Real-Time Sensing in Smart Cities

Subjects: Others

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To aid urban planners and residents in understanding the nuances of day-to-day urban dynamics, we actively pursue the improvement of data visualisation tools that can adapt to changing conditions. An architecture was created and implemented that ensures secure and easy connectivity between various sources, such as a network of Internet of Things (IoT) devices, to merge with crowdsensing data and use them efficiently.

Keywords: smart cities ; crowdsensing ; geofencing ; data visualisation ; mobile applications

1. Introduction

A smart city is an urban environment that integrates Information and Communication Technology (ICT) and the Internet of Things (IoT) to enhance the quality of life for its inhabitants, optimise resource efficiency, and improve overall sustainability through interconnected infrastructure, data-driven decision-making, and citizen engagement [1]. Urban centres increasingly depend on IoT and its expanding domains, as they attract the attention of academia, industry, and civil society [2]. Today, the main focus is on promoting citizens' quality of life, assessing the impact of intelligent technologies, and ensuring the social, economic, and environmental sustainability of cities [3]. At the heart of this urban transformation are two fundamental technological components: crowdsourcing and crowdsensing. Crowdsourcing allows citizens to participate actively in collecting data and evaluating services. At the same time, crowdsensing takes advantage of the ubiquity of sensors and mobile devices to facilitate the exchange of large amounts of valuable information in urban environments.

Active community participation is essential in developing plans for managing municipalities [4]. Despite the advances in sensorization and the use of mobile devices, some urban areas do not fully exploit these technologies. These devices could be interconnected by implementing a comprehensive platform that provides diverse solutions operating at multiple levels and dimensions. The level of community involvement in the process is correlated with effectiveness in addressing relevant community concerns. Research results indicate that communities with abundant physical resources, highly skilled human capital, and strong social networks demonstrate greater competence when encouraged and included in the process [4].

2. Crowdsensing and Crowdsourcing

Mobile crowdsensing has emerged as a highly favored approach to urban sensing, offering the ability to accumulate and disseminate significant amounts of data while monitoring and detecting the habits and movements of city dwellers in urban environments [5]. Crowdsensing is a method in which many individuals use mobile devices equipped with sensors to collaboratively share sensory data to quantify, examine, or deduce issues of common interest [6]. In the context of smart cities, crowdsourcing initiatives facilitate the active and passive participation of citizens in collecting data on various aspects of a city's operations, services, quality of life, and environment. Mobile crowdsourcing utilises the synergy between sensor technology and human input and analysis. This synergy proves especially valuable when assessing concerns related to the urban environment, such as the quality of municipal services and the ramifications of political decisions on residents' quality of life [7].

Shahrour et al. [7] state that crowdsourcing contributes to three critical success factors in smart city projects. The first factor concerns data acquisition, with mobile crowdsourcing enabling the development of cost-effective, high-caliber monitoring systems for urban infrastructures, services, and the environment. In addition, user feedback based on sensor-derived data is proving indispensable for capturing the needs and preferences of the population, as well as for understanding the genuine impact of smart city initiatives on resident's quality of life. The second factor revolves around involving citizens in local development and activities. Through mobile crowdsourcing, local authorities can access citizens' ideas and feelings about smart city initiatives and their tangible consequences. The third factor is the creation of smart applications supported by crowdsourcing, including, but not limited to, smart navigation, real-time public transportation services, ride-sharing arrangements, risk alerts, emergency responses, and disturbance notifications. By establishing cost-effective, crowdsourcing-driven monitoring systems as a viable alternative to traditional smart city monitoring devices, mobile crowdsourcing has the potential to accelerate the implementation of smart city projects. This research has identified a myriad of crowdsourcing methodologies applicable to smart cities. These cover the orchestration and management of crowdsensing campaigns and experiences, the collaborative selection of geographical boundary locations for bike sharing, emotional mapping to facilitate public discourse in shared spaces, the provision of information about the city and user satisfaction through mobile platforms, mobile crowdsensing with the ability to use extremities for potentially dangerous crowd situations, the use of social media data to monitor large-scale crowd events, the detection of on-street parking spaces through mobile crowdsourcing, and the evaluation of sound environments through crowdsourcing data. These methodologies use mobile devices, sensors, and community participation to collect and analyse data for smart city applications.

3. API Standards

There are several API standards used for various smart city applications, such as

- Traffic data APIs: These APIs usually adhere to communication standards based on REST or the Simple Object Access Protocol (SOAP). They provide endpoints for accessing traffic data, such as information on congestion, accidents, and road conditions, often in JavaScript Object Notation (JSON) or eXtended Markup Language (XML) format [8].

