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Inertial Sensing for Estimating Human Kinematics

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The development of a computer-controlled assistive mobility device is dependent on the ability to accurately predict the joint kinematics (i.e., the joint angles, velocities, and accelerations). While modern motion capture systems have allowed for tremendous advances in human motion analysis, they are large, constrained to laboratory environments, and typically expensive. These factors make them unsuitable for integration into real-world mobile devices. Fortunately the availability of inertial sensing in compact, lightweight form factors, with low-power consumption and wireless capability, provides a promising alternative for accurate estimation of joint kinematics.

Inertial measurement units (IMUs) are generally composed of accelerometers, gyroscopes, magnetometers, or subsets thereof. Recent work has shown promise for systems including IMUs that obtain reliable estimations of the relevant joint angles and velocities (Weinberg, 2006; Roetenberg, 2007, Bamberg, 2008). In this symposiast, we present a methodology that includes an extended Kalman filter for estimating the joint orientations using three-dimensional accelerations, angular velocities, and magnetic field measurements. This implementation of the Kalman filter enables a nonlinear description of the dynamics, permitting a more accurate prediction, thereby increasing the robustness of the estimation. When estimating the orientation of a single joint, measurements from two IMUs placed on adjoining body segments are necessary. For example, if interested in complete lower limb gait kinematics, seven IMUs are required to obtain the hip, knee, and ankle angles—one on the pelvis, and one on each limb segment.

The accurate and precise determination of the joint kinematics using IMUs can increase the understanding of human motion outside the laboratory environment (e.g., sport performance, pathological gait analysis, daily disability monitoring, etc.). In addition, it also enables the development of assistive mobility devices, such as prostheses and orthoses, when integrated with the appropriate feedback control algorithms.

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