Where Are You? Human Activity Recognition with Smartphone Sensor Data

Gulustan Dogan [a], Iremnaz Cay [b], Sinem Sena Ertas [b], Şeref Recep Keskin [c], Nouran Alotaibi [a], and Elif Sahin [a]

[a]University of North Carolina Wilmington, NC, USA [b]Istanbul Sabahattin Zaim University, Istanbul, Turkey [c]Gazi University, Ankara, Turkey

Abstract

The main purpose of this research is to recognize eight modes of locomotion and transportation activities from the inertial sensor data of a smartphone. This research is part of the Sussex-Hawaii Locomotion (SHL) recognition challenge. We compared multiple machine learning approaches to classify the eight different activities, which are Still, Walk, Run, Bike, Car, Bus, Train, and Subway. First, we performed feature engineering using a wide set of statistical domain features that were computed and their quality was evaluated. Then, the appropriate machine learning model was chosen.

Background

The source of the dataset for this SHL recognition challenge is the Sussex-Huawei Locomotion Dataset [1,2]. The measurements for this dataset have been taken from three participants. The participants movements have been recorded in eight different transportation and locomotion activities, which are Still, Walk, Run, Bike, Car, Bus, Train, and Subway. Figure 1 shows the distribution of those activities. Each one of the participants carried four smartphones at four body positions independently, and the position of the phone was unknown to them. The smartphone sensor data includes measurements of acceleration, gravity, rate of turn, linear acceleration, magnetic field, orientation of the device, and atmospheric pressure. The dataset contained train, validate, and test subsections.

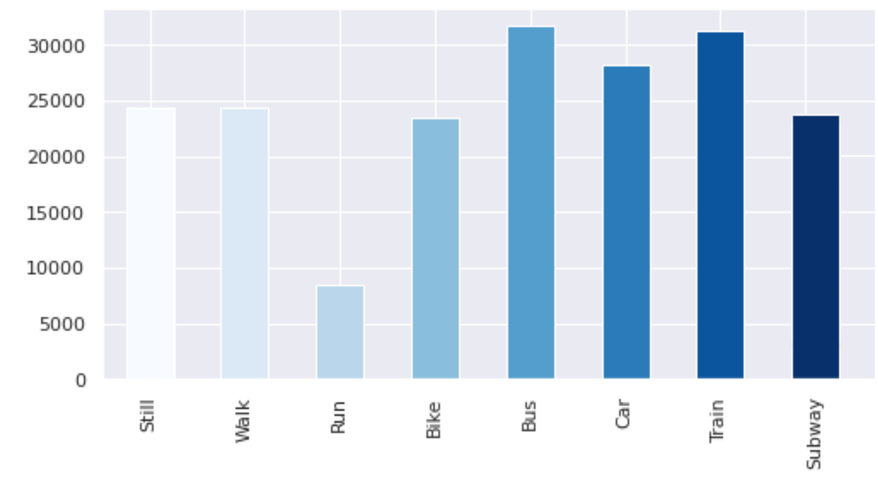

Figure 1. Distributions of the Activities in the SHL Preview Train Dataset

Results

After comparing the results of the different machine learning models when adding different modalities, we found that adding all sensor modalities made improvement in model performance except for the sensor data for the orientation as it is shown in Figure 2. Therefore, we decided not to include the orientation sensor data in any part of the training phase.

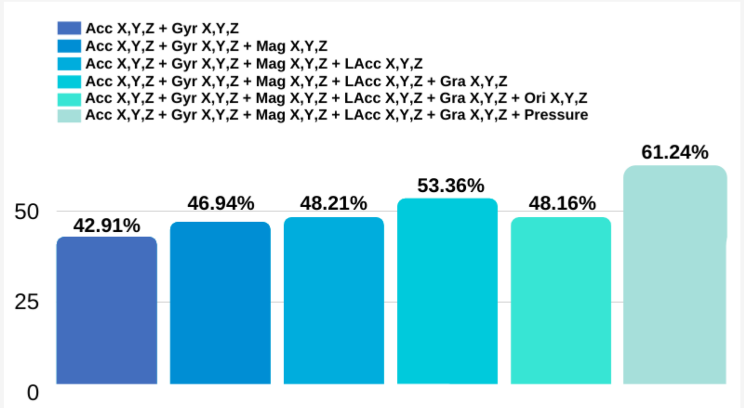

Figure 2. Validation Accuracy Based on Used Modalities

Additionally, using only the training set for model training has yielded an accuracy of 61.2% with the validation set. The model performance has been improved effectively by incorporating the validation data for model training as it is illustrated in Table 1. We took 20% of validation data into training data to evaluate the improved accuracy score. An equal number of samples from each locomotion-transportation mode category were taken from validation data to avoid overfitting. Rest of the validation data is used for testing the model.