- Public transport APIs: Public transport APIs often follow open standards, such as the General Transit Feed Specification (GTFS), which defines a standard format for sharing information about public transport timetables, routes, and stops. These APIs often use REST to access real-time data, such as the location of vehicles [9].

- Parking APIs: Parking APIs may vary in their standards, but they often use REST to provide real-time information on the availability of parking spaces. They may adhere to secure communication protocols to guarantee data integrity [10].

- Air quality APIs: APIs that monitor air quality usually use REST communication protocols to provide up-to-date information on air quality at different locations in the city. Data can be transmitted in formats such as JSON or XML [11].

- Public lighting APIs: Public lighting or street lighting APIs can use communication standards such as Message Queuing Telemetry Transport (MQTT) to control lights based on light and motion sensors. This enables effective communication between sensors and control systems [12].

- Emergency service APIs: These APIs generally follow secure communication protocols like Hypertext Text Transfer Protocol Secure (HTTPS) to ensure the security of emergency-related information. They can provide real-time data about accidents, fires, and other critical situations [13].

In summary, the standards of APIs in smart city applications can vary. However, they often include REST, specific protocols for data types (e.g., GTFS for public transport), and security measures to protect sensitive information [14]. These standards ensure the interoperability and reliability of the APIs used to enhance efficiency and quality of life in smart cities. One significant area for improvement in this implementation is the absence of standardised practices in the sensitisation initiatives commonly used in smart cities, which is not uncommon, and to mitigate the absence of established criteria in the accessible data, the suggested framework incorporates a RESTful API to tackle this concern.

4. Data Visualisation

Data visualisation is paramount to comprehending, evaluating, and conveying the extensive and intricate datasets produced within smart cities; by data visualisation techniques, it is possible to process and present the data. Urban planning facilitates city development, land-use planning, and infrastructure optimisation. For public transportation, real-time transit data visualisation helps commuters with route planning, enhancing the overall efficiency of transit systems. Environmental monitoring leverages visualisations to track air quality, weather patterns, and energy consumption, bolstering sustainability initiatives [15][16][17]. In emergency response, geographic information system-based visualisations enable rapid, data-driven responses to disasters and emergencies. Moreover, data visualisation contributes to citizen engagement by empowering residents with insights and encouraging their participation in local governance. It further extends to gamification techniques to engage and inform the population effectively [18][19].

Significant progress has been made in data visualisation approaches to effectively handle the increasing complexity and volume of data in smart city contexts; such advances include the use of dashboards that offer real-time insights via interactive visual representations such as charts, maps, and interfaces [20]. By implementing such tools, policymakers and citizens can actively explore data while incorporating machine learning algorithms to assist in identifying patterns, anomalies, and correlations within extensive datasets. Consequently, it facilitates the decision-making process. Moreover, using data visualisation methods to depict information chronologically serves to augment comprehension of patterns, facilitate the ability to predict future events, and aid in improving municipal operations, among various other advantages [21].

A plethora of software tools and platforms have emerged to facilitate data visualisation in the context of smart cities. Tableau is widely used to construct dynamic dashboards and reports, link disparate data sources, and provide real-time visualisation. Microsoft's Power BI software allows its customers to visualize data and access various business intelligence features. The software in question also facilitates effortless linkage to IoT data sources. QlikView and Qlik Sense are other applications with associative data modeling capabilities that let users explore data relationships interactively [22][23]. Furthermore, while pre-made solutions are prevalent, it is occasionally feasible to develop one's software by incorporating customisation and parameterization. Integrating a graphical library (ChartJS, LineJS, Google Charts, Leaflet) with a JavaScript framework (e.g., Angular, ReactJS, VueJS) is the prevailing method.

Despite the substantial advancements in data visualisation in smart city contexts, several persistent challenges continue to shape this field. These challenges include the delicate balance between data privacy and accessibility, the imperative for scalability to manage ever-expanding.

5. Mobile Apps

The development of crowdsensing involves integrating sensory data collection through users' mobile devices, allowing citizens to contribute to the collective through their devices. It provides personalised, intelligent information to each citizen, empowering them to make informed decisions and leverage community resources [24].

