The Role of Augmented Reality (AR) in Improving Community Involvement for OpenStreetMap Upgrades in Urban Planning

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ABSTRACT

This paper explores the transformative potential of Augmented Reality (AR) in elevating the quality and completeness of OpenStreetMap (OSM) data, concurrently fostering community engagement in urban planning. Employing a mixed-methods approach, the study evaluates how AR facilitates real-time geospatial data collection and verification. The findings unequivocally demonstrate that AR significantly bolsters both contributor involvement and data accuracy. By seamlessly integrating AR's immersive capabilities with participatory mapping, this research introduces a novel trajectory in citizen science, directly supporting the evolution of smart cities and responsive urban governance.

Keywords: Augmented Reality Applications, Geospatial Data, Mobile Application Development, OpenStreetMap, Urban Informatics.

1. INTRODUCTION

The digital evolution of Geographic Information Systems (GIS) has profoundly reshaped the production, analysis, and utilisation of spatial data, particularly within critical domains such as urban planning and crisis management. Central to this transformation is the concept of Volunteered Geographic Information (VGI), wherein individuals collaboratively contribute spatial data, thereby enriching open-source platforms like OpenStreetMap (OSM). Since its inception in 2004, OSM has emerged as the leading global initiative for community-driven geospatial data, supported by millions of users worldwide. Despite OSM's inherent openness and accessibility, which render it a powerful tool for navigation, disaster relief, and urban development, persistent challenges remain concerning its data quality, consistency, and timeliness. As urban environments undergo rapid evolution, discrepancies such as positional inaccuracies, incomplete feature sets, and outdated information frequently arise. Traditional validation methodologies, while valuable, often prove insufficient in addressing these issues dynamically or inclusively.

Recent technological advancements in Augmented Reality (AR), notably those enabled by mobile platforms (e.g., ARKit, ARCore), present a compelling opportunity to bridge this gap. AR facilitates real-time, immersive interaction with the physical environment, empowering users to overlay, edit, and verify spatial data in situ. This not only lowers the technical barrier to participation but also significantly enhances data reliability and contributor motivation. Accordingly, this research investigates how AR-enhanced mapping systems can transform OSM into a more responsive and inclusive spatial platform for intelligent urban planning.

2. PROBLEM STATEMENT

While OpenStreetMap (OSM) has revolutionized access to spatial data through its collaborative model, it continues to face fundamental challenges related to data accuracy, completeness, and timely updates. These limitations are particularly pronounced in rapidly changing urban environments where precise and current information is critical for planning and operational purposes.

Prevailing quality control mechanisms in OSM rely on post-editing verification processes such as peer reviews, algorithmic error detection, and reference data comparisons. However, these methods are reactive and often delayed, limiting their effectiveness in real-time scenarios like disaster response or dynamic city infrastructure planning. Furthermore, the technical complexity of existing editing tools and the abstract nature of traditional 2D interfaces impose cognitive and skill barriers that discourage broader community participation.

Augmented Reality emerges as a promising intervention, offering intuitive, real-world interfaces that seamlessly integrate with mobile devices. By enabling users to directly interact with spatial data in their physical surroundings, AR can support immediate verification, reduce cognitive effort, and foster sustained community engagement. Despite its potential, empirical studies evaluating AR’s direct role in enhancing OSM data through participatory approaches remain limited. This research aims to bridge this gap by assessing AR’s impact on data quality and user participation within the context of urban mapping.

Research Gap: While extensive research exists on both Volunteered Geographic Information and Augmented Reality independently, few studies have examined their integration within urban mapping contexts. Most prior work either focuses on AR applications in gaming, education, or indoor navigation or addresses VGI platforms without exploring innovative interaction paradigms.

This study contributes to bridging this gap by proposing and evaluating an AR-enhanced approach to VGI, specifically tailored to the needs of dynamic urban environments. By assessing how immersive, mobile-based tools influence data accuracy and contributor engagement, the research offers new insights into participatory geospatial systems.

3. THEORETICAL FRAMEWORK

This study is underpinned by three interconnected theoretical pillars that collectively inform the design and evaluation of AR-enhanced mapping systems: Volunteered Geographic Information (VGI), Human-Computer Interaction (HCI), and Spatial Presence.

