

Chapter

SMARTPHONE-BASED SYSTEMS FOR DRIVING EVALUATION

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ABSTRACT

Smartphones play important roles in intelligent transportation systems and driving behavior evaluation contexts. By data mining of smartphone data, the driving style can be recognized efficiently. Then any incentive or punitive mechanisms can be applied to encourage the drivers to perform better. The insurance and enforcement departments can easily use smartphone-based systems to check the driving behaviors gradually. Since, a smartphone consists of many sensors, memory and a high processing power, it can be used as a black-box for storing the driver statue. When an agency needs to understand something about driving or crashing, the smartphone data can be analyzed to clear the situations. However, such data should be collected with low energy consumption. To this aim, the multiple criteria such as precision, frequency, energy consumption, data quality, security and privacy are factors to select a reasonable set of sensors

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for data collection and data mining. In this problem, the type of communication is also important. For preprocessing of these data, different filters are developed to clean data and remove noise and outliers. For sensors fusion and to model data, some neural networks or other machine learning algorithms can be applied. Then, the data are compressed by some intervals, Fourier transforms, wavelets transforms, statistical distribution, stochastic variables or fuzzy quantities. To extract the knowledge from these data, the necessary features can be extracted from the raw data by the aid of matrix decomposition, PCA, deep learning, etc. Sometimes, it is necessary to reduce the dimension of features by feature selection methods. For processing, based on the needs, we can implement data visualizers, predictors, classifiers, frequent pattern miners or clusters extractors. We discuss on the different concepts of data mining approaches on smartphone data in this chapter. Some applications based on these processed data are developed to warn drivers or pedestrians, to define insurance encouragement, or to provide a background for autonomous driving.

Keywords: smartphone sensors, data mining, sensor fusion, feature extraction, feature selection, machine learning, driving profiling

Contents

Smartphone-Based Systems for Driving Evaluation	1
ABSTRACT	1
1. Introduction	4
1.1. Sensors	5
1.2. Algorithms	5
2. Smartphone Sensors	7
3. Communication Infrastructure	13
4. Preprocessing on Sensors Data	17
4.1. Quality Assurance.....	18
4.2. Data Visualization	18
4.3. Data Cleaning.....	22
4.4. Data Integration	23
4.5. Data Reduction	24
4.6. Data Transformation and Data Discretization.....	25
4.7. Feature Extraction.....	26
4.8. Transportation Feature Extraction.....	30
4.9. Feature Selection	34
4.10. Data Compression	35
4.12. Evaluation Measures.....	36
5. Processing on Smartphone Data	37
5.1. Regression	37
5.2. Supervised Learning Methods	38
5.3. Unsupervised Learning Methods.....	39
5.4. Frequent Patterns Mining	41
6. Driving Evaluation Approaches	41
6.2. Driving Evaluation.....	43
6.3. Driving Scoring	65
6.4. Privacy and Smartphone-Based Evaluation.....	67
7. Conclusion	68
Acknowledgments	68
8. References	69

8. REFERENCES

- Abbasi, Elham, Mehdi Ghatee, and Mohammad Ebrahim Shiri. 2013. "FRAN and RBF-PSO as two components of a hyper framework to recognize protein folds". *Computers in biology and medicine* 43, no. 9: 1182-1191.
- Abbasi, Elham, Mohammad Ebrahim Shiri, and Mehdi Ghatee. 2016. "Root-quartic mixture of experts for complex classification problems." *Expert Systems with Applications* 53: 192-203.
- Abpeykar, Shadi, and Mehdi Ghatee. 2014. "Supervised and unsupervised learning DSS for incident management in intelligent tunnel: A case study in Tehran Niayesh tunnel." *Tunnelling and Underground Space Technology* 42 (2014): 293-306.
- Abpeykar, Shadi, and Mehdi Ghatee. 2018. "An ensemble of RBF neural networks in decision tree structure with knowledge transferring to accelerate multi-classification." *Neural Computing and Applications*: 1-21.
- Abpeykar, Shadi, and Mehdi Ghatee. 2018. "Decent direction methods on the feasible region recognized by supervised learning metamodels to solve unstructured problems." *Journal of Information and Optimization Sciences* 39, no. 6: 1245-1262.
- Abpeykar, Shadi, Mehdi Ghatee, and Hadi Zare. 2019. "Ensemble decision forest of RBF networks via hybrid feature clustering approach for high-dimensional data classification." *Computational Statistics & Data Analysis* 131 (2019): 12-36.
- Ahmad, Amir, and Lipika Dey. 2007. "A k-mean clustering algorithm for mixed numeric and categorical data." *Data & Knowledge Engineering* 63, no. 2: 503-527.
- Akyildiz, Ian F., Weilian Su, Yogesh Sankarasubramaniam, and Erdal Cayirci. 2002. "A survey on sensor networks." *IEEE communications magazine* 40, no. 8: 102-114.