Previous literature on enhancing the quality of life within smart cities by incorporating crowdsensing, crowdsourcing, and geofences in mobile applications is evaluated. Devices and applications can use geofences to give helpful information to citizens when they are near an area of interest. The expansion of crowdsensing users and the development and implementation of smart cities share the objective of integrating citizens into intelligent environments via personalised information that is context-sensitive and transmitted via mobile applications.

According to Amaxilatis et al. [25], integrating IoT devices with smartphone applications is crucial for fostering and enhancing creative ecosystems in urban regions since this empowers users to verify and embrace new services. The authors concluded that the pervasive and routine smartphone usage among individuals provides a substantial opportunity for researchers to collect detailed and perceptive observations of urban surroundings.

Fernandes et al. [26], developed a mobile device platform that enables users to access comprehensive information about the current and future state of the city. The platform also provides context-aware smart notifications with relevant information. The platform incorporates a gamification mechanism incorporating user perception, evaluation, and satisfaction with their city to encourage continued usage. Meanwhile, Foschini et al. [5] presented ParticipAct, a mobile crowdsensing platform that uses edge nodes to identify potential hazardous crowd scenarios. This platform is particularly useful in emergencies, such as the ongoing COVID-19 pandemic, as it allows individuals to avoid dangerous crowd situations and receive suggestions for safer routes or places. ParticipAct has users install a sensing client application on their smartphones, which sends the collected information to a centralised cloud server. Researchers and platform administrators create these targeted sensing campaigns.

In summary, smart cities utilise information and communication technology to maximize infrastructure, facilitate cooperation, and promote innovation, all while ensuring efficient services. Active citizen participation in crowdsensing solutions can improve emergency management, environmental monitoring, healthcare and well-being, e-commerce, and other facets of smart cities. Mobile crowdsensing is an excellent method for gathering data in smart cities. Several methods can be implemented to promote public engagement, such as monetary incentives, entertainment, and service.

