Transportation Research Part C 69 (2016) 193–207

Contents lists available at ScienceDirect

Transportation Research Part C

journal homepage: www.elsevier.com/locate/trc

Integrated solution for anomalous driving detection based on BeiDou/GPS/IMU measurements

Rui Sun [a,*], Ke Han [a,b], Jun Hu [b], Yanjun Wang [a], Minghua Hu [a], Washington Yotto Ochieng [a,b]

[a] College of Civil Aviation, Nanjing University of Aeronautics and Astronautics, Nanjing 211106, China
[b] Department of Civil and Environmental Engineering, Imperial College London, SW7 2AZ, United Kingdom

ARTICLE INFO

Article history:
Received 2 November 2015
Received in revised form 3 June 2016
Accepted 7 June 2016
Available online 11 June 2016

Keywords:
BeiDou
Anomalous driving detection
Unscented Particle Filter
Fuzzy Inference System

ABSTRACT

There has been an increasing role played by Global Navigation Satellite Systems (GNSS) in Intelligent Transportation System (ITS) applications in recent decades. In particular, centimeter/decimetre positioning accuracy is required for some safety related applications, such as lane control, collision avoidance, and intelligent speed assistance. Lane-level Anomalous driving detection underpins these safety-related ITS applications. The two major issues associated with such detection are (1) accessing high accuracy vehicle positioning and dynamic parameters; and (2) extraction of irregular driving patterns from such information. This paper introduces a new integrated framework for detecting lane-level anomalous driving, by combining Global Positioning Systems (GPS), BeiDou, and Inertial Measurement Unit (IMU) with advanced algorithms. Specifically, we use Unscented Particle Filter (UPF) to perform data fusion with different positioning sources. The detection of different types of Anomalous driving is achieved based on the application of a Fuzzy Inference System (FIS) with a newly introduced velocity-based indicator. The framework proposed in this paper yield significantly improved accuracy in terms of positioning and Anomalous driving detection compared to state-of-the-art, while offering an economically viable solution for performing these tasks.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

The rapid growth of road transportation caused by urbanization and motorization has been accompanied by increased risk of traffic accidents. Reducing the occurrence of accidents requires not only the enhancement of the safety consciousness of the drivers and the general public, but also the development and deployment of technological measures to reduce transportation related risks. Intelligent Transportation System (ITS) technologies play a vital role in the assessment and improvement of driving safety, e.g. driving performance evaluation, anomalous driving detection, lane control, and collision avoidance. The safety performance of road transportation systems could be significantly enhanced when accurate and reliable information regarding anomalous driving detection is available and processed in a timely fashion. Real-time identification of vehicle driving patterns is a promising approach for anomalous driving detection. The underpinning idea is to extract anomalous driving cues from information obtained from the vehicle's motion sensors, including position, orientation, and velocity, to classify different dangerous driving styles and provide warning messages with recommended actions.

Lecce and Calabrese (2008) develop a driving information collection system based on a specific senor and GPS receiver, and apply pattern matching for the classification of driving styles. Their study is preliminary and does not present simulation

* Corresponding author.
E-mail address: rui.sun@nuaa.edu.cn (R. Sun).

http://dx.doi.org/10.1016/j.trc.2016.06.006
0968-090X/© 2016 Elsevier Ltd. All rights reserved.

Nomenclature

DOP	Dilution of Precision
EKF	Extended Kalman Filter
EKFCA	Extended Kalman Filter with Constant Acceleration
EKFCTRA	Extended Kalman Filter with Constant Turn Rate and Acceleration
FIS	Fuzzy Inference System
FNN	Fuzzy Neural Network
GDOP	Geometric Dilution of Precision
GEO	Geosynchronous Orbit
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
HDOP	Horizontal Dilution of Precision
IGSO	Inclined Geostationary Orbit
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
ITS	Intelligent Transportation System
MEO	Medium Earth Orbit
PDOP	Position Dilution of Precision
PF	Particle Filter
UKF	Unscented Kalman Filter
UPF	Unscented Particle Filter
UPFCA	Unscented Particle Filter with Constant Acceleration
UPFCTRA	Unscented Particle Filter with Constant Turn Rate and Acceleration
VDOP	Vertical Dilution of Precision

or field test results. Chang et al. (2008) propose a machine learning mechanism based on Radial Basis Probability Neural Network (RBPNN) to calculate the safety level of a vehicle using trajectory and velocity data obtained from vision sensors. Both simulations and field tests are used to assess this method. However, this system only provides a coarse classification of the safety levels, namely "safe", "cautious", and "dangerous". In addition, the performance of the vision sensor is susceptible to adverse weather conditions during the field test. Similar methods have been developed by Imkamon et al. (2008) and Krajewski et al. (2009), with yet again crude classification of the hazard levels and no quantifiable performance indicators. Dai et al. (2010) combine mobile phones, accelerometers, and orientation sensors to detect vehicle maneuvres typically associated with driving under influence. The acceleration patterns extracted from sensor readings are compared with patterns obtained from real-world driving tests. However, the success of such detection is not quantified, although it is argued that the system performance could be improved if GPS information were integrated. Saruwatari et al. (2012) introduce a method for detecting abnormal driving, which includes meandering, transverse motion, and sudden acceleration. The extraction of abnormal vehicle motions is performed by applying a multi-linear relationship in spatial-temporal images in the sense of group behavior. This research, however, does not present any simulation or field experiment results.

Although the aforementioned real-time driving pattern detection approaches have shown some potential for anomalous driving detection, several technical barriers remain to be surmounted. Firstly, the effective use of vision sensors is largely dependent on weather conditions. Secondly, some methods heavily rely on the readings of high grade GPS or similar motion sensors, the cost of which may hinder their widespread practical use. Moreover, most of the anomalous driving detection systems discussed before are still at an early stage of development, with few simulations or field tests. Last but no least, most such systems do not offer a robust algorithm to distinguish or quantify different types of anomalous driving styles, and their efficiency and reliability need to be further examined.

In order to address these issues, Sun et al. (2015) propose an integrated solution for lane-level anomalous driving detection, which takes advantage of high accuracy estimation of vehicle positions and dynamic parameters, and combines them with different types of anomalous driving identification method. That paper has identified a critical threshold (0.5 m) in terms of the positioning accuracy, where only positioning errors below this value ensure the validity and effectiveness of the lane-level anomalous driving detection. Unfortunately, due to the insufficient accuracy of GPS positioning, it is impossible to achieve an accuracy of 0.5 m for all instances, and the capability of any positioning methods to reach such accuracy is of critical importance to the successful detection of anomalous driving. In this paper, we have made considerable improvement over the method by Sun et al. (2015) in terms of accuracy, reliability, and practicality. This is done through both technological innovation and algorithm advancement. In particular, we introduce BeiDou as a new source of positioning data, and propose a new UPF-based GNSS/IMU fusion model.

BeiDou is a Chinese satellite navigation system initiated in 2000. By the end of 2012, the basic system construction was finished, and it has, since then, covered China and Asia-Pacific areas by providing regional continuous positioning, navigation, timing and short message communication services. It is expected that the BeiDou system will reach a global coverage and become one of the four largest Global Navigation Satellite Systems (GNSSs) in the world by 2020, along with GPS, GLO-

Download English Version:

https://daneshyari.com/en/article/524726

Download Persian Version:

https://daneshyari.com/article/524726

Daneshyari.com