Neural Networks Terrain Classification using Inertial Measurement Unit for an Autonomous Vehicle

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Abstract: This research is focusing on the terrain classification using data from an Inertial Measurement Unit acquired during vehicle motion. The proposed classifier is different from the vibration-based classifier in the fact that it uses the relationship between different axis of input as well as the spectral information to classify the difference between terrains. The data from the Inertial Measurement Unit (IMU) are three axes acceleration and three axes angular velocity. The acquired data are preprocessed and filtered by fuzzy rules, then classified by a neural network into 5 categories: flat plane, rugged terrain, grassy terrain, incline plane and unclassified. The trained networks were experimentally validated with 100 samples in each category. The result shows that the proposed classification method can classify a flat plane, rugged terrain, and incline plane 100% correctly. For grassy terrain, it can be classified correctly about 80%.

Keywords: Neural Network, Terrain Classification, 6 DOF Inertial Measurement Unit.

1. INTRODUCTION

Currently, technology related to an autonomous vehicle has been widely discussed. The terrain classification is one of the features needed in a navigation or a localization system for an autonomous vehicle. Most researches in terrain classification focused on the technique that required an input from a camera such as works by Talukder et al. (2002) [1] and Larson, Voyles & Demir (2004) [2]. The other approach is to use multiple sensors including odometry sensor, Inertial Measurement Unit together with range sensor such as works by Ojeda et al (2005) [3]. Brookes, Lagnemma and Dobowsky (2005) [4] suggested the method of terrain classification based on vibration measurement from an accelerometer using the linear discriminant analysis for the planetary exploration rovers.

2. TERRAIN CLASSIFICATON

Output data from IMU consists of AccX (x-axis acceleration), AccY (y-axis acceleration), AccZ (z-axis acceleration), Roll (x-axis angular velocity), Pitch (y-axis angular velocity) and Yaw (z-axis angular velocity).

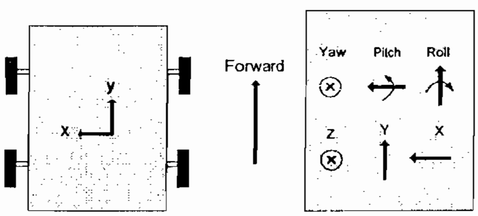

Fig. 1 The car axes.

According to Fig. 1, the car moved forward along the y-axis. The x-axis and the z-axis were the directions that it moved horizontally and vertically, respectively. As the car travelled on four kinds of terrain, flat plane, rugged terrain, grassy terrain, and incline plane, the output data from IMU was considered. While the car was moving, the acceleration data became quite noisy, thus less reliable for terrain classification. However, when traveling on grassy terrain, y-axis acceleration output magnitude was quite small when compared with the other terrains. Moreover, Roll (y-axis angular velocity) was the important variable for terrain classification. For flat plane, Roll magnitude and its variance were small, but for rugged terrain, the variance of Roll was quite large. For grassy terrain, Yaw and AccY were considered as these two signals were small in magnitude, and when the car moved on incline terrain, the result of Roll magnitude output was very small. Thus, 5 signals including running average of AccY, running average of Roll, running average of Pitch, running average of Yaw, and running standard deviation of Roll, were used as inputs of fuzzy logic filtering stage.

3. SYSTEM DESIGN

A localization system for a vehicle is usually done by analyzing and determining the relationship between various kinds of sensor measurements. As each sensor have its own behavior, advantages, and drawbacks. Therefore, the more data fusion from multi-sensor, the more accurate position estimation. The designed position estimation algorithm can be seen in Fig. 2. GPS and rear wheel encoder were used as inputs of position estimation using Extended Kalman filter with multiple models switching. The multiple models are designed according to the kinds of terrain that the vehicle travelled on, which consist of flat plane, rugged terrain, grassy terrain, and incline plane. In each case, the data from IMU are different, and the estimated state variables change according to the terrain. This paper