A Short Review of Constructing Noise Map Using Crowdsensing Technology

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Abstract. The advent of crowdsensing technology has provided a promising possibility for monitoring noise pollution in large-scale areas. Constructing noise map by using mobile smart phones in a cost-effective manner is being widely used in the city and industrial plants. In this short paper, the state-of-the-art crowdsensing-based noise map applications are first summarized. Furthermore, open research challenges associated with building up noise map are highlighted.

Keywords: Crowdsensing · Noise map · Mobile phone

1 Introduction

In the past decades, the increasing development of mobile smartphones has greatly evolved the crowdsensing technology, which allows citizens having smart phones and common goals to participate in measuring, uploading, and reporting events of interests with the help of enriched sensors embedded in smart phones, such as microphones, cameras, and the Global Positioning System (GPS) [1,2]. Particularly, the use of microphone and the GPS in smart phones has the capabilities of measuring precise sound level and geographical locations in ambient environment, and finally providing a solution to noise pollution monitoring [3] and constructing noise map as an alternative to traditional methods. In the smart cities, noise map is capable of providing sound level information for authorities and residents related to noise pollution distribution in regions of interest, such as streets, markets, and communities [4]. Traditionally, noise map methods include simulation-based maps, sensor networks, and grassroots campaigns; however, most of them require professional devices and human resources with an expensive way in both financial and time consumption [5]. In recent decades, crowdsensing-based noise map applications have been successfully applied in monitoring noise pollution in the filed of transport, community, and industrial

I. Romdhani et al. (Eds.): CollaborateCom 2017, LNICST 252, pp. 37–43, 2018.
https://doi.org/10.1007/978-3-030-00916-8_4

plants in modern cities [6]. For instance, some urban noise map applications have been implemented, such as industrial noise map [7], traffic road noise maps of the city of Split, Croatia [8], and noise maps of New York City [9].

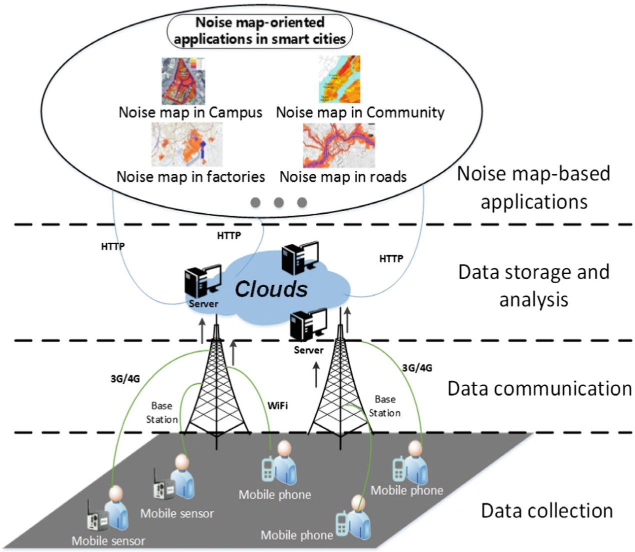

Fig. 1. Noise map based on crowdsensing in smart cities.

2 Crowdsensing-Based Noise Map in Smart Cities

In contrast with the use of professional devices to monitor noise pollution on-site, the application of crowdsensing-based noise map enjoys the advantage of widely used population participated in measuring and reporting noise pollution with the use of cost-effective smart phones. In general, the crowdsensing-based model for constructing noise map can be briefly divided into four levels: (1) data collection: amounts of sound level data is measured and uploaded by using mobile devices which can be not only smart phones, but also mobile devices having the capability of measuring sound level and communication functionalities [10]; (2) data communication: participators upload and report noise pollution by means of various networks, such as 3rd Generation and 4th Generation (3G/4G), WiFi, and even nearest base station supporting wireless communication (e.g., bluetooth and wireless sensor networks) [11]; (3) data storage and analysis: spatial-temporal data is persistently saved and analyzed related to applications of interest [1]; (4) noise map-based applications: urban applications are applicable to not only monitor noise pollution but also provide services associated with alleviating noise pollution [12]. The big picture of noise map based on crowdsensing in smart cities is shown in Fig. 1.

