2017 NSF CYBER-PHYSICAL SYSTEMS PRINCIPAL INVESTIGATORS' MEETING

EAGER: A Cloud-assisted Framework for Improving Pedestrian Safety in Urban Communities using Crowd-sourced Mobile and Wearable Device Data (Award #1637290, Award Start Date: July 15, 2016)

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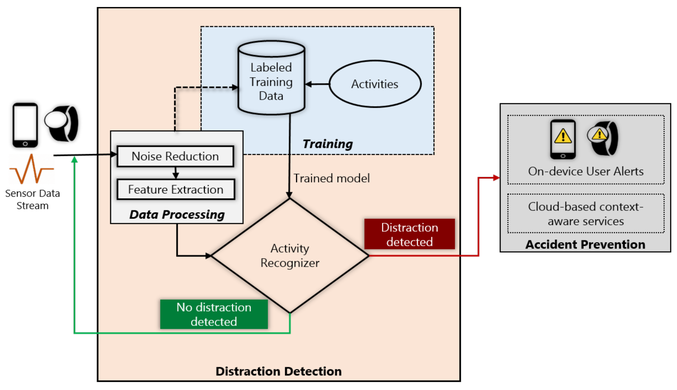
Research Goal

Design of an accurate, efficient and usable ***pedestrian safety system*** that provides timely feedback and protection against ***pedestrian distractions***.



Key Challenge

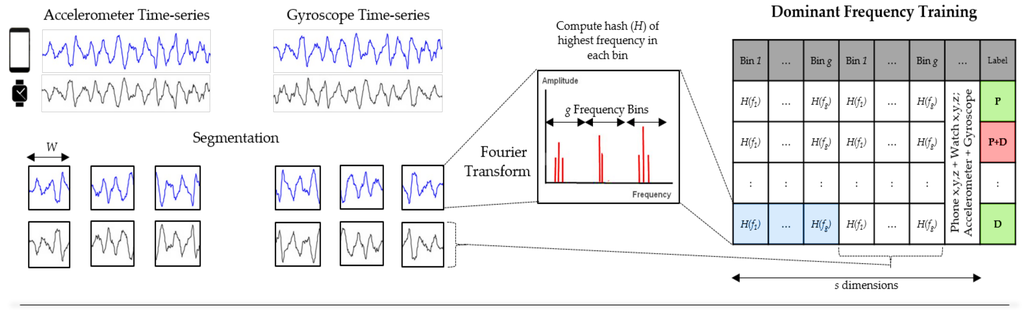
- ***Accurate*** and ***real-time*** detection of distraction-related activities using ***multi-sensor*** data obtained from pedestrian mobile devices, for example, smartphones and wrist-wearables.

Technical Approach

- Generalize the problem of detecting pedestrian distractions as a ***concurrent activity recognition*** (or ***CAR***) problem.
- ***Design*** and ***train*** an efficient CAR model that employs inertial or motion sensor data from multiple mobile devices to recognize concurrent pedestrian activities (distracted + non-distracted).
- ***Evaluate*** the efficiency and accuracy of the trained model in recognizing pedestrian distractions using real pedestrian data.

Proposed CAR Model – DFAM

- Dominant frequency-based activity matching (or DFAM)
  - –Inspired from the audio matching algorithm proposed by Avery Wang [1].



DFAM Activity Classification

$H(f_1)$	...	$H(f_g)$	$H(f_1)$	...	$H(f_g)$	...	a_c

Scoring Function

$$S_{i,j}(a_c) = \begin{cases} 0 & \text{if } \sum_{k=1}^{s} F({}^{c}H_k, {}^{\text{train}}H_k^{i,j}) = 0 \\ (\frac{1}{s})^s & \text{if } \sum_{k=1}^{s} F({}^{c}H_k, {}^{\text{train}}H_k^{i,j}) = 1 \\ (\frac{2}{s})^s & \text{if } \sum_{k=1}^{s} F({}^{c}H_k, {}^{\text{train}}H_k^{i,j}) = 2 \\ \vdots & \vdots \\ (\frac{s-1}{s})^s & \text{if } \sum_{k=1}^{s} F({}^{c}H_k, {}^{\text{train}}H_k^{i,j}) = s-1 \\ 1 & \text{if } \sum_{k=1}^{s} F({}^{c}H_k, {}^{\text{train}}H_k^{i,j}) = s \end{cases} \qquad F(a,b) = \begin{cases} 0 & a \neq b \\ 1 & a = b \end{cases}$$