Train Set	Validation Set	Random Forest Classifier	Gradient Boosting Classifier
Train	Validation(100%)	61%	63%
Train + Validation (20%)	Validation (80%)	73%	71%

Table 1. The Success Rates Before and After Merging of Validation Data with Train Data

Table 2 shows the success rate for different models. Based on the table, the most successful machine learning algorithms are Random Forest, Gradient Boosting and Gaussian Naive Bayesian. Therefore, we used those algorithms in the voting classifier system. Finally, our model can classify still, bike, walk, and car activities better than the other categories. That is based on the confusion matrix for our model, which is shown in Figure 3.

Machine Learning Model	Validation Accuracy	Validation Precision	Validation Recall	Validation F1 Score
Voting System (Random Forest + Gradient Boosting + Gaussian NB)	73%	74%	66%	68%
Voting System (Random Forest + Gradient Boosting + Decision Tree)	71%	74%	63%	64%
Random Forest	73%	74%	65%	65%
Gradient Boosting	71%	70%	66%	68%
Gaussian Naive Bayes	53%	59%	48%	50%
AdaBoost	47%	47%	50%	47%

Table 2. Machine Learning Models Success Rates

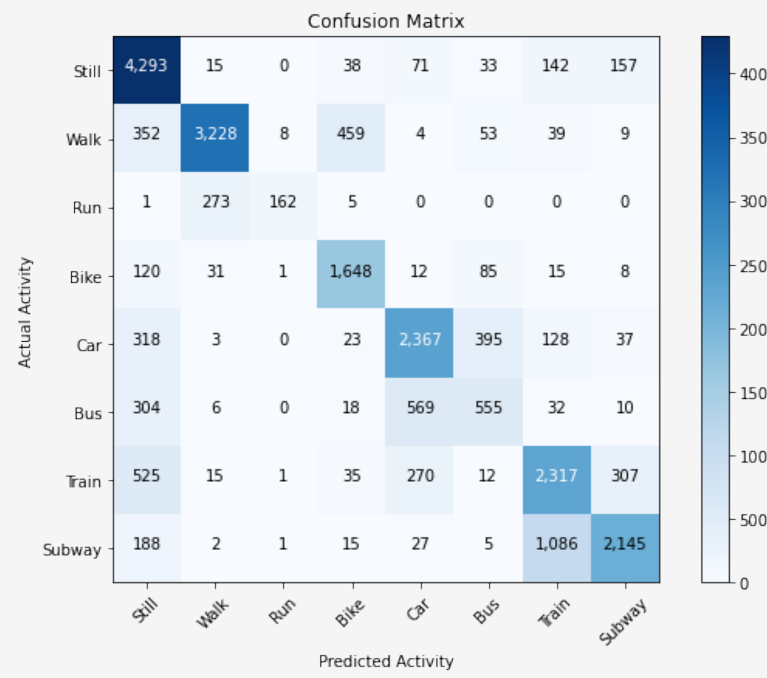

Figure 3. Confusion Matrix of Voting System Prediction

Methods

First, feature extraction was performed by calculating the mean, Mean Absolute Deviation (MAD), Standard Deviation (STD), and minimum and maximum value of each sample. Then, we compare multiple machine learning models and used the one that has higher accuracy. Random Forest, Gradient Boosting, Gaussian Naive Bayesian methods gave the best accuracies. Therefore, we decided to use a Voting classifier to combine them. Training our first model started with only two modalities, which are the acceleration and the rate of turn. After getting the statistical results for the first model, we continued adding modalities to observe model performance.

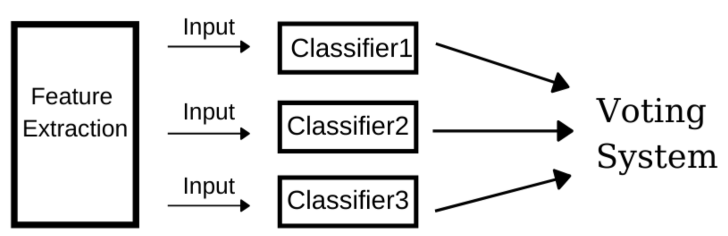

Figure 4. Schematic Diagram of the Voting System Classifier

Conclusion

Random Forest, Gradient Boosting, and Gaussian Naive Bayesian algorithms are the best between the developed models in recognizing locomotion and transportation activites. We used these models with the Voting System Classifier. Our model can classify still, bike, walk, and car activities better than the other categories. We believe this is because the other activities are considered to have faster movement; thus they have similar sensor patterns.

References

[1] Hristijan Gjoreski, Mathias Ciliberto, Lin Wang, Francisco Javier Ordonez Morales, Sami Mekki, Stefan Valentin, and Daniel Roggen. 2018. The university of sussex-huawei locomotion and transportation dataset for multimodal analytics with mobile devices. IEEE Access 6 (2018), 42592–42604

[2] Lin Wang, Hristijan Gjoreski, Mathias Ciliberto, Sami Mekki, Stefan Valentin, and Daniel Roggen. 2019. Enabling reproducible research in sensor-based transportation mode recognition with the Sussex-Huawei dataset. IEEE Access 7 (2019), 10870–10891