Table 1. A summary of state-of-the-art for noise map.

	Authors	Year	Objectives	Contributions	Data sources
Crowdsensing-based noise map	Maisonneuve et al. [13]	2009	Measuring and map noise pollution	Data calibration, community exposure, standards/interoperability	A mobile application named NoiseTube
	Kanjo et al. [14]	2010	Urban noise monitoring and map	Data calibration, community exposure, standards, unobtrusiveness, context awareness	A mobile application named NoiseSPY
	Rena et al. [15]	2010	Participatory urban noise map system	Data calibration, community exposure, unobtrusiveness, context awareness	A mobile application named Ear-Phone
	Schweizer et al. [16]	2011	Real-time participatory noise maps	1. Design an open urban sensing platform da_sense, which can also monitors toxic gases 2. Data calibration, community exposure, participatory	A mobile application named NoiseMap
	D'Hondt et al. [17]	2013	Verify the official noise map	Construct purely measurement-based noise maps with error margins	A mobile application named NoiseTube
	Liu et al. [9,10,18]	2014	Diagnose the noise pollution in NYC	1. A three dimension tensor for data analyzing [18] 2. Location ranking and noise composition analysis [9] 3. Compute the average of the top 10% big measurements as the real noise level [10]	311 complaint data, social media, road network data, Points of Interests (POIs)
	Hachem et al. [19]	2015	Customize the urban civics middleware for monitoring noise pollution	Apply data assimilation techniques to noise with mobile unplanned sensing	Microphone devices
	Poslončec-Petrić et al. [8]	2016	Dynamic noise map	Design web platform based on 3D urban information model	A mobile application named NoiseTube
	Zhu et al. [20]	2016	Accurate noise level measurements	Present a system iCal based on calibrating smartphones, consisting node-based calibration and crowdsourcing-based calibration	Microphone devices
	Kumar et al. [21]	2017	Monitor road traffic noise	1. A fuzzy inference system 2. Visualize the noise level and endanger degree on Google Maps by overlaying colors	Microphone devices
	Bozkurt et al. [7]	2017	Numerical simulation of industrial noise map	1. Numerical simulation on the basis of the prevailing sound propagation conditions 2. Designe noise barriers	B&K 2260 Sound and Frequency Analyser and microphone devices
Others	Rosão et al. [22]	2015	Recreational activities in strategic noise map	Main methods for noise characterization and modeling	N/A
	Wei et al. [23]	2016	Dynamic interpolation methods for accurately updating a noise map	Correction terms for sources path and propagation paths	Sensor nodes
	Cai et al. [24,25]	2016 2017	Update noise map in Guangzhou	1. Calculate noise pressure level deviation, then some roads can be directly updated by adding [24] 2. Only the S-R noise attenuation items update by a speed-density model [25]	Geographic Information System (GIS) & GPS & Videos

In practice, the microphones are widely used to measure acoustic data samples and simulate the frequency response of human hearing by an A-weighting filter [5]. Usually, sound level, timestamp, and GPS information as well as annotations can be collected from participators related to where, when, and what kinds of data sources of noise pollution. However, due to these heterogeneities introduced by devices made by different companies, deviation exists in crowdsensing data contributed by participators, such as sound level and GPS data. Moreover, the purposes of contributing data using personal cost are also different. Taking this into account, in the recent decade, researchers have conducted a series of studies to improve the feasibility and accuracy of noise map. The typical techniques and applications related to noise map are summarised in Table 1.