References

1. Caragliu, A.; Del Bo, C.; Nijkamp, P. Smart Cities in Europe. J. Urban Technol. 2011, 18, 65–82.
2. Nižetić, S.; Šolić, P.; de-Ipiña González-de Artaza, D.L.; Patrono, L. Internet of Things (IoT): Opportunities, issues and challenges towards a smart and sustainable future. J. Clean. Prod. 2020, 274, 122877.
3. Sousa, R.; Lopes, D.; Silva, A.; Durães, D.; Peixoto, H.; Machado, J.; Novais, P. Sustainable and Social Energy on Smart Cities: Systematic Review. In Communications in Computer and Information Science; Springer Nature Switzerland: Berlin/Heidelberg, Germany, 2022; pp. 72–84.
4. Hsiao, H. ICT-mixed community participation model for development planning in a vulnerable sandbank community: Case study of the Eco Shezi Island Plan in Taipei City, Taiwan. Int. J. Disaster Risk Reduct. 2021, 58, 102218.
5. Foschini, L.; Martuscelli, G.; Montanari, R.; Solimando, M. Edge-enabled Mobile Crowdsensing to Support Effective Rewarding for Data Collection in Pandemic Events. J. Grid Comput. 2021, 19, 28.
6. Yang, M.; Zhu, T.; Liang, K.; Zhou, W.; Deng, R.H. A blockchain-based location privacy-preserving crowdsensing system. Future Gener. Comput. Syst. 2019, 94, 408–418.
7. Shahrour, I.; Xie, X. Role of internet of things (IoT) and crowdsourcing in smart city projects. Smart Cities 2021, 4, 1276–1292.
8. Wagner, J.M.; Eschbach, M.; Vosseberg, K.; Gennat, M. Travel Time Estimation by means of Google API Data. IFAC-PapersOnLine 2020, 53, 15434–15439.
9. Ge, L.; Sarhani, M.; Voß, S.; Xie, L. Review of Transit Data Sources: Potentials, Challenges and Complementarity. Sustainability 2021, 13, 11450.
10. Biyik, C.; Allam, Z.; Pieri, G.; Moroni, D.; O'Fraifer, M.; O'Connell, E.; Olariu, S.; Khalid, M. Smart Parking Systems: Reviewing the Literature, Architecture and Ways Forward. Smart Cities 2021, 4, 623–642.
11. Schulte, K. 'Real-time' air quality channels: A technology review of emerging environmental alert systems. Big Data Soc. 2022, 9, 20539517221101346.
12. Kuncicky, R.; Kolarik, J.; Soustek, L.; Kuncicky, L.; Martinek, R. IoT Approach to Street Lighting Control Using MQTT Protocol. In AETA 2018—Recent Advances in Electrical Engineering and Related Sciences: Theory and Application; Zelinka, I., Brandstetter, P., Trong Dao, T., Hoang Duy, V., Kim, S.B., Eds.; Springer: Cham, Switzerland, 2020; pp. 429–438.
13. Fraga-Lamas, P.; Fernández-Caramés, T.M.; Suárez-Albela, M.; Castedo, L.; González-López, M. A Review on Internet of Things for Defense and Public Safety. Sensors 2016, 16, 1644.
14. Alves, C.; Chaves, A.; Rodrigues, C.; Ribeiro, E.; Silva, A.; Durães, D.; Machado, J.; Novais, P. Survey for Big Data Platforms and Resources Management for Smart Cities. In Hybrid Artificial Intelligent Systems; García Bringas, P., Pérez García, H., Martínez de Pisón, F.J., Villar Flecha, J.R., Troncoso Lora, A., de la Cal, E.A., Herrero, Á., Martínez Álvarez, F., Psaila, G., Quintián, H., et al., Eds.; Springer: Cham, Switzerland, 2022; pp. 393–404.
15. Pal, D.; Triyason, T.; Padungweang, P. Big data in smart-cities: Current research and challenges. Indones. J. Electr. Eng. Inform. (IJEEI) 2018, 6, 351–360.
16. Burch, M.; Staudt, Y.; Frommer, S.; Uttenweiler, J.; Grupp, P.; Hähnle, S.; Scheytt, J.; Kloos, U. Pasvis: Enhancing public transport maps with interactive passenger data visualizations. In Proceedings of the 13th International Symposium on Visual Information Communication and Interaction, Eindhoven, The Netherlands, 8–10 December 2020; pp. 1–8.
17. Kiani, A.; Azhar, S.; Riaz, Z. Real-time environmental monitoring, visualization, and notification system for construction H&S management. J. Inf. Technol. Constr. 2014, 19, 72–91.
18. Zica, M.; Ionica, A.C.; Leba, M. Gamification in the context of smart cities. In IOP Conference Series: Materials Science and Engineering; IOP Publishing: Bristol, UK, 2018; Volume 294, p. 012045.
19. Latifi, G.R.; Monfared, M.P.; Khojasteh, H.A. Gamification and citizen motivation and vitality in smart cities: A qualitative meta-analysis study. GeoJournal 2022, 87, 1217–1230.
20. Gorodov, E.Y.; Gubarev, V.V. Analytical review of data visualization methods in application to big data. J. Electr. Comput. Eng. 2013, 2013, 969458.
21. Park, S.; Bekemeier, B.; Flaxman, A.; Schultz, M. Impact of data visualization on decision-making and its implications for public health practice: A systematic literature review. Inform. Health Soc. Care 2022, 47, 175–193.
22. Zeferino, E.F.; Mpofu, K.; Makinde, O.; Ramatsetse, B. Establishment of an Appropriate Data Analytic Platform for Developing a Wisdom Manufacturing System Using Decision Techniques. In Proceedings of the Global Conference on

Sustainable Manufacturing, Berlin, Germany, 5–7 October 2022; pp. 622–629.

23. Muntean, M. Considerations Regarding Business Intelligence in Cloud Context. Inform. Econ. 2015, 19, 55–67.
24. Pereira, P.; Linhares Silva, A.; Machado, R.; Silva, J.; Durães, D.; Machado, J.; Novais, P.; Monteiro, J.; Melo-Pinto, P.; Fernandes, D. Comparison of Different Deployment Approaches of FPGA-Based Hardware Accelerator for 3D Object Detection Models. In Proceedings of the Progress in Artificial Intelligence: 21st EPIA Conference on Artificial Intelligence, EPIA 2022, Lisbon, Portugal, 31 August–2 September 2022; pp. 285–296.
25. Amaxilatis, D.; Mylonas, G.; Diez, L.; Theodoridis, E.; Gutiérrez, V.; Muñoz, L. Managing pervasive sensing campaigns via an experimentation-as-a-service platform for smart cities. Sensors 2018, 18, 2125.
26. Fernandes, B.; Neves, J.; Analide, C. SafeCity: A Platform for Safer and Smarter Cities. In Advances in Practical Applications of Agents, Multi-Agent Systems, and Trustworthiness, Proceedings of the 18th International Conference, PAAMS 2020, L'Aquila, Italy, 7–9 October 2020; Springer: Cham, Switzerland, 2020; Volume 12092, pp. 412–416.