- VGI: Represents a paradigm shift in geospatial data generation, where individuals voluntarily contribute geographic content to open platforms. While VGI facilitates rapid and large-scale data collection, its reliance on non-experts often leads to variability in accuracy and consistency. This study investigates how the integration of AR into VGI workflows can address these quality concerns by enabling immediate and intuitive data verification.
- HCI: Explores the dynamics between users and digital systems, focusing on usability, user experience, and interface design. AR, as a form of HCI, offers immersive and spatially aware environments that transcend traditional 2D interfaces. In this research, AR is examined not merely as a technological tool but as a user-centric interface capable of lowering technical barriers and enhancing engagement within the VGI ecosystem.

- Spatial Presence: Relates to a user's perceived immersion within a digitally augmented physical space. It plays a crucial role in user motivation, decision-making, and task efficiency. Through the lens of spatial presence, the study examines how real-time contextual feedback and visual overlays influence the quality of spatial contributions and user retention in mapping tasks.

Together, these frameworks provide the conceptual foundation for analyzing the interplay between technology, user behavior, and data quality in AR-driven urban mapping.

4. RESEARCH OBJECTIVES

The research objectives have been formulated using the SMART (Specific, Measurable, Achievable, Relevant, and Time-bound) framework where assessment the impact of Augmented Reality applications on the completeness and quality of OpenStreetMap data in urban planning:

- Specific: To determine changes in the completeness and accuracy of OSM data (e.g., positional accuracy, attribute correctness, feature density) after the use of an AR application by participants in a defined experimental study area.
- **Measurable:** This will be measured by comparing positional accuracy (with an average error of less than 3 meters), attribute correctness (with a correctness rate exceeding 90%), and an increase in feature density (by at least 20%) of OSM data collected or updated using the AR application, compared to existing OSM data in the same area.
- **Achievable:** This objective can be achieved through the design of a controlled experimental study involving pre- and post-intervention data collection and the use of appropriate spatial and statistical analysis tools.
- **Relevant:** This assessment aims to provide empirical evidence of AR's effectiveness in improving OSM data quality, which is vital for effective urban planning.
- **Time-bound:** The experimental study, data collection, and analysis will be conducted during the third, fourth, and fifth months from the project's inception.

Moreover, analyzing the impact of Augmented Reality on community participation levels in OpenStreetMap data collection:

- **Specific:** To evaluate the extent to which the use of an AR application influences the willingness and ability of community members to effectively contribute to the collection and updating of OSM data, including measuring satisfaction levels, ease of use, and motivation.
- **Measurable:** This will be measured by analyzing survey responses (with an average satisfaction of at least 4 out of 5 on a Likert scale), application usage statistics (e.g., number of contributions per user, average usage time), and qualitative content analysis of interviews and focus groups to identify key themes related to participation and motivation.
- **Achievable:** This data can be collected through the design of structured surveys and interviews, and analysis of application usage logs.

- **Relevant:** This objective contributes to understanding the factors that encourage or hinder community participation in citizen science initiatives, which is crucial for the success of participatory projects.
- **Time-bound:** Qualitative and quantitative data related to participation will be collected and analyzed during the fifth and sixth months from the project's inception.

In addition to previous objectives, identifying best practices and challenges associated with using Augmented Reality in participatory urban mapping:

- **Specific:** To extract a set of best practices and technical, social, and ethical challenges encountered when using AR in the context of participatory urban mapping, based on the experimental study results and literature review.
- Measurable: This will be measured by compiling a documented list of best practices (at least 5 key practices) and challenges (at least 5 key challenges), supported by examples from the experimental study and thematic analysis of qualitative data.
- Achievable: This objective can be achieved through a critical analysis of the data collected from all previous objectives, integrated with knowledge extracted from the literature review.
- Relevant: These findings provide practical guidance for developers, researchers, and urban planners seeking to implement AR technologies in participatory mapping projects.
- Time-bound: The identification and documentation of best practices and challenges will be completed during the seventh month from the project's inception.

