

# Literature Review of Passive Behavioural Monitoring

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## 1 Literature Review

Some researches have been done with regard to estimating social density, especially more are focused on crowd density, with varieties in the aims. The aims are not only focused on behavioral monitoring, ranging from building mitigation to pilgrimage.

Video processing has limitations such as weather conditions, illumination changes, limited viewing angle, and density and brightness problem.

Although currently most people bring a smartphone with them, this does not imply that we could directly count the WiFi probe-request as a 100% proxy to people count in certain area. This is because not everyone will turn on the WiFi module of their mobile phone, or some people might have more than one WiFi enabled device.

Benefits of crowd counting are, for example, surveillance, mitigation and rescue, business related benefits, such as retail store analysis, even infrastructure evaluation and development crowd and queue management. Such arrangement could be made accordingly to fit with the current crowd condition. Good example of sentences - [8].

GSM location has an issue with privacy[2].

MAC is only a proxy since it does not infer directly to personal information, such as name or contact.

A research from [26] proposes a way to detect crowds using Bluetooth. The crowd density is quantized into 7 groups, ranging from nearly empty to extremely high (crowded). Several features were also devised in this research, ranging from bla bla. The method was chosen due to bla bla. The experiments were set up for 3 times, with 4 hours of duration each. 10 students were recruited to carry out the experiments. The results show that bla bla.

Furthermore, [6] alleges that the existence of social relationships is possible to be uncovered by using WiFi probe signals.

Human queue is also possible to be monitored using WiFi, as demonstrated in [24]. It is based on RSSI that is measured by a single WiFi monitor.

WiFi and Bluetooth were also used to estimate crowd densities and pedestrian flows in [18].

A research [2] utilizes MAC address data to determine spatio-temporal movement of human in terms of space utilization.

Bluetooth data is also used to analyze spatio-temporal movements of visitors event in Belgium [22].

Movements pattern and landmark preferences are possible to be extracted from publicly available photo repositories, such as Flickr and Panoramio, as presented in [9].

An interesting insight is found in [4], this research goal and method are really similar with our research.

A research [13] is also a little bit similar with the Paul's research.

Bluetooth, again is proven to be a potential source of tracking socially contextual behavior, as seen in [7]. Using Bluetooth trace, Chen, et. al. has shown the result with 85,8% accuracy.

A combination of WiFi fingerprinting and PDR is used to monitor Indoor environment by means of crowdsourcing [17].

A work [1] alleges that WiFi prevails Bluetooth in several criteria. Firstly, Bluetooth requires longer time to discover. More than 90% of detected MAC address were WiFi MAC address. MAC is unique address for most IEEE 802 technologies.

An online survey was conducted in [5] to collect sensor sources and contexts that are relevant for ambulatory assessment. This is important as existing mobile apps only provide time-triggered prompts for experience sampling method rather than event-triggers. In fact, event-trigger prompts could give more accurate information as it is sampled at the moment which is of interest for a psychologist. The result shows that most relevant sensors are time, date, and user activity. However, location, notifications, and accelerometer data is also of interest. However, several issue emerge, i.e., not all of the sensors are accessible in Android, as some of them require root privilege.

A work [27] tried to count the crowd using CSI, which is proven to have a monotonic relation with the number of moving people. The result seems promising, although some errors are observed.

A more energy efficient method to exploit sensor in smartphone is presented in [12]. It makes use of, what they called, *Smartphone App Opportunities*. The approach is named Piggyback Crowd Sensing (PCS).

Bluetooth has again proven to be one reliable method to estimate crowd density [25]. The work alleges that it could even reach 82% accuracy in the best case.

[16] describes the possibility to use ZigBee to estimate crowd density by measuring the RSSI and LQI. This approach requires prior infrastructure.

More approach on WSN is described in [30]. With similar solution in [16], [30] employs more WSN. It has normal and large-scale experiment.

[23] explains the possibility of tracking people movement and contact by using bluetooth and wifi.

Another point of view to track pedestrian flocks is presented in [11]. It uses WiFi signals with 3 different features to infer the flocks.

A paper [3] pres

[21] a method that combine geo-fencing with coarse WiFi localization for building evacuation.

An example of crowd monitoring is presented in [14], where it is implemented for Hajj in Mecca, Saudi Arabia. It utilizes RFID tags along with a specialized app for monitoring the pilgrims.

A good experiment that tried to find the correlation with WiFi probe-request counts and real people counts is presented in [28]. It employs wifi monitor mode and manual people counting by using tally counter.

