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Real time joint angle measurement method using multiple wearable sensors

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Abstract

With the advent of wearable products, many wearable devices have come to the market that are trying to understand human behavior. A key challenge of this would be to understand human body motion as the human body can be modelled as an articulated system with complex joint movements. This paper contributes with a real-time joint angle measurement method with multiple wearable sensors using quaternions, which describes the orientation and rotation in 3D world. The study propose two approaches solving this: (1) quaternion vector rotation based joint angle calculation, (2) gravity vector based joint angle calculation. Each approach has its limitations and a real world application might be able to fuse both methods to get a reasonable output. In this method, we place multiple wearable inertial measurement units (IMU) in known locations of the body, calibrate them to remove errors of placement and calculate real time joint angles based on sensor outputs.

Keywords: Iinertial measurement unit, Joint angle measurement, Quaternions, Wearable sensors,

Introduction

Understanding human behavior through human motion is gaining attraction in multitudes of fields such as athletics training, movie making and health status diagnostic (Chen, 2013). In special occasions this has helped to analyze complex human behaviors such as identifying unique walking patterns (Piorek et al., 2017). This specially needs understanding of the 3D kinematics of human joint angles. The traditional methods of estimating the 3D joint angular kinematics are based on data provided by optoelectronic stereo photogrammetric systems (OSS). These systems are expensive and are limited by the volume of capture (Picerno et al., 2008). Some authors calculate limb angle by using Euler angle based methods (Roetanberg et al., 2009) where famous gimbal lock becomes a problem. To overcome this restriction, a combination of IMU sensors can be used. While IMU sensors can be fixed to different body segments of the human body, they give abstract data with respect to the earth coordinate system but not related to each other. On the other hand, representing the orientation of a given sensor in the 3D world becomes complex as there can be complex movements. This becomes a limitation to calculate joint angles in an articulated complex system such as human body in real time.

While Eular angles are used to represent orientation (Seel et al., 2014) they introduce a limitation known as gimbal lock (Chen, 2013). As a better approach, the study selects quaternions to represent the 3D orientation of a rigid body in 3D space. Using quaternions as the representation method, methods of calculating a joint angle in 3D space in real-time is proposed.