- Alvarez, Alberto Diaz, Francisco Serradilla Garcia, José Eugenio Naranjo, Jose Javier Anaya, and Felipe Jimenez. 2014. "Modeling the driving behavior of electric vehicles using smartphones and neural networks." *IEEE Intelligent Transportation Systems Magazine* 6, no. 3: 44-53.
- Anjum, A., M. Ilyas. "Activity recognition using smartphone sensors", *IEEE Consumer Communications and Networking Conference (CCNC)*, (2013): 914-919.
- Araniti, Giuseppe, Claudia Campolo, Massimo Condoluci, Antonio Iera, and Antonella Molinaro. 2013. "LTE for vehicular networking: a survey." *IEEE communications magazine* 51, no. 5: 148-157.
- Araújo, Rui, Ângela Igreja, Ricardo de Castro, and Rui Esteves Araujo. 2012. "Driving coach: A smartphone application to evaluate driving efficient patterns." In *Intelligent Vehicles Symposium (IV)*, 2012 IEEE, pp. 1005-1010.
- Arróspide, Jon, Luis Salgado, and Marcos Nieto. 2012. "Video analysis-based vehicle detection and tracking using an MCMC sampling framework." *EURASIP Journal on Advances in Signal Processing* 2012, no. 1: 2.
- Asadi, Reza, and Mehdi Ghatee. 2015. "A rule-based decision support system in intelligent hazmat transportation system." *IEEE Transactions on Intelligent Transportation Systems* 16, no. 5: 2756-2764.
- Astarita, Vittorio, Demetrio Carmine Festa, and Vincenzo Pasquale Giofrè. 2018. "Mobile Systems applied to Traffic Management and Safety: a state of the art." *Procedia computer science* 134: 407-414.
- Bagheri, Mehrdad, Matti Siekkinen, and Jukka K. Nurminen. 2014. "Cellular-based vehicle to pedestrian (V2P) adaptive communication for collision avoidance." *International Conference on Connected Vehicles and Expo (ICCVE)*, pp. 450-456.
- Bandeira, Jorge, Tiago G. Almeida, Asad J. Khattak, Nagui M. Roupail, and Margarida C. Coelho. 2013. "Generating emissions information for route selection: Experimental monitoring and routes characterization." *Journal of Intelligent Transportation Systems* 17, no. 1: 3-17.
- Bejani, Mohammad Mahdi, and Mehdi Ghatee. 2018. "A context aware system for driving style evaluation by an ensemble learning on