For instance, Maisonneuve et al. [13] proposed a platform in 2009, NoiseTube, which provides the functionality of GPS calibration and noise distribution visualization. The detail capabilities of NoiseTube were evaluated in [17]. Afterwards, Kanjo et al. [14] proposed a mobile platform, NoiseSPY, to monitor noise pollution using smartphones. Meanwhile, Rana et al. [15] presented the design, implementation and performance evaluation of an end-to-end participatory urban noise map system called Ear-Phone. Furthermore, a participatory sensing prototype, called NoiseMap [16], was proposed for providing an open urban sensing platform, aiming at collecting noise levels by using smartphones and gas information in ambient environment by using wireless sensor nodes. In addition, to avoid the data sparsity of noise levels, a three dimension tensor was modeled in [18], which presents regions, time slots, and noise categories, using a context-aware tensor decomposition method to fill in the missing entries. Liu et al. [10] proposed a method for calculating the average of the 10% maximum measurements as the noise level for which can actually reflect people's tolerance to noise. Moreover, Zhu et al. [20] presented a system, called iCal, for accurate noise level measurements based on calibrating smartphones. And researches in [8] created a real-time dynamic noise map based on 3D Urban Information Model. Recently, a data assimilation method was utilized by Hachem et al. [19], for the purpose of generating more accurate noise maps that combine simulated and measured noise levels. Kumar et al. [21] made use of a fuzzy inference system to classify the impact of noise pollution on human health and visualized the noise level on Google Maps by overlaying colors corresponding to the impact on health. Bozkurt et al. [7] studied the numerical simulation-based industrial noise map and designed noise barriers for reducing excessive noise.

In purpose of further enhancing the performance of constructing noise map, a number of published literatures dedicated to providing reliable and robust data services. Giving an example, for noise map system update, Wei et al. [23] proposed an updating method for dynamic noise map based on interpolation. Additionally, Cai et al. [24,25] further investigated a large-scale three dimension system for rapidly updating road traffic noise map. To justify the need of inclusion of entertainment noise, recreational activities in strategic noise map is classified and modeled in [22].

3 Open Research Challenges in Crowdsensing-Based Noise Map

There are still many limitations and open research challenges in crowdsensing-based noise map since noise propagation can be easily influenced by objects in the travel path. In urban regions, traffic is the main source of outdoor noise and usually difficult to predict due to the feature of continuous movement. To sum up, several factors may have effects on noise map performance, such as:

1. The microphones have different deviation for noise measurement (e.g., linearity and noise reduction techniques).
2. Unexpected sound level interference generated from objects and ambient environment (e.g., the weather and user movements).
3. Noise sources in some regions have multiple types (e.g., human activities, industrial noise, traffic noise, construction noise).
4. Users' private issues during participatory activities (e.g., GPS, acoustic file).
5. Stability of the connectivity between devices for full coverage of targeted areas of interest.
6. The key technical issues associated with spatial-temporal data towards noise map, such as sparse data storage, data calibration, and data reconstruction.

4 Conclusions

In this short paper, the typical crowdsensing-based applications for the noise map applied in smart cities are briefly presented and summarized. Furthermore, the general implementation and systems of crowdsensing-based noise map applications are summarised. Finally, open research challenges are discussed to further investigate the feasibility and effectiveness of noise map in smart cities.

Acknowledgement. This work is partially supported by Science and Technology Planning Project of Guangdong Province (No. 2017A050506057), China Maoming Engineering Research Center on Industrial Internet of Things (No. 517018), International and Hong Kong, Macao & Taiwan collaborative innovation platform and major international cooperation projects of colleges in Guangdong Province (No. 2015KGJHZ026).

References

1. Guo, B., et al.: Mobile crowd sensing and computing: the review of an emerging human-powered sensing paradigm. ACM Comput. Surv. (CSUR) **48**(1), 1–31 (2015)
2. Shu, L., Chen, Y., Huo, Z., Bergmann, N., Wang, L.: When mobile crowd sensing meets traditional industry. IEEE Access **5**(99), 15300–15307 (2017)
3. Anon: Future noise policy: European commission green paper. Noise News International, vol. 5, pp. 74–94(21), June 1997

