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Gyroscopic Drift Compensation by Using Low Cost Sensors for Improved Attitude Determination

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***Abstract*— Desire of inexpensive Electro-Optic and Micro-Electro-Mechanical System (MEMS) inertial sensors has drastically been increased in the recent times for both military and commercial applications. Beside the traditional applications, reduced cost of such sensors has opened new domains in personal navigation. This paper provides a framework for attitude estimation using miniaturized and cost-effective Inertial Measurement Units (IMU). Sensor fusion of gyroscope, accelerometer and True Air Speed (TAS) sensor helps in minimizing the characteristic time growing error present in gyroscopic integrated data. A novel approach of TAS model development is implemented to generate true air speed data in the absence of TAS sensor. The presence of linear acceleration is estimated and eliminated by means of gyroscope and TAS model. Due to the slight difference in two direction vectors, an error function is estimated and constantly compensated by using a Proportional-Integral (PI) block. Coarse tuning of PI gains is applied and simulated results are produced to assess the filter performance by using real vehicle data. It has been presented that the proposed filter can be used to compute a reasonably accurate attitude solution by using low cost inertial sensors when external aiding is unavailable or not useful.**

***Keywords* — Attitude, Complementary Filter, True Air Speed Model, Air Turbulence Model, Inertial Sensors, Body Frame.**

NOMENCLATURE

b frame	Body frame
e frame	Earth frame
i frame	Inertial frame
n frame	Navigation frame (NED frame)
$\boldsymbol{C_b^e}$ frame	Transformation matrix from *b* to *e*
$\boldsymbol{C_b^i}$ frame	Transformation matrix from *b* to *i*
$\boldsymbol{C_b^n}$ frame	Transformation matrix from *b* to *n*
$\boldsymbol{C_e^i}$	Transformation matrix from *e* to *i* frame
$\boldsymbol{C_e^n}$ frame	Transformation matrix from *e* to *n*
$\boldsymbol{f^b}$	Specific force in *b* frame
$\boldsymbol{g}_l$	Local gravity vector
Ω_e	Angular rate of the Earth
$\boldsymbol{\omega_{ib}^b}$	Gyroscope provided angular rates
$\boldsymbol{\omega_{eb}^b}$	Angular rate of *body* w.r.t to *e* frame expressed in *b* frame
$\boldsymbol{\omega_{ie}^e}$	Angular rate of Earth w.r.t to *i* frame expressed in *e* frame
ϕ	Roll angle (*p*)
θ	Pitch angle (*q*)
ψ	Yaw angle (*r*)
L	Latitude
l	Longitude

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I. INTRODUCTION

Precise attitude measurement remains the foremost requirement in all aerial applications. It plays a vital role in maneuvering of an aircraft/Unmanned Aerial Vehicle (UAV) or a guided missile to follow a trajectory to achieve the set targets. Moreover, with the rapid growth of industrial automation, attitude determination has become very critical in the field of robotics and humanoids [1]. Due to recent increased demand of cheaper and reliable systems, it has become the prime concern to utilize cheaper sensors i.e., low cost IFOG (Interferometic Fiber Optic Gyroscope) and MEMS (Micro Electro-Mechanical System) based inertial sensors, with more sophisticated state estimation algorithms [2]. However, the complexity of such algorithm increases as the quality of the measuring sensor decreases. Without relying on any external reference, data fusion of available sensors can minimize the attitude errors with an intelligent and robust attitude algorithm.

Over the past decades, major research has been carried out to minimize the time growing attitude error with minimum computational requirements. Earlier, Shuster and Oh [3] have used TRIAD algorithm for the deterministic attitude while the QUEST (Quaternion-Estimator) algorithm has been implemented to measure the optimal attitude of spacecraft in weighted configuration [4]. Markely [5] has also presented a comparison of different attitude representations using two vector measurement approaches. A similar work has also been