- smartphone sensors data.” *Transportation Research Part C: Emerging Technologies* 89: 303-320.
- Bejani, Mohammad Mahdi, and Mehdi Ghatee. 2019. “Convolutional Neural Network with Adaptive Regularization to Classify Driving Styles on Smartphones.” *IEEE transaction on Intelligent Transportation Systems*, 1-10.
- Belkin, Mikhail, and Partha Niyogi. 2003. “Laplacian eigenmaps for dimensionality reduction and data representation.” *Neural computation* 15, no. 6 (2003): 1373-1396.
- Bhavsar, Parth, Ilya Safro, Nidhal Bouaynaya, Robi Polikar, and Dimah Dera. 2017. “Machine Learning in Transportation Data Analytics.” In *Data Analytics for Intelligent Transportation Systems*, pp. 283-307.
- Bierlaire, Michel, Jingmin Chen, and Jeffrey Newman. 2013. “A probabilistic map matching method for smartphone GPS data.” *Transportation Research Part C: Emerging Technologies* 26: 78-98.
- Blachnik, Marcin, and Włodzisław Duch. 2011. “LVQ algorithm with instance weighting for generation of prototype-based rules.” *Neural Networks* 24, no. 8: 824-830.
- Bo, Cheng, Xuesi Jian, Taeho Jung, Junze Han, Xiang-Yang Li, Xufei Mao, and Yu Wang. 2017. “Detecting driver’s smartphone usage via nonintrusively sensing driving dynamics.” *IEEE Internet of Things Journal* 4, no. 2: 340-350.
- Burrus, C. Sidney, Ramesh A. Gopinath, Haitao Guo, Jan E. Odegard, and Ivan W. Selesnick. 1998. *Introduction to wavelets and wavelet transforms: A primer*. Vol. 1. New Jersey: Prentice hall.
- Byon, Young-Ji, Baher Abdulhai, and Amer Shalaby. 2009. “Real-time transportation mode detection via tracking global positioning system mobile devices.” *Journal of Intelligent Transportation Systems* 13, no. 4: 161-170.
- Campolo, Claudia, Antonio Iera, Antonella Molinaro, Stefano Yuri Paratore, and Giuseppe Ruggeri. 2012. “SMaRTCaR: An integrated smartphone-based platform to support traffic management applications.” In *First International Workshop on Vehicular Traffic Management for Smart Cities (VTM)*, 2012, pp. 1-6. IEEE.

- Castignani, German, Thierry Dermann, Raphaël Frank, and Thomas Engel. 2015. "Driver behavior profiling using smartphones: A low-cost platform for driver monitoring." *IEEE Intelligent Transportation Systems Magazine* 7, no. 1: 91-102.
- Chen, Shuyan, and Wei Wang. 2009. "Decision tree learning for freeway automatic incident detection." *Expert systems with applications* 36, no. 2: 4101-4105.
- Chen, Cong, Yanyan Chen, Jianming Ma, Guohui Zhang, and C. Michael Walton. 2018. "Driver behavior formulation in intersection dilemma zones with phone use distraction via a logit-Bayesian network hybrid approach." *Journal of Intelligent Transportation Systems* 22, no. 4: 311-324.
- Chen, Huizhong, Sam S. Tsai, Georg Schroth, David M. Chen, Radek Grzeszczuk, and Bernd Girod. 2011. "Robust text detection in natural images with edge-enhanced maximally stable extremal regions." In *Image Processing (ICIP), 2011 18th IEEE International Conference on*, pp. 2609-2612.
- Chen, Jingmin, and Michel Bierlaire. 2015. "Probabilistic multimodal map matching with rich smartphone data." *Journal of Intelligent Transportation Systems* 19, no. 2: 134-148.
- Chen, Po-Han, Heng-Kuang Shen, Chi-Yang Lei, and Luh-Maan Chang. 2012. "Support-vector-machine-based method for automated steel bridge rust assessment." *Automation in Construction* 23: 9-19.
- Chen, Min, Yin Zhang, Yong Li, Shiwen Mao, and Victor CM Leung. 2015a. "EMC: Emotion-aware mobile cloud computing in 5G." *IEEE Network* 29, no. 2: 32-38.
- Chen, Zhenghua, Han Zou, Hao Jiang, Qingchang Zhu, Yeng Chai Soh, and Lihua Xie. 2015b. "Fusion of WiFi, smartphone sensors and landmarks using the Kalman filter for indoor localization." *Sensors* 15, no. 1: 715-732.
- Cheng, Hui, and K. C. Gupta. 1989. "An historical note on finite rotations." *Journal of Applied Mechanics* 56, no. 1: 139-145.
- Chhabra, Rishu, Seema Verma, and C. Rama Krishna. 2017. "A survey on driver behavior detection techniques for intelligent transportation

