Multiple-Sensor Based Approach for Road Terrain Classification

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Certificate of Original Authorship

I, Shifeng Wang, certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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LIST OF ABBREVIATIONS

CRUISE	CAS Research Ute for Intelligence, Safety and Exploration
c/m	cycles/meter
DARPA	Defense Advanced Research Projects Agency
DMU	Differential Measurement Unit
FFT	Fast Fourier Transform
FPS	Frame per Second
FWT	Fast Wavelet Transform
GLCM	Grey-Level Co-occurrence Matrix
GPS	Global Positioning System
IMU	Inertial Measurement Unit
LRF	Laser Range Finder
MSE	Mean Squared Errors
MV	Majority Vote
PCA	Principal Component Analysis
PSD	Power Spectral Density
RPM	Revolutions per Minute
SVM	Support Vector Machine
USB	Universal Serial Bus

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ABSTRACT

Complete perception of the environment around a vehicle plays a crucial role in safe driving. Those include other stationary or dynamic objects, drivable regions, road signs and terrain types. In this thesis, classification of terrain types is investigated. Knowledge of the road terrain is useful to improve passengers' safety and comfort in road vehicles. It is also useful for bounding safe navigational routes for autonomous vehicles. Therefore, the aim of this thesis is to develop a methodology to identify impending road terrain types by using on-board sensors.

Two kinds of sensors are used in this research. The first kind of sensors measure parameters of the vehicle in terms of vibration and speed. Therefore, these sensors can only produce measurements while the vehicle is navigating on a particular terrain. The second type of sensors measure properties of the terrain in terms of structure and visual cues, for example cameras and Laser Range Finders (LRFs). These sensors can even produce measurements of impending terrain types. However, all those kinds of sensors have their own advantages and disadvantages. In this thesis, it is proposed to fuse them to improve the terrain type classification results.

The sensor fusion is achieved using Markov Random Field (MRF). The MRF model is designed to contain five nodes and five cliques which describe the relationships between the classification results of the accelerometer, camera, and two LRFs. The MRF model's energy function is appropriately synthesized to improve the classification accuracies of the impending terrains. Experiments carried out on a real vehicle test-bed, CRUISE (CAS Research Ute for Intelligence, Safety and Exploration) on different types of roads with various speeds show that the MRF based fusion algorithm lead to significant improvements (approximate 30%) of the road terrain classification accuracies.

Keywords—*road terrain classification, Markov Random Field, sensor data fusion, acceleration, image, Laser Range Finder*