論 文 の 内 容 の 要 旨

Thesis Summary

論文題目 **Methodologies for Automatic Detection of Transportation Mode using Data collected through Multiple Sensors**
(複数のセンサー情報を用いた交通機関自動判別手法)

氏　　名　　ムハマド アワイス シャフィク
（Shafique Muhammad Awais)

The construction, expansion, rehabilitation or discontinuation of any transportation infrastructure requires the collection of ground data, which will provide the basis for the planned operation. Similarly, policies implemented to meet certain targets, e.g. pollution control, traffic reduction, sustainability etc. also require extensive research, which is again based on data. The vitality of the data makes the collection all the more important. Conventionally, household trip data was collected by questionnaire surveys, which is still being practiced in many parts of the world even today. The collection method was later improved to conduct the surveys online. These methods have an inherent problem of dependence on the memory of the respondent. Due to this dependence, accuracy of data cannot be assured. Shortcomings include inaccuracies in recording the starting and ending times, underreporting due to missing short trips and non-response. To address the source issue, passive data collection methodologies have recently evolved.

This dissertation deals with the state of the art technique to gather and interpret travel related data. Data recorded by various sensors can be used to identify the mode of travel used by the person carrying the device. For this purpose, the most recent method is to use supervised learning algorithms like support vector machine (SVM), neural network (NN), Naïve Bayes (NB), decision trees (DT), adaptive boosting (AdaBoost), random forest (RF) etc. The current research also benefits from the use of supervised learning algorithms. The first part of the dissertation deals with the data collected by sensors integrated in a purpose-built wearable device named Behavioral Context Addressable Loggers in the Shell (BCALs). BCALs was employed to collect travel data from three cities of Japan namely Niigata, Gifu and Matsuyama. The accelerometer and GPS data was directly processed by the device and some basic features were yielded for the analysis. Overall accuracy of around 80 % was achieved to distinguish among four modes of transportation, i.e. walk, bicycle, car and train. The minimum accuracy per mode was reported to be 56 %. Upon further processing the data using moving window concept to extract a number of useful features from accelerometer data alone and using 70 % randomly selected data to train different algorithms, the classification results improved. Among the four classification algorithms tested, random forest performed best and for a final selection of 125 point moving window size, an overall accuracy of around 99 % was achieved, with minimum accuracy of 97 %.

To adopt the methodology for data collected from smartphones, only GPS data and acceleration data along 3 axes, collected by BCALs, was used as raw data. Resultant acceleration and average resultant acceleration was calculated from the individual accelerations, using moving window concept for the latter feature. From GPS data, distance and time between consecutive readings were calculated. GPS coordinates were further used to extract driving and walking distance and time using Google Maps distance matrix API. The only personal attributes collected i.e. gender and age, were also included as features. Again 30 % data was tested using random forest and the overall classification accuracy turned out to be more than 99 %. Best feature selection revealed that only four variables were enough to achieve similar accuracy.

Sensors' data using smartphones was collected by participants in Kobe city. The data was used to compare the performance of various classification algorithms for travel mode detection. Boosted decision trees was most accurate closely followed by random forest but because random forest was much quicker and the difference in accuracy was not much, it was preferred and used in the studies to follow.

Again moving window concept was used to extract various features from accelerometer data, including standard deviation, skewness and kurtosis. Gyroscope readings were directly used as features. Moving window size of 10 minutes and 10 % learning data amount was selected. The collected data was scaled down to reduced data recording frequencies to acquire an energy-efficient solution. For six modes of transportation, the overall accuracy ranged from 99.96 % for 10 Hz data to 94.48 % for 0.2 Hz data but at the same time, the computational times ranged from 304.86 seconds to 3.53 seconds. The results suggested that a compromise needs to be agreed upon between the accuracy and computational time. Later, speed calculated from GPS data was used as raw data along with resultant acceleration calculated from accelerometer data, to extract features. Because of imbalanced data, a modification was introduced to devise weighted random forest. The results were improved further by employing a 2-step post-processing method. Weighted random forest improved the accuracy to a maximum 13 % and post-processing further improved by a maximum 13 %. 10-fold cross-validation was used to validate the results. Down-sampling provided additional refinement, resulting in 98.42% overall accuracy for 0.067 Hz data. The last chapter studies the possibility of utilizing the mode choice model along with the machine learning algorithm. The combination yielded an astonishing 99% overall accuracy with no mode accuracy less than 90%.