- systems.” *7th International Conference on Cloud Computing, Data Science & Engineering-Confluence*, pp. 36-41.
- Cho, Sung-Bae. 2016. “Exploiting machine learning techniques for location recognition and prediction with smartphone logs.” *Neurocomputing* 176: 98-106.
- Choi, Sam-Wook, Dai-Jin Kim, Jung-Seok Choi, Heejune Ahn, Eun-Jeung Choi, Won-Young Song, Seohee Kim, and Hyunchul Youn. 2015. “Comparison of risk and protective factors associated with smartphone addiction and Internet addiction.” *Journal of behavioral addictions* 4, no. 4: 308-314.
- Corripio, J. Rosales, DM Arenas González, AL Sandoval Orozco, LJ García Villalba, Julio Hernandez-Castro, and Stuart James Gibson. 2013. “Source smartphone identification using sensor pattern noise and wavelet transform.” *5th International Conference on Imaging for Crime Detection and Prevention (ICDP 2013)*: 1-16.
- Johnson, Derick A., and Mohan M. Trivedi. 2011. “Driving style recognition using a smartphone as a sensor platform.” In *Intelligent Transportation Systems (ITSC), 2011 14th International IEEE Conference on*, pp. 1609-1615.
- Dabiri, Sina, and Kevin Heaslip. 2018. “Inferring transportation modes from GPS trajectories using a convolutional neural network.” *Transportation research part C: Emerging technologies* 86: 360-371.
- Dai, Jiangpeng, Jin Teng, Xiaole Bai, Zhaohui Shen, and Dong Xuan. 2010. “Mobile phone based drunk driving detection.” In *Pervasive Computing Technologies for Healthcare (PervasiveHealth), 2010 4th International Conference on-NO PERMISSIONS*, pp. 1-8.
- Darvishvand, Fateme G., Mehdi Ghatee, and Hamid Reza Eftekhari. 2016. “Using 3G and 4G/LTE for collision warning systems in vehicular network.” *The 15th International Conference on Traffic And Transportation Engineering*. Tehran.
- Daubechies, Ingrid. 1990. “The wavelet transform, time-frequency localization and signal analysis.” *IEEE transactions on information theory* 36, no. 5: 961-1005.

- De Vries, Nic J., Marelle H. Davel, Jaco Badenhorst, Willem D. Basson, Febe De Wet, Etienne Barnard, and Alta De Waal. 2014. "A smartphone-based ASR data collection tool for under-resourced languages." *Speech communication* 56: 119-131.
- Deffenbacher, Jerry L., Eugene R. Oetting, and Rebekah S. Lynch. 1994. "Development of a driving anger scale." *Psychological reports* 74, no. 1 (1994): 83-91.
- Derbel, Oussama. 2018. "Belief and fuzzy theories for driving behavior assessment in case of accident scenarios." *International journal of automotive technology* 19, no. 1: 167-177.
- Do, Trinh Minh Tri, and Daniel Gatica-Perez. 2014. "The places of our lives: Visiting patterns and automatic labeling from longitudinal smartphone data." *IEEE Transactions on Mobile Computing* 13, no. 3: 638-648.
- Dou, Adam Ji, Vana Kalogeraki, Dimitrios Gunopulos, Taneli Mielikinen, Ville Tuulos, Sean Foley, and Curtis Yu. 2011. "Data clustering on a network of mobile smartphones." In *2011 IEEE/IPSJ International Symposium on Applications and the Internet*, pp. 118-127.
- Dula, Chris S., and Mary E. Ballard. 2003. "Development and Evaluation of a Measure of Dangerous, Aggressive, Negative Emotional, and Risky Driving 1." *Journal of Applied Social Psychology* 33, no. 2: 263-282.
- Eftekhari, Hamid Reza, and Mehdi Ghatee. 2017. "The lower bound for dynamic parking prices to decrease congestion through CBD." *Operational Research* 1-27.
- Eftekhari, Hamid Reza, and Mehdi Ghatee. 2016. "An inference engine for smartphones to preprocess data and detect stationary and transportation modes." *Transportation Research Part C: Emerging Technologies* 69: 313-327.
- Eftekhari, Hamid Reza, 2017. *Driving modeling with respect to the awareness about vehicle and route*. Tehran, Iran: PhD Dissertation, Department of Computer Science, Amirkabir University of Technology.
- Eftekhari, Hamid Reza, and Mehdi Ghatee. 2018. "Hybrid of discrete wavelet transform and adaptive neuro fuzzy inference system for overall driving behavior recognition." *Transportation Research Part F: Traffic Psychology and Behaviour* 58: 782-796.

