An Ontology-Based System for Detecting and Repairing Road Potholes through Community Involvement

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***Abstract*— Potholes pose significant risks to road safety, endangering both human lives and vehicle integrity. Enhancing the safety of road infrastructure hinges on the prompt identification and repair of these potholes. This article introduces an affordable pothole detection system that engages citizens by utilizing smartphones to efficiently report these dangers. The system uses people's mobile devices to capture images of potholes and record their location using GPS data rather than expensive or complex machine learning detection techniques. The reports are then geolocated on a map, allowing for a clear visual representation of the distribution of potholes in the area. Once reported, these potholes are recorded using an ontology and integrated into road maintenance management systems. We use a generic ontology called "a lightweight implementation of the unified fundamental ontology (gUFO)" for the implementation of our ontology, the system provides an organized and scalable framework for classifying pothole-related data. This method facilitates seamless data integration, ensures consistency across different data sources, and improves interoperability with existing infrastructure systems. The system's ability to efficiently share and interpret data is enhanced by Semantic Web technologies, thereby promoting road safety and actively involving the community in improving urban infrastructure through a smart and interconnected network.**

Keywords*— Pothole, Citizen Participation, Road Safety, Ontology, GPS Integration, Semantic Web

I. Introduction

Potholes are a persistent problem on urban and suburban roads, posing safety risks and causing substantial vehicle damage. These depressions in the pavement can form rapidly, particularly after heavy rain or snow, leading to costly repairs for drivers and increasing the likelihood of accidents. Traditional pothole detection methods, such as laser scanning and accelerometers, are effective but often costly and resource-intensive, limiting their scalability and real-time responsiveness.

This paper proposes a low-cost, scalable pothole detection system that leverages citizen participation [1]. Citizens can capture photos and GPS coordinates of potholes by using her smartphones, which are then geolocated on a map to provide a visual representation of pothole distribution. These reports are analyzed using an ontology-based approach, specifically a lightweight implementation of the Unified Foundational Ontology (gUFO) [2], [3], to structure and categorize pothole-related data efficiently.

The integration of semantic web [4], [5] technologies facilitates seamless data sharing and interoperability with existing road maintenance systems, enabling real-time alerts to drivers and optimizing maintenance schedules. By involving citizens in the reporting process, this system enhances road safety, reduces maintenance costs, and contributes to a more proactive model of urban infrastructure management. This approach demonstrates the potential of combining ontology with community engagement to address the ongoing challenge of pothole detection and repair.

The remainder of this paper is organized as follows: Section I introduces the study; Section II provides a literature review; Section III describes the methodology; Section IV presents the system design; Section V discusses the results and projected system performance; and Section VI concludes the study by summarizing findings and suggesting future work.

II. Literature Review

A. Traditional Pothole Detection Methods and Advanced Technologies

Historically, pothole detection has relied on laser scanning, accelerometers, and video analysis [6], [7]. These techniques, while accurate, require significant financial investment in specialized equipment and human resources, making them unsuitable for large-scale, continuous monitoring across road networks. Advancements in Internet of Things (IoT) technologies and edge computing have introduced new possibilities for autonomous, real-time pothole detection [8]–[10]. For example, frameworks leveraging GPS sensors and machine learning models offer scalable and efficient detection and localization of potholes [6], [8], [9]. Such advancements aim to reduce the reliance on expensive equipment, enabling municipalities to adopt cost-effective solutions for road infrastructure management. However, challenges persist, including data reliability and integration with broader urban management systems.

B. Integration of Semantic Web Technologies and Ontologies

To address the