4. Miller, L., Springthorpe, C., Murphy, E., King, E.A., et al.: Environmental noise mapping with smartphone applications: a participatory noise map of West Hartford, CT. In: INTER-NOISE and NOISE-CON Congress and Conference Proceedings, vol. 252, pp. 445–451, June 2016
5. Maisonneuve, N., Stevens, M., Ochab, B.: Participatory noise pollution monitoring using mobile phones. **15**(1, 2), 51–71 (2010)
6. Leao, S., Zhou, W.: Monitoring exposure to traffic noise with mobile phones in China: a review of context. Int. J. Inf. Comput. Sci. (IJICS) **3**, 52–63 (2014)
7. Bozkurt, T.S., Demirkale, S.Y.: The field study and numerical simulation of industrial noise mapping. J. Build. Eng. **9**(Supplement C), 60–75 (2017)
8. Poslončec-Petrić, V., Vuković, V., Frangeš, S., Bačić, Ž.: Voluntary noise mapping for smart city. In: ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. III-4/W1, pp. 131–137, August 2016
9. Wang, Y., Zheng, Y., Liu, T.: A noise map of New York city. In: Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication, pp. 275–278, September 2014
10. Liu, T., Zheng, Y., Liu, L., Liu, Y., Zhu, Y.: Methods for sensing urban noises. Technical report MSR-TR-2014-66, May 2014
11. Ganti, R.K., Ye, F., Lei, H.: Mobile crowdsensing: current state and future challenges. IEEE Commun. Mag. **49**(11), 32–39 (2011)
12. Guillaume, G., et al.: Noise mapping based on participative measurements. Noise Mapp **3**, 140–156 (2016)
13. Maisonneuve, N., Stevens, M., Niessen, M.E., Steels, L.: NoiseTube: measuring and mapping noise pollution with mobile phones. Inf. Technol. Environ. Eng. **2**(6), 215–228 (2009)
14. Kanjo, E.: NoiseSPY: a real-time mobile phone platform for urban noise monitoring and mapping. Mob. Netw. Appl. **15**(4), 562–574 (2010)
15. Rana, R.K., Chou, C.T., Kanhere, S.S., Bulusu, N., Hu, W.: Ear-Phone: an end-to-end participatory urban noise mapping system. In: Proceedings of the 9th ACM/IEEE International Conference on Information Processing in Sensor Networks, IPSN 2010, pp. 105–116, January 2010
16. Schweizer, I., Bärtl, R., Schulz, A., Probst, F., Mühläuser, M.: NoiseMap-real-time participatory noise maps. In: Second International Workshop on Sensing Applications on Mobile Phones, November 2011
17. D'Hondt, E., Stevens, M., Jacobs, A.: Participatory noise mapping works! An evaluation of participatory sensing as an alternative to standard techniques for environmental monitoring. Pervasive Mob. Comput. **9**(5), 681–694 (2013)
18. Zheng, Y., Liu, T., Wang, Y., Zhu, Y., Liu, Y., Chang, E.: Diagnosing New York city's noises with ubiquitous data. In: Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing, pp. 715–725, September 2014
19. Hachem, S., Mallet, V., Pathak, A., Raverdy, P.G., Bhatia, R.: Monitoring noise pollution using the urban civics middleware. In: IEEE First International Conference on Big Data Computing Service and Applications, pp. 52–61, March 2015
20. Zhu, Y., Li, J., Liu, L., Tham, C.K.: iCal: intervention-free calibration for measuring noise with smartphones. In: IEEE 21st International Conference on Parallel and Distributed Systems (ICPADS), pp. 85–91, December 2015
21. Kumar, R., Mukherjee, A., Singh, V.: Traffic noise mapping of Indian roads through smartphone user community participation. Environ. Monit. Assess. **189**(1), 17 (2017)

22. Rosão, V., Grilo, Á.: The inclusion of recreational activities in strategic noise maps. In: Euronoise, January 2015
23. Wei, W., Van Renterghem, T., De Coensel, B., Botteldooren, D.: Dynamic noise mapping: a map-based interpolation between noise measurements with high temporal resolution. Appl. Acoust. **101**, 127–140 (2016)
24. Cai, M., Yao, Y., Wang, H.: A traffic-noise-map update method based on monitoring data. J. Acoust. Soc. Am. **141**(4), 2604–2610 (2017)
25. Cai, M., Zhang, Z., Ma, X., Li, F.: Rapid updating if 3D road traffic noise maps in large cities. Noise Control. Eng. J. **64**(3), 335–341 (2016)