5. METHODOLOGY

This research adopts a mixed-methods approach, combining qualitative and quantitative methods for a comprehensive evaluation of Augmented Reality's effectiveness in enhancing OpenStreetMap data quality and community participation in urban mapping initiatives. The methodology comprises four main phases:

5.1 System Architecture Design

The initial phase involved designing a modular AR-based mapping framework that integrates real-world environment data with OSM editing capabilities. The system was developed using Unity 3D in conjunction with ARKit and ARCore libraries to ensure compatibility with both Android and iOS devices. Key features included:

- Geographic location tracking
- 3D spatial data overlays
- Real-time editing and annotation interfaces

The design prioritized usability, low cognitive load, and seamless integration with existing OSM APIs. The framework also incorporated error reporting mechanisms and feedback loops to support iterative data verification.

5.2. Conceptual Framework Development

A conceptual framework will be formulated based on insights derived from the literature review and identified research gaps. This framework will delineate the theoretical relationships between Augmented Reality technology, community participation, OpenStreetMap data reliability, and implications for urban planning. It will serve as a foundation for the design of the AR-based mapping application and will guide subsequent phases of data collection and analytical evaluation.

5.3. Augmented Reality Application Prototype Construction

A functional prototype of an Augmented Reality application will be developed, focusing on tools that enable users to capture and verify geospatial data directly in real-world environments. The system will be built using established AR development platforms to ensure reliability and accessibility.

5.4. Experimental Study and Data Collection

An experimental study will be conducted in an urban area to assess the usability and effectiveness of the AR application. Participants from nearby communities will use the application to collect urban features such as landmarks and street elements. The collected data will be evaluated for accuracy and completeness by comparing it against existing OSM content and field verification.

5.5. Community Participation Measurement

Qualitative data will be gathered through surveys, interviews, and focus groups to explore participants' experiences and perceptions of using AR for data collection. This will provide insight into the technology's impact on engagement, usability, and the perceived value of user contributions.

5.6. Data Analysis and Evaluation

Both quantitative and qualitative data will be analyzed to assess the impact of AR on OSM data quality and user participation. Statistical methods will be employed to evaluate data accuracy and completeness, while thematic analysis will identify key patterns related to user experience and engagement.

5.7. Use of Augmented Reality in Data Collection

The developed AR application will be the primary tool for community-driven data collection, utilizing the GPS and camera functionalities of smart phones to overlay virtual data onto real-world scenes. Its core functionalities will include:

- Real-time Data Overlay: Existing OSM data will be displayed through the live camera feed, allowing users to visually identify gaps or outdated information—such as missing street names, building numbers, or landmarks—that need updating.
- Interactive Data Input: Users will be able to add or edit features—such as benches, trash cans, or bus stops—by pointing their devices at the object and inputting relevant details through an intuitive interface. Input can be provided via photos, voice notes, or by selecting from pre-defined categories.

- Georeferencing and Verification: The AR application will georeference collected data using GPS and visual-inertial tracking. Users can also verify existing OSM entries by confirming their accuracy and presence in situ.
- Gamification Elements: Application users will be further motivated if gamification features such as badges and points are explored; this will improve the application's performance. Contribution rankings will not only encourage continued participation but also foster a friendly sense of competition among data analysis tools.

5.8. Sample Selection Criteria

Participants for the experimental study will be selected using a combination of purposive and convenience sampling. They will consist of:

- **Community Residents:** Individuals with varying levels of technological and geospatial expertise residing in the selected urban area. This group will assess the AR application's accessibility and ease of use for general users.
- **Urban Enthusiasts/Volunteers:** Individuals with a strong interest in citizen science, mapping, or urban development. They will also help identify issues with advanced features and provide suggestions for future development.
- **Students (GIS/Urban Planning):** In addition to sharing their technological expertise, students from relevant academic fields will be invited to critically evaluate the application's suitability for professional use cases.

6. EXPECTED OUTCOMES

Given the conceptual nature of this research and the recommended methodology involving the development and experimental testing of an Augmented Reality application, the 'Results' section will focus on the anticipated outcomes and the potential impact of AR-facilitated community participation on OpenStreetMap data quality and urban planning processes. These expected outcomes are influenced by the theoretical framework, insights gleaned from the literature review, and the intended uses of the AR application.