[19] evaluates crowd counting using WiFi probe-request signal. The result showed that this is possible, although achieved not in really high accuracy.

A combination with Drones for people counting is presented in [21]. [20] presents a brief explanation about the method in indoor measurement. However, no ground truth explanation is present.

Audio tones are also proven to be a good potential method to infer crowd count [10]. However, in this method every tracked phone must be pre-installed with the audio tone generating app. Thus, this method is unable to track phones which are not pre-installed with the app.

[8] presents crowd counting method that leverages single WiFi transmitter and receiver. This method does not require prior data training, which makes this method novel.

RSSI is used to infer people count in a controlled environment, as presented in [29].

Smartphone trajectories are tracked using captured WiFi signals in [15]. The error is up to 70 meters compared to the GPS ground truth.

[Why How] Literature on Topic Literature on Method Theoretical Approach  
Find a Hole Look for debates

## 2 Conclusion

Write your conclusion here.

## References

- [1] Naeim Abedi, Ashish Bhaskar, and Edward Chung. Bluetooth and Wi-Fi MAC Address Based Crowd Data Collection and Monitoring : Benefits , Challenges and Enhancement. *Australasian Transport Research Forum 2013 Proceedings 2*, (October):1–17, 2013.
- [2] Naeim Abedi, Ashish Bhaskar, and Edward Chung. Tracking spatio-temporal movement of human in terms of space utilization using Media-Access-Control address data. *Applied Geography*, 51:72–81, 2014.
- [3] Nasimuddim Ahmed, Avik Ghose, Amit K. Agrawal, Chirabrata Bhaumik, Vivek Chandel, and Abhinav Kumar. SmartEvacTrak: A people counting and coarse-level localization solution for efficient evacuation of large

- buildings. In *2015 IEEE International Conference on Pervasive Computing and Communication Workshops, PerCom Workshops 2015*, pages 372–377. IEEE, mar 2015.
- [4] Anja Bachmann. Towards smartphone-based sensing of social interaction for ambulatory assessment. *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2015 ACM International Symposium on Wearable Computers - UbiComp '15*, pages 423–428, 2015.
  - [5] Anja Bachmann, Robert Zetzsche, Till Riedel, Michael Beigl, Markus Reichert, Philip Santangelo, and Ulrich Ebner-Priemer. Identification of relevant sensor sources for context-aware ESM apps in ambulatory assessment. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2015 ACM International Symposium on Wearable Computers - UbiComp '15*, pages 265–268, New York, New York, USA, 2015. ACM Press.
  - [6] Marco V. Barbera, Alessandro Epasto, Alessandro Mei, Vasile C. Perta, and Julinda Stefa. Signals from the crowd: Uncovering social relationships through smartphone probes. *Proceedings of the 2013 Conference on Internet Measurement Conference*, pages 265–276, 2013.
  - [7] Z Chen, Yiqiang Chen, Shuangquan Wang, and Junfa Liu. Inferring social contextual behavior from bluetooth traces. In *Proceedings of the 2013 ACM conference on Pervasive and ubiquitous computing adjunct publication*, pages 267–270, New York, New York, USA, 2013. ACM Press.
  - [8] Simone Di Domenico, Giuseppe Bianchi, and Roma Tor. A Trained-once Crowd Counting Method Using Differential WiFi Channel State Information. *Proceedings of the 3rd International on Workshop on Physical Analytics - WPA '16*, pages 37–42, 2016.
  - [9] Piotr Jankowski, Natalia Andrienko, Gennady Andrienko, and Slava Kisilevich. Discovering Landmark Preferences and Movement Patterns from Photo Postings. *Transactions in GIS*, 14(6):833–852, dec 2010.
  - [10] Pravein Govindan Kannan, Seshadri Padmanabha Venkatagiri, Mun Choon Chan, Akhihebbal L. Ananda, and Li-Shiuan Peh. Low cost crowd counting using audio tones. *Proceedings of the 10th ACM Conference on Embedded Network Sensor Systems - SenSys '12*, page 155, 2012.
  - [11] M B Kj&#x00E6;rgaard, M Wirz, D Roggen, and G Tr&#x00F6;ster. Mobile sensing of pedestrian flocks in indoor environments using WiFi signals, 2012.
  - [12] Nicholas D. Lane, Yohan Chon, Lin Zhou, Yongzhe Zhang, Fan Li, Dongwon Kim, Guanzhong Ding, Feng Zhao, and Hojung Cha. Piggyback CrowdSensing (PCS): energy efficient crowdsourcing of mobile sensor data

by exploiting smartphone app opportunities. *Proceedings of the 11th ACM Conference on Embedded Networked Sensor Systems*, page 7, 2013.