- Eftekhari, Hamid Reza, and Mehdi Ghatee. 2019. "A similarity-based neuro-fuzzy modeling for driving behavior recognition applying fusion of smartphone sensors." *Journal of Intelligent Transportation Systems*: 1-12.
- Eftekhari, Hamid Reza, Ali Reza Jalalian, and Mehdi Ghatee. 2016. "Binary Programming Model to Optimize RSU Placement for Information Dissemination." *International Conference on Vehicle Technology and Intelligent Transport Systems (VEHITS 2016)*. Rome.
- Eldén, Lars. 2007. *Matrix methods in data mining and pattern recognition*. Vol. 4. SIAM.
- Engelbrecht, Jarret, Marthinus Johannes Booysen, Gert-Jan van Rooyen, and Frederick Johannes Bruwer. 2015. "Survey of smartphone-based sensing in vehicles for intelligent transportation system applications." *IET Intelligent Transport Systems* 9, no. 10: 924-935.
- Eren, Haluk, Semiha Makinist, Erhan Akin, and Alper Yilmaz. 2012. "Estimating driving behavior by a smartphone." In *Intelligent Vehicles Symposium (IV)*, 2012 IEEE, pp. 234-239.
- Faghani Omran, Mohammad J. 2016. *Cellphone network data processing in advanced traveller information system ATIS*. Tehran, Iran: MSc. thesis, Department of Computer Science, Amirkabir University of Technology.
- Ghatee, Mehdi, and Malihe Niksirat. 2013. "A Hopfield neural network applied to the fuzzy maximum cut problem under credibility measure." *Information Sciences* 229: 77-93.
- Ghatee, Mehdi. 2014. "Solution of the generalized interval linear programming problems: pessimistic and optimistic approaches." *Journal of Computing and Security* 1 (2):159-167.
- Guan, Adrian, Steven H. Bayless, and Radha Neelakantan. 2011. "Connected vehicle insights." *Trends in computer vision*. Technology scan series 2012.
- Han, Jiawei, Jian Pei, and Micheline Kamber. 2011. *Data mining: concepts and techniques*. Elsevier.
- Handel, Peter, Isaac Skog, Johan Wahlstrom, Farid Bonawiede, Richard Welch, Jens Ohlsson, and Martin Ohlsson. 2014. "Insurance telematics:

- Opportunities and challenges with the smartphone solution.” *IEEE Intelligent Transportation Systems Magazine* 6, no. 4: 57-70.
- Hibbeler, Russell Charles. 2001. *Engineering Mechanics*. Pearson Education.
- Hoseini-Tabatabaei, Seyed Amir, Alexander Gluhak, and Rahim Tafazolli. 2013. “A survey on smartphone-based systems for opportunistic user context recognition.” *ACM Computing Surveys (CSUR)* 45, no. 3: 27.
- Hromic, Hugo, Danh Le Phuoc, Martin Serrano, Aleksandar Antonić, Ivana P. Žarko, Conor Hayes, and Stefan Decker. 2015. “Real time analysis of sensor data for the internet of things by means of clustering and event processing.” *IEEE International Conference on Communications (ICC)*, pp. 685-691.
- Hung, Nguyen Quoc Viet, Hoyoung Jeung, and Karl Aberer. 2013. “An evaluation of model-based approaches to sensor data compression.” *IEEE Transactions on Knowledge and Data Engineering* 25, no. 11: 2434-2447.
- Izadi, Davood, Jemal H. Abawajy, Sara Ghanavati, and Tutut Herawan. 2015. “A data fusion method in wireless sensor networks.” *Sensors* 15, no. 2: 2964-2979.
- Jahangiri, Arash, and Hesham A. Rakha. 2015. “Applying Machine Learning Techniques to Transportation Mode Recognition Using Mobile Phone Sensor Data.” *IEEE Trans. Intelligent Transportation Systems* 16, no. 5: 2406-2417.
- Johnson, Derick A., and Mohan M. Trivedi. 2011. “Driving style recognition using a smartphone as a sensor platform.” *14th International IEEE Conference on Intelligent Transportation Systems (ITSC)*, pp. 1609-1615.
- Joubert, Johan W., Dirk de Beer, and Nico de Koker. 2016. “Combining accelerometer data and contextual variables to evaluate the risk of driver behaviour.” *Transportation research part F: traffic psychology and behaviour* 41: 80-96.
- Kalra, Nidhi, and Divya Bansal. 2014. “Analyzing driver behavior using smartphone sensors: a survey.” *Int. J. Electron. Electr. Eng* 7, no. 7: 697-702.

