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ROLL AND PITCH ESTIMATION VIA AN ACCELEROMETER ARRAY AND SENSOR NETWORKS

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ABSTRACT−In this paper, a roll and pitch estimation algorithm using a set of accelerometers and wireless sensor networks (S/N) is presented for use in a passenger vehicle. While an inertial measurement unit (IMU) is generally used for roll/pitch estimation, performance may be degraded in the presence of longitudinal acceleration and yaw motion. To compensate for this performance degradation, a new roll and pitch estimation algorithm is proposed that uses an accelerometer array, global positioning system (GPS) and in-vehicle networks to get information from yaw rate and roll rate sensors. Angular acceleration and roll and pitch approximation are first calculated based on vehicle kinematics. A discrete Kalman filter is then applied to estimate both roll and pitch more precisely by reducing noise from the running engine and from road disturbance. Finally, the feasibility of the proposed algorithm is shown by comparing its performance experimentally with that of an IMU in the framework of an indoor test platform as well as a test vehicle.

KEY WORDS : Accelerometer array, Roll estimation, Pitch estimation, Kalman filter, Sensor networks

NOMENCLATURE

θ : pitch, [rad]
ϕ : roll, [rad]
ψ : yaw, [rad]
$\dot{\theta}$: pitch rate, [rad/s]
$\dot{\phi}$: roll rate, [rad/s]
$\dot{\psi}$: yaw rate, [rad/s]
$\ddot{\theta}$: angular acceleration of pitch, [rad/s^2]
$\ddot{\phi}$: angular acceleration of roll, [rad/s^2]
$\ddot{\psi}$: angular acceleration of yaw, [rad/s^2]
P_m : measurement of $\ddot{\theta}$, [rad/s^2]
Q_m : measurement of $\dot{\phi}$, [rad/s]
P_{bias}, Q_{bias} : measurement bias
w_θ, w_ϕ : process noise
v_θ, v_ϕ : measurement noise
g : gravity, [m/s^2]
Δt : sampling time, [sec.]

SUBSCRIPTS
A, B, C : sensor nodal point
G : center of rotation
l, *r* : left, right
fr, *rr* : front, rear

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1. INTRODUCTION

As an interest in active safety systems for a passenger vehicles has increased, multiple sensor types have been developed and implemented to obtain information on vehicle dynamics. In particular, inertial sensors such as accelerometers and gyroscopes have received much attention, with applications ranging from front/side crash sensing for airbag control and roll stability control to automotive navigation systems (Kim *et al*., 2006; Ungoren and Peng, 2004; Siemens, 2007; VTI, 2007). However, the devices and sensors for active safety systems have until recently been designed separately and independently, as shown in Figure 1 (Siemens, 2007; VTI, 2007; Bosch, 2007). The primary reason for this may come from the fact that large automobile manufactures subcontract the supply of the active safety devices and systems to smaller scale manufactures (Mostov *et al*., 1997). While many of the active safety systems are in general operated independently, most of them rely on the same types of micro electro mechanical system (MEMS) inertial sensors (refer to Figure 1) and a full integration of these sensors will be the logical and inevitable direction to reduce cost in the near future.

Over the last decade, much effort has been made to estimate both roll and pitch angle, as these values represent key information for active safety control of a vehicle. Most of the approaches in the literature are based