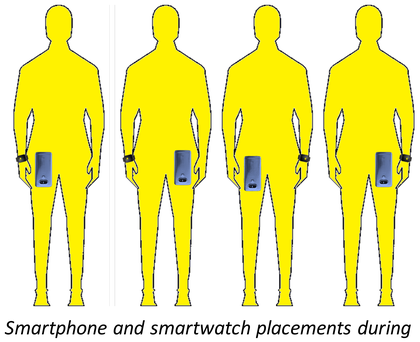
$$\arg\max_i \sum_j S_{i,j}(a_c) \quad \forall a_i \in \mathbb{P} \times \mathbb{D}$$

Comparison with Existing CAR Models

Support Vector Machine (SVM), Decision or Classification Trees (DT), Random Forests (RF), Naive Bayes (NB), k-Nearest Neighbors (k-NN) [2,3].

Experimental Setup

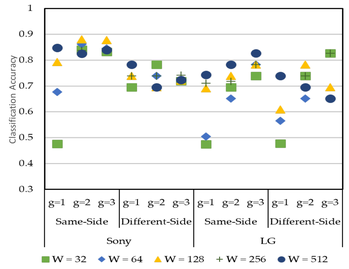
- ***14 distracted activities****: Reading, eating, using smartphone, or drinking* ***while*** climbing stairs, walking or running.
- ***22 participants*** with smartphone on the wrist and a paired smartphone in their front trouser pocket.
- 4 smartwatch–smartphone placements.
- 2 different smartwatches.
- CAR models comparatively evaluated using participant data for ***accuracy***, ***response time*** and on-device ***energy consumption***.



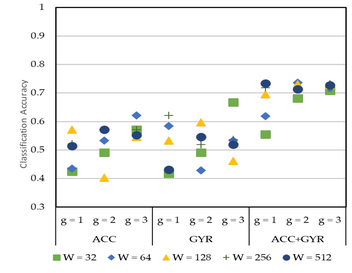
Smartphone and smartwatch placements during data collection

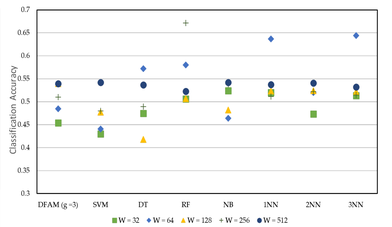
Evaluation Results

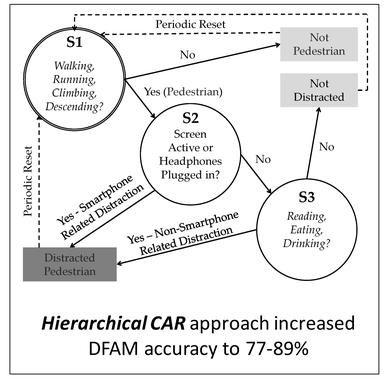
DFAM performance results for different window (W) and bin sizes (*g)* shows accuracy comparable to other CAR models with an improved response time and energy consumption.



DFAM classification accuracy for different combinations of device placements and sensors







Hierarchical CAR approach increased DFAM accuracy to 77-89%

	DFAM	SVM	DT	RF	NB	1-NN	2-NN	3-NN
Response Time (ms)	640-1150	2000-6000	1200-4480	2800-10630	890-2980	2800-8600	1900-8600	2900-6600
CPU Utilization	0.5-4.5%	1.3-8%	0.3-1.6%	0.5-7.4%	0.7-2.4%	1.5-3.8%	1.2-3%	1.2-2.9%
Power Consumption (mW)	33.3-129.5	33.3-188.7	33.3-85.1	85.1-222	40.7-96.2	85.1-214.6	85.1-188.7	85.1-218.3
RAM Utilization (MB)	20-24	26-53	17-67	56-108	19-29	15-26	29-53	30-92 MB

Comparative performance of all CAR models

Publications & Future Work

- N. Vinayaga-Sureshkanth, A. Maiti, M. Jadliwala, K. Crager, J. He, and H. Rathore, "Towards a Practical Pedestrian Distraction Detection Framework using Wearables", submitted to ***IEEE PerCom***, ***2018***.
- Integration of DFAM with an on-device and cloud based accident prevention framework and evaluation using a ***large-scale testbed***.

References

1. A. Wang, "An industrial strength audio search algorithm." in *ISMIR*, 2003.
2. M. Shoaib, S. Bosch, O. D. Incel, H. Scholten, and P. J. Havinga, "Complex human activity recognition using smartphone and wrist-worn motion sensors," *Sensors*, 2016.
3. L. Liu, Y. Peng, S. Wang, M. Liu, and Z. Huang, "Complex activity recognition using time series pattern dictionary learned from ubiquitous sensors," *Information Sciences*, 2016.