientation which is the same as the smartwatch orientation (pitch, roll, yaw). This estimation is combined with the combined estimate obtained from accelerometer and compass to obtain the final **Wrist orientation**. The second step is to use this wrist orientation to help project the accelerometer data into the global frame of reference. Once the gravity component is removed, the linear acceleration is obtained. From here, its easy to obtain the velocity and the wrist location. Regarding the results, the wrist orientation is within 10-15 degrees while the wrist location error is unbounded! The authors conclude that this could be due to the errors in the MEMS sensors and the system won't work in unconstrained space.
2. State Estimation : This is an update over Experiment 1 since the authors conclude that the posture space is constrained. (DoF = Elbow location (2) + Wrist location (2) + Wrist rotation (1) = 5). Thus, the sensor data can be taken as the observation and estimate the 5 DoF's as the five unknowns. The compass can be considered as the posture while gyroscope is considered the differential of the posture (velocity) and the accelerometer as the double differential of the posture (acceleration). From here, it is seen that there are 15 dimensions of data (5 posture, 5 from gyroscope and 5 from accelerometer). The authors however try to reduce the dimensions since it is not efficient to use 15 dimensions).

   Since the authors already have a good estimate of wrist orientation (step 1), for a given wrist orientation, they realise that arm posture space is small. Goal : To find out this cloud for each wrist orientation.

   The authors begin by assigning three angles θ_1, θ_2, θ_3 for the shoulder and θ_4, θ_5 for elbow. Thus,

   a. Elbow Location is dependent on : θ_1, θ_2
   b. Wrist Location is dependent on : θ_1, θ_2, θ_3, θ_4
   c. Wrist orientation is dependent on : θ_1, θ_2, θ_3, θ_4, θ_5

   From here, a one to many mapping is done. Viterbi & HMM provide the optimal solution.

   In conclusion, the paper proposes a method to track postures using sensors from a smartwatch. The paper takes in the input from human kinematics and IMU sensors and fuses this observation into a HMM for training. The paper obtained a tracking error of 7.9 cm for elbow and 9.2 cm for wrist which is promising and can be improved in further work.

However, there were a few points that needed more clarity :

Questions :

1. The person needs to be still while recording movements. This could be an issue if we would like to make use of it in domains such as sports analytics, etc. How would the authors such issues?
2. Need to express the arm posture in the torso coordinate system. Can this be taken care of in the future?
3. The Hidden Markov Model and Viterbi decoding algorithms are offline algorithms (needs all the data from start to end to process) and are slow. It would be good if we can have a system that can be on-line (can process just the input and does not need all the data).

More details about the paper

Shen, S., Wang, H., & Roy Choudhury, R. (2016, June). I am a smartwatch and i can track my user's arm. In Proceedings of the 14th annual international conference on Mobile systems, applications, and services (pp. 85-96).