- [13] Lu Luo, Jun Yang, Xuan Bao, Zhixian Yan, and Yifei Jiang. SWAN: A Novel Mobile System to Track and Analyze Social Well-being. In *Adjunct Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2015 ACM International Symposium on Wearable Computers*, pages 703–712, New York, New York, USA, 2015. ACM Press.
- [14] Ricardo O. Mitchell, Hammad Rashid, Fakir Dawood, and Ali Alkhalidi. Hajj crowd management and navigation system: People tracking and location based services via integrated mobile and RFID systems. In *International Conference on Computer Applications Technology, ICCAT 2013*, 2013.
- [15] A. B. M. Musa and Jakob Eriksson. Tracking unmodified smartphones using wi-fi monitors. *Proceedings of the 10th ACM Conference on Embedded Network Sensor Systems - SenSys '12*, page 281, 2012.
- [16] Masayuki Nakatsuka. A Study on Passive Crowd Density Estimation using Wireless Sensors. In *The Fourth International Conference on Mobile Computing and Ubiquitous Networking*, 2008.
- [17] Valentin Radu, Lito Kriara, and Mahesh K. Marina. Pazl: A mobile crowd-sensing based indoor WiFi monitoring system. In *2013 9th International Conference on Network and Service Management, CNSM 2013 and its three collocated Workshops - ICQT 2013, SVM 2013 and SETM 2013*, pages 75–83. IEEE, oct 2013.
- [18] Lorenz Schauer, Martin Werner, and Philipp Marcus. Estimating Crowd Densities and Pedestrian Flows Using Wi-Fi and Bluetooth. *Proceedings of the 11th International Conference on Mobile and Ubiquitous Systems: Computing, Networking and Services*, pages 171–177, 2014.
- [19] André Schmidt. Low-cost Crowd Counting in Public Spaces. 2014.
- [20] E Vattapparamban, B S #199;iftler, &#304; G&#252;ven&#231;, K Akkaya, and A Kadri. Indoor occupancy tracking in smart buildings using passive sniffing of probe requests, 2016.
- [21] Edwin Vattapparamban. People Counting and occupancy Monitoring using WiFi Probe Requests and Unmanned Aerial Vehicles. *FIU Electronic Theses and Dissertations*, 2016.
- [22] Mathias Versichele, Tijs Neutens, Matthias Delafontaine, and Nico Van de Weghe. The use of Bluetooth for analysing spatiotemporal dynamics of human movement at mass events: A case study of the Ghent Festivities. *Applied Geography*, 32(2):208–220, 2012.

- [23] Long Vu, Klara Nahrstedt, Samuel Retika, and Indranil Gupta. Joint bluetooth/wifi scanning framework for characterizing and leveraging people movement in university campus. *Proceedings of the 13th ACM international conference on Modeling analysis and simulation of wireless and mobile systems*, pages 257–265, 2010.
- [24] Yan Wang, Jie Yang, Hongbo Liu, and Yingying Chen. Measuring human queues using WiFi signals. In *Proceedings of the 19th annual international conference on Mobile computing & networking*, pages 235–237, New York, New York, USA, 2013. ACM Press.
- [25] Jens Weppner and Paul Lukowicz. Collaborative Crowd Density Estimation with Mobile Phones. *Proc. of ACM PhoneSense*, 2011.
- [26] Jens Weppner and Paul Lukowicz. Bluetooth based collaborative crowd density estimation with mobile phones. *2013 IEEE International Conference on Pervasive Computing and Communications (PerCom)*, pages 193–200, mar 2013.
- [27] W Xi, J Zhao, X Y Li, K Zhao, S Tang, X Liu, and Z Jiang. Electronic frog eye: Counting crowd using WiFi, 2014.
- [28] Ooi Boon Yaik, Kong Zan Wai, Ian K.T.Tan, and Ooi Boon Sheng. Measuring the Accuracy of Crowd Counting using Wi-Fi Probe-Request-Frame Counting Technique. *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, 8(2):79–81, 2016.
- [29] Takuya Yoshida. Estimating the number of people using existing WiFi access point in indoor environment. In *6th European Conference of Computer Science (ECCS '15)*, pages 46–53, 2015.
- [30] Yaoxuan Yuan, Chen Qiu, Wei Xi, and Jizhong Zhao. Crowd Density Estimation Using Wireless Sensor Networks. *2011 Seventh International Conference on Mobile Ad-hoc and Sensor Networks*, pages 138–145, dec 2011.