- Kanarachos, Stratis, Stavros-Richard G. Christopoulos, and Alexander Chroneos. 2018. "Smartphones as an integrated platform for monitoring driver behaviour: The role of sensor fusion and connectivity." *Transportation Research Part C: Emerging Technologies* 95: 867-882.
- Kent, John T. 1983. "Information gain and a general measure of correlation." *Biometrika* 70, no. 1: 163-173.
- Kervick, Aoife. 2016. *An evaluation of smartphone driver support systems for young drivers-acceptance, efficacy, and driver distraction*. PhD diss., School of Psychology, National University of Ireland, Galway.
- Ktusek, Adrian, Marcin Kurdziel, Mateusz Paciorekl, Piotr Wawrykal, and Wojciech Turekl. 2018. "Driver Profiling by Using LSTM Networks with Kalman Filtering." In *2018 IEEE Intelligent Vehicles Symposium (IV)*, pp. 1983-1988.
- Lajunen, Timo, and Dianne Parker. 2001. "Are aggressive people aggressive drivers? A study of the relationship between self-reported general aggressiveness, driver anger and aggressive driving." *Accident Analysis & Prevention* 33, no. 2: 243-255.
- Lee, Boon-Giin, and Wan-Young Chung. 2012. "A smartphone-based driver safety monitoring system using data fusion." *Sensors* 12, no. 12: 17536-17552.
- Lee, Boon Giin, Jae-Hee Park, Chuan Chin Pu, and Wan-Young Chung. 2016. "Smartwatch-based driver vigilance indicator with kernel-fuzzy-C-means-wavelet method." *IEEE Sensors Journal* 16, no. 1: 242-253.
- Lee, SeokJu, Girma Tewolde, and Jaerock Kwon. 2014. "Design and implementation of vehicle tracking system using GPS/GSM/GPRS technology and smartphone application." *IEEE World Forum on Internet of Things (WF-IoT)*, pp. 353-358.
- Lin, Miao, and Wen-Jing Hsu. 2014. "Mining GPS data for mobility patterns: A survey." *Pervasive and mobile computing* 12: 1-16.
- Liou, Yi-Chaung. 2001. "Device for holding securely a mobile phone dialing device on the steering wheel of a motor vehicle." U.S. Patent 6,209,767, issued April 3, 2001.
- López, Jesús R., Luis C. González, Johan Wahlström, Manuel Montes y Gómez, Leonardo Trujillo, and Graciela Ramírez-Alonso. 2018. "A

