Ubiquitous and Mobile Computing
CS 528: *Accelerator-Based Transportation Mode Detection on Smartphones*

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Main Idea and alternatives

Main Idea: Tracking transportation behavior of individuals

- Detect whether the user is moving
- How the user move (bus? Train? Or walk.)

Previous work use GPS:

1. High power consumption
2. Satellite problem
3. Not accurate

Accelerometer-based technique

1. Low power consumption
2. Measure human behavior directly
3. Contain high detailed information

What is Accelerometer? Challenge?

https://www.youtube.com/watch?v=i2U49usFo10

https://www.youtube.com/watch?v=Faxv0uFtuwI

Challenge: Extract irrelevant information about movement, e.g, gravity, user interaction and noise.

Preprocessing and Gravity Estimation

1. Low-pass filter to remove jitter.
2. Aggregate measurement using a sliding window with duration of 1.2 seconds
3. Project the sensor measurements to a global reference frame

Limitations:

1. Assume noise and observed accelerometer patterns uncorrelated
2. Orientation of sensors may suddenly change

To solve it, a new algorithm proposed

Algorithm 1 Gravity $(Accelerometer_{window}, TH_{var})$

if ... / pseudocode:

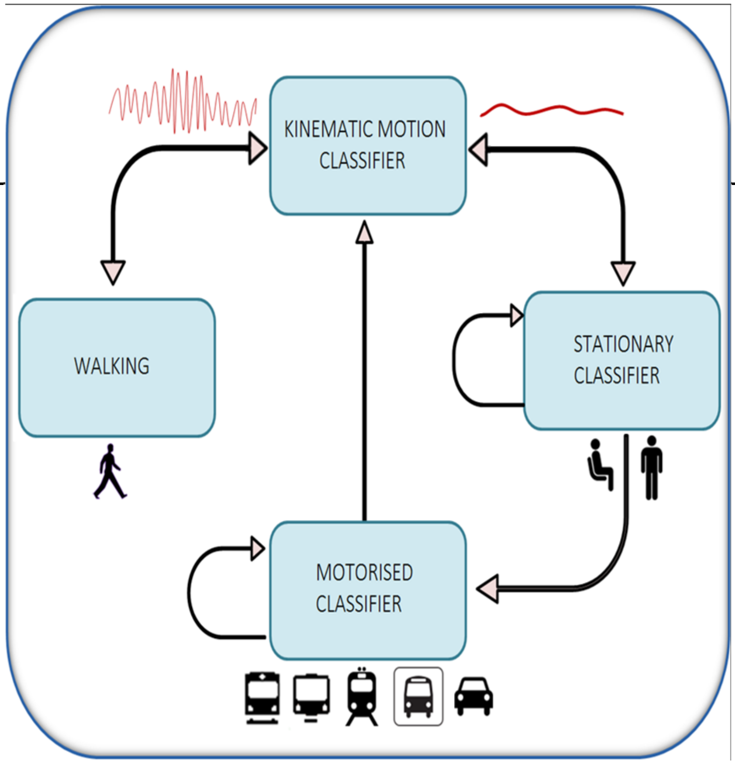
$W_{mean} = mean(Accelerometer_{window})$
$W_{var} = var(Accelerometer_{window})$
if $||W_{mean} - G_{est}|| \geq 2\text{m/s}^2$ **then**
  $TH_{var} = \epsilon$ ▷ Reset variance threshold
end if
if $W_{var} < 1.5$ **then**
  if $W_{var} < TH_{var}$ **then**
    $G_{est} = W_{mean}$
    $TH_{var} = (W_{var} + TH_{var})/2$
    $VarIncrease = TH_{var} * \epsilon_{inc}$
  else
    $TH_{var} = TH_{var} + VarIncrease$
  end if
else
  $G_{est} =$ `MizellEstimate(5s)`
end if

Dynamically adjust the variance threshold according to movement pattern

Allow the variance threshold to increase until a hard upper threshold is reached

Exceed threshold, use Mizell technique to calculate Gravity

What is Segment?



Each activity has a duration of several minutes.

Feature Extraction

Frame based feature

Peak-based features

Segment based features

Domain	Features
Statistical	Mean, STD, Variance, Median, Min, Max, Range, Interquartile range Kurtosis, Skewness, RMS
Time	Integral, Double integral, Auto-Correlation, Mean-Crossing Rate,
Frequency	FFT DC,1,2,3,4,5,6 Hz, Spectral Energy, Spectral Entropy, Spectrum peak position, Wavelet Entropy, Wavelet Magnitude
Peak	Volume (AuC), Intensity, Length, Kurtosis, Skewness
Segment	Variance of peak features (10 features), Peak frequency (2 features), Stationary duration, Stationary frequency

Classification

- Adaptive Boosting

  Iteratively learn weak classifiers that focus on different subsets of the training data and to combine these classifiers into one strong classifier

- Segment – based classification

  1. Aggregate classification results of frame and peak features over an observed segment
  2. Compute the classification result of the segment based features

- Kinematic Motion classifier

  Utilize frame-based accelerometer features extracted from each window to distinguish between pedestrian and other modalities

- Stationary classifier

  Use both peak features and frame based features to tell stationary or other modes

- Motorized classifier

  Used to distinguish between different motorized transportation modes.

