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Efficient Smartphone Sensor Analysis for Behavioral Profiling in Transportation Research: A Case Study of Driver and Passenger Classification

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POLICY BRIEF

BACKGROUND AND OBJECTIVES

The increasing use of portable devices, such as smartphones and wearables, in transportation research highlights an ongoing effort to improve transportation safety and efficiency in a cost-effective and unobtrusive manner. Researchers have utilized data from smartphone sensors, equipped with a range of sensors including accelerometers, gyroscopes, GPS, microphones, and cameras, to tackle issues such as texting while driving. An important use case for smartphone sensing in transportation research has been to examine differences in driving behavior between drivers and passengers. This particular research focus (i.e., driver versus passenger classification) advances the understanding of driving style characterization, which can aid in analyzing user travel patterns and traffic conditions. However, incorporating mobile sensors into transportation applications for real-world use entails balancing between the application's effectiveness in classifying driving behavior and the phone's battery longevity, crucial for sustaining usability without rapid resource depletion of the device. This is critical because prolonged utilization of mobile sensors by applications can swiftly deplete a device's battery, possibly leading to user discontent and reduced app engagement.

Our research aims were twofold. First, we aimed to conduct the first analysis of distinguishing between drivers and passengers using smartphone sensor data collected in a natural manner. Second, we aimed to further understanding on suitable methods for the deployment of mobile sensor-based classification systems for transportation research, particularly considering the limited resources inherent in many of these devices. Key research tasks included assessing the feasibility of small time frame windows in capturing sufficient data for multiple machine learning classifiers to accurately distinguish between drivers and passengers during vehicle trips; evaluating the performance of machine learning classifiers in the context of the driver versus passenger classification task; and assessing the influence of different dimensionality reduction and feature selection techniques on the classification of drivers versus passengers as these techniques have the potential to further streamline computational resources.

METHODOLOGY

We conducted 145 staged in-vehicle trips around the University of South Florida's Tampa campus, using six volunteers and various Android devices equipped with Sensor Logger v1.181 to record data from accelerometer, gyroscope, gravity, magnetometer, and orientation sensors at up to 100Hz. Each trip simulated typical urban commutes, with data collected from both the driver's and passenger's devices. Ground truth information, such as passenger or driver status, timestamps, and trip origins and destinations, was recorded. The collected data was divided into time windows ranging from 3 to 90 seconds, and statistical features (e.g., average, variance, quartiles) were extracted for each positional axis (x, y, z) to create a robust feature set.

We explored the feasibility of distinguishing between drivers and passengers using minimal data, prioritizing resource efficiency to reduce power and storage demands. Machine learning classifiers, including decision trees, random forests, and support vector machines, were tested alongside feature selection (e.g., variance thresholding) and dimensionality reduction techniques like PCA and random projection. A total of 504 classification experiments were conducted, evaluating combinations of classifiers, feature selection, and dimensionality reduction across 21 time windows. These experiments aimed to identify optimal data collection durations, analyze accuracy fluctuations, and assess strategies for achieving high accuracy with minimal computational overhead.

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RESEARCH FINDINGS

Our findings demonstrated consistent trends in classifying drivers and passengers using various machine learning classifiers. Feature selection generally outperformed dimensionality reduction techniques, particularly with decision tree and random forest classifiers, achieving accuracies of 0.892 to 0.97 on standardized features. Smaller data windows (as brief as 3 seconds) were sufficient for effective classification, with performance improving as the window size decreased. Feature standardization also played a critical role, with standardized data yielding accuracies between 0.80 and 0.97, significantly outperforming non-standardized data. However, the benefits of standardization diminished with shorter data collection periods, becoming negligible in smaller windows.

Across classifiers, the random forest consistently achieved the highest performance, with accuracies of up to 0.97 for standardized features. Dimensionality reduction, particularly PCA, performed well but generally lagged behind feature selection, especially for support vector machines, where lower accuracy (0.552 to 0.62) was observed with non-standardized data. Notably, shorter time windows (under 5 seconds) demonstrated significant classification potential, emphasizing the importance of efficient data collection strategies for sensor-based classification tasks.

POLICY AND PRACTICE RECOMMENDATIONS

Based on our findings, several policy and practice recommendations emerge to potentially enhance the effectiveness of machine learning-based classification tasks using smartphone sensor data:

1. **Emphasize Shorter Data Collection Periods**: The results highlight the significant advantages of using shorter data windows, especially under 5 seconds, which offered sufficient discriminatory power in the context of driver vs. passenger classification. Organizations should consider optimizing data collection times to balance classification performance and resource usage, avoiding unnecessary long sampling periods when feasible.

2. **Prioritize Feature Standardization for Larger Data Sets**: For datasets with larger collection periods, implementing feature standardization should be a priority to improve classification accuracy. The consistency observed in performance with standardized data underscores its importance for accurate results, particularly for time-intensive data collection. However, for smaller datasets, the benefits of standardization may lessen, suggesting a more flexible approach to preprocessing for shorter data spans.

3. **Evaluate Feature Selection and Dimensionality Reduction**: The superior performance of feature selection techniques, especially for tree-based classifiers, suggests that organizations should prioritize feature selection while also considering dimensionality reduction methods like PCA. While our studies found feature selection to be more effective in most cases, PCA offered benefits in specific scenarios, indicating that these techniques should be applied selectively based on the task. Importantly, the choice between feature selection and dimensionality reduction should be empirically validated for each application, as the optimal approach may vary depending on the context and dataset characteristics.

4. **Adopt a Data-Driven Approach for Policy Development**: Policymakers should incorporate findings from such studies into guidelines for sensor-based data collection, classification, and processing systems. This would ensure that data collection protocols are optimized to both meet classification goals and conserve resources, fostering more sustainable and efficient practices in areas such as transportation.

For more information on this project, download the entire report at nicr.usf.edu or contact **nicr@usf.edu**

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