- Genetic Programming Approach for Driving Score Calculation in the Context of Intelligent Transportation Systems.” *IEEE Sensors Journal* 18, no. 17: 7183-7192.
- Lotfi, Roya, and Mehdi Ghatte. 2018. “Smartphone based Driving Style Classification Using Features Made by Discrete Wavelet Transform.” arXiv preprint arXiv:1803.06213 (2018).
- Lotfi, Roya, Mehdi Ghatte, and Seyed Shakib Vedaie, 2017. “Dangerous Driving Maneuver Detection Based on the Smartphone on the Steering Wheel applying physical-trigonometric relationships.” *The 16th International Conference on Traffic and Transportation Engineering*. Tehran.
- Lu, Dang-Nhac, Duc-Nhan Nguyen, Thi-Hau Nguyen, and Ha-Nam Nguyen. 2018. “Vehicle Mode and Driving Activity Detection Based on Analyzing Sensor Data of Smartphones.” *Sensors* 18, no. 4: 1036.
- Mazimpaka, Jean Damascène, and Sabine Timpf. 2016. “Trajectory data mining: A review of methods and applications.” *Journal of Spatial Information Science* 2016, no. 13: 61-99.
- Mohan, Prashanth, Venkata N. Padmanabhan, and Ramachandran Ramjee. 2008. “Nericell: rich monitoring of road and traffic conditions using mobile smartphones.” In *Proceedings of the 6th ACM conference on Embedded network sensor systems*, pp. 323-336. ACM.
- Mumtaz, Shahid, Kazi Mohammed Saidul Huq, Muhammad Ikram Ashraf, Jonathan Rodriguez, Valdemar Monteiro, and Christos Politis. 2015. “Cognitive vehicular communication for 5G.” *IEEE Communications Magazine* 53, no. 7: 109-117.
- Murphy, Enda, and Eoin A. King. 2016. “Testing the accuracy of smartphones and sound level meter applications for measuring environmental noise.” *Applied Acoustics* 106: 16-22.
- Navidi, Neda, and Rene Jr. Landry. 2017. “Driving Behavior Assessment Using Fuzzy Inference System and Low-Cost Inertial Sensors.” *Journal of Traffic and Transportation Engineering* 5: 217-227.
- Nasreen, Shamila, Muhammad Awais Azam, Khurram Shehzad, Usman Naem, and Mustansar Ali Ghazanfar. 2014. “Frequent pattern mining

- algorithms for finding associated frequent patterns for data streams: a survey." *Procedia Computer Science* 37: 109-116.
- Nitsche, Philippe, Peter Widhalm, Simon Breuss, Norbert Brändle, and Peter Maurer. 2014. "Supporting large-scale travel surveys with smartphones—a practical approach." *Transportation Research Part C: Emerging Technologies* 43: 212-221.
- Paefgen, Johannes, Flavius Kehr, Yudan Zhai, and Florian Michahelles. 2012. "Driving behavior analysis with smartphones: insights from a controlled field study." In *Proceedings of the 11th International Conference on mobile and ubiquitous multimedia*, p. 36. ACM.
- Park, Yongtae, Jihun Ha, Seungcho Kuk, Hyogon Kim, Chieh-Jan Mike Liang, and JeongGil Ko. 2014. "A feasibility study and development framework design for realizing smartphone-based vehicular networking systems." *IEEE transactions on mobile computing* 13, no. 11: 2431-2444.
- Pashaei, Ali, Mehdi Ghatee, and Hedieh Sajedi. 2019. "Convolution neural network joint with mixture of extreme learning machines for feature extraction and classification of accident images." *Journal of Real-Time Image Processing*: 1-16. DOI: <https://doi.org/10.1007/s11554-019-00852-3>.
- Peng, Hanchuan, Fuhui Long, and Chris Ding. 2005. "Feature selection based on mutual information criteria of max-dependency, max-relevance, and min-redundancy." *IEEE Transactions on pattern analysis and machine intelligence* 27, no. 8: 1226-1238.
- Piotr, Błaszczyk, Wojciech Turek, Aleksander Byrski, and Krzysztof Cetnarowicz. 2015. "Towards credible driver behavior modeling." *IEEE 18th International Conference on Intelligent Transportation Systems (ITSC)*, pp. 1557-1562.
- Rasouli, Soora, ed. 2014. *Mobile technologies for activity-travel data collection and analysis*. IGI global.
- Ronao, Charissa Ann, and Sung-Bae Cho. 2016. "Human activity recognition with smartphone sensors using deep learning neural networks." *Expert Systems with Applications* 59: 235-244.