Performance Evaluation

1. Accuracy of transportation mode detection

	Precision			Recall		
	Peaks	Wang	Reddy	Peaks	Wang	Reddy
Stationary	96.1 (0.5)	57.3 (4.5)	81.6 (1.0)	70.0 (2.1)	59.5 (2.3)	70.6 (2.9)
Walk	93.1 (0.1)	87.2 (0.2)	97.7 (0.1)	95.9 (0.1)	89.1 (0.2)	95.9 (0.1)
Bus	78.2 (4.2)	71.1 (1.4)	67.3 (1.6)	78.0 (3.3)	70.4 (1.4)	86.2 (6.4)
Train	68.2 (5.0)	32.1 (0.8)	7.7 (4.4)	80.1 (4.0)	31.6 (0.7)	55.4 (11.9)
Metro	64.5 (5.9)	54.4 (0.6)	70.1 (8.8)	82.0 (2.6)	51.4 (0.9)	56.6 (3.5)
Tram	84.0 (2.1)	58.1 (0.8)	82.8 (7.5)	86.1 (2.1)	58.2 (0.8)	64.5 (7.0)
Mean	80.1 (2.9)	60.0 (1.4)	68.0 (3.9)	82.1 (2.4)	60.2 (1.1)	71.6 (5.3)

1. power consumption

Application	**Energy**
Peaks TMD	**85 mW**
Wang TMD	50 mW
Reddy TMD	240 mW
Active call	680 mW
Music player	50 mW
Video recording	930 mW
Video playing	660 mW
Accelerometer	21 mW
Magnetometer	48 mW
Gyroscope	130 mW
Microphone	105 mW
GPS sampling	176 mW
Background	140 mW
Phone screen	470 mW

TMode	Precision	Recall
Stationary	61.9 (-34.2)	64.0 (-6.0)
Walk	93.0 (-0.1)	93.0 (-2.9)
Bus	71.6 (-6.6)	71.5 (-6.5)
Train	25.1 (-43.1)	54.9 (-25.2)
Metro	60.1 (-4.4)	56.0 (-26.0)
Tram	69.6 (-14.4)	66.7 (-19.4)
Mean	63.6 (-16.5)	67.7 (-14.3)

Table 8: Detection accuracy for cross-user evaluation without the peak features.

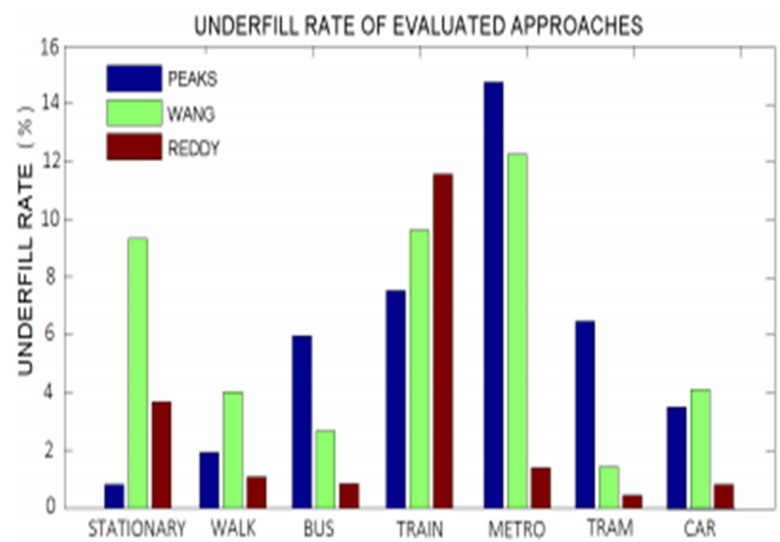
Performance Evaluation

3 Generalization performance of classifiers

TMode	Precision			Recall		
	Peaks	Wang	Reddy	Peaks	Wang	Reddy
Stationary	96.0	51.5	80.9	72.9	52.6	78.0
Walk	92.4	84.1	97.7	97.3	85.4	91.1
Bus	85.2	59.1	63.1	86.7	77.3	78.7
Train	75.9	24.8	4.4	80.7	49.3	43.6
Metro	67.1	50.4	58.1	72.7	37.9	35.3
Tram	87.7	70.9	72.4	90.0	42.1	40.1
Car	90.1	79.3	89.9	96.7	80.1	95.4
Mean	84.9	60.0	66.7	85.3	60.7	66.0

Table 11: Generalization experiment of our detection system.

4 Latency of the detection (Not good)



Thank you!