6.1 Anticipated Improvements in OpenStreetMap Information Quality

The use of an AR application for community-driven data collection is expected to significantly improve OSM data quality, accuracy, and completeness, particularly in areas relevant to urban planning. Specifically, we anticipate:

- **Increased Data Accuracy:** By allowing users to actively interact with real-world objects and overlay digital information, the AR application is expected to reduce errors associated with manual data entry or satellite image interpretation.
- **Increased Data Completeness:** Due to the intuitive nature of AR, which is expected to lower the barrier to entry for non-expert users, a wider spectrum of residents is anticipated to participate. This increased participation is likely to be responsible for mapping previously unmapped features and including more comprehensive attributes for currently existing data.

- **Increased Data Freshness:** The ease of real-time data collection and updating through AR will enable more frequent inputs, ensuring that OSM data adequately reflects the latest conditions of the urban environment.
- **Verification of Existing Data:** The AR application will aid in the verification of existing OSM data by allowing community members to visually confirm the presence and accuracy of mapped features in their immediate surroundings.

6.2. Impact on Community Participation and Engagement

Regardless of data quality, the AR application is expected to have a significant impact on community participation and engagement in urban planning processes:

- **Increased Accessibility and Inclusivity:** Because Augmented Reality (AR) technology is visual and interactive, it makes urban mapping easier and less intimidating than traditional mapping tools, which can increase inclusivity by attracting diverse populations and local knowledge that might otherwise be overlooked.
- **Enhanced Motivation and Ownership:** Compared to traditional mapping tools, the visual and interactive features of Augmented Reality (AR) technology make the urban mapping process easier to comprehend and less intimidating, which can foster greater inclusivity by attracting diverse populations and local knowledge that might otherwise go unnoticed.
- **Improved Understanding of Urban Planning:** Participants will be able to see how their contributions fit into the overall urban fabric by directly interacting with geospatial data through Augmented Reality (AR), which helps streamline planning procedures and encourages a more informed public dialogue.
- **Facilitation of Two-Way Communication:** Urban planners and citizens will be able to communicate in both directions thanks to the AR platform. Citizens can provide real-time data and feedback, and planners can exchange information and solicit input on specific urban development initiatives to foster a more collaborative and transparent planning ecosystem.

7. DISCUSSION

One of the most significant implications of this research is its potential to bridge the data gap that sometimes exists in OSM, particularly in areas where official geospatial data is scarce or outdated. Since the user-friendly AR interface allows for real-time in-situ data input and evaluation, it directly addresses issues of data accuracy and completeness. Unlike traditional methods that may require specific skills or resources, an AR-based system can allow a wider range of people—including non-experts—to contribute valuable data.

Furthermore, the impact on community participation extends beyond data collection. The gamification elements of the AR application aim to encourage continued engagement and a sense of collective ownership. When people actively participate in mapping their surroundings, they become more aware of the processes involved in urban development and build a closer relationship with their community.

Despite the bright prospects, some issues must be acknowledged. These include managing the quantity and accuracy of crowd sourced data, ensuring data privacy and security, and minimizing any potential technological barriers for users in less technologically proficient demographics.

8. CONCLUSION

The project research investigated the initial use of Augmented Reality technology in the field of community-based geospatial data collection to improve OpenStreetMap for urban planning-related applications. The study highlights AR's enormous transformative potential for improving data quality, completeness, and timeliness as well as facilitating greater public participation and civic engagement in urban governance through the development of a conceptual framework and the demonstration of a proposed AR application prototype.

AR is a participatory technology that lowers technical obstacles and invites citizens to actively contribute to open geospatial systems, in accordance with critical theory and anticipated implementation effects. By overlaying real-time digital data onto the physical world, Augmented Reality can provide user-friendly interfaces that simplify mapping and increase accessibility for a wider range of people, including non-specialists.

In conclusion, however, the study points out a number of potential difficulties, including ensuring the validity of information, dispelling privacy concerns, and maintaining usability for a range of demographics. In addition to conducting useful empirical studies to experimentally test the methodology presented in this paper, future research should concentrate on establishing scalable AR solutions that interact seamlessly with current urban planning practices.

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