- Roweis, Sam T., and Lawrence K. Saul. 2000. "Nonlinear dimensionality reduction by locally linear embedding." *Science* 290, no. 5500: 2323-2326.
- Saiprasert, Chalermopol, Suttipong Thajchayapong, Thunyasit Pholprasit, and Chularat Tanprasert. 2014. "Driver behaviour profiling using smartphone sensory data in a V2I environment", *International Conference on Connected Vehicles and Expo (ICCVE)*, pp. 552-557.
- Srinivasan, Vijay, Saeed Moghaddam, Abhishek Mukherji, Kiran K. Rachuri, Chenren Xu, and Emmanuel Munguia Tapia. 2014. "Mobileminer: Mining your frequent patterns on your phone." In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, pp. 389-400. ACM.
- Teimouri, Fateme, and Mehdi Ghatte. 2018. "A real-time warning system for rear-end collision based on random forest classifier." arXiv preprint arXiv:1803.10988.
- Toledo, Tomer. 2007. "Driving behaviour: models and challenges." *Transport Reviews* 27, no. 1: 65-84.
- Toledo, Tomer, and Tsippy Lotan. 2006. "In-vehicle data recorder for evaluation of driving behavior and safety." *Transportation Research Record: Journal of the Transportation Research Board* 1953: 112-119.
- Van Der Maaten, Laurens. 2014. "Accelerating t-SNE using tree-based algorithms." *The Journal of Machine Learning Research* 15, no. 1: 3221-3245.
- Van Ly, Minh, Sujitha Martin, and Mohan M. Trivedi. 2013. "Driver classification and driving style recognition using inertial sensors." In *Intelligent Vehicles Symposium (IV)*, 2013 IEEE, pp. 1040-1045.
- Wahlström, Johan, Isaac Skog, and Peter Händel. 2015. "IMU alignment for smartphone-based automotive navigation." In *Information Fusion (Fusion)*, 2015 18th International Conference on, pp. 1437-1443.
- Wahlström, Johan. 2017. *Sensor Fusion for Smartphone-based Vehicle Telematics*. PhD diss., KTH Royal Institute of Technology, 2017.
- Wahlström, Johan, Isaac Skog, and Peter Händel. 2017. "Smartphone-based vehicle telematics: A ten-year anniversary." *IEEE Transactions on Intelligent Transportation Systems* 18, no. 10: 2802-2825.

- Wahlström, Johan, Isaac Skog, and Peter Händel. 2015. "Driving behavior analysis for smartphone-based insurance telematics." In *Proceedings of the 2nd workshop on Workshop on Physical Analytics*, pp. 19-24. ACM.
- Wen, Jiahui, Mingyang Zhong, and Zhiying Wang. 2015. "Activity recognition with weighted frequent patterns mining in smart environments." *Expert Systems with Applications* 42, no. 17-18: 6423-6432.
- Xiong, Hui, Gaurav Pandey, Michael Steinbach, and Vipin Kumar. 2006. "Enhancing data analysis with noise removal." *IEEE Transactions on Knowledge and Data Engineering* 18, no. 3: 304-319.
- Ye, Yang, Yu Zheng, Yukun Chen, Jianhua Feng, and Xing Xie. 2009. "Mining individual life pattern based on location history." In *Mobile Data Management: Systems, Services and Middleware, 2009. MDM'09. Tenth International Conference on*, pp. 1-10, IEEE.
- Zadeh, Roya Bastani, Mehdi Ghatee, and Hamid Reza Eftekhari. 2018. "Three-phases smartphone-based warning system to protect vulnerable road users under fuzzy conditions." *IEEE Transactions on Intelligent Transportation Systems* 19, no. 7: 2086-2098.
- Zhang, Junping, Fei-Yue Wang, Kunfeng Wang, Wei-Hua Lin, Xin Xu, and Cheng Chen. 2011. "Data-driven intelligent transportation systems: A survey." *IEEE Transactions on Intelligent Transportation Systems* 12, no. 4: 1624-1639.
- Zhao, Qingwen, Yanmin Zhu, Chao Chen, Hongzi Zhu, and Bo Li. 2013. "When 3G meets VANET: 3G-assisted data delivery in VANETs." *IEEE Sensors Journal* 13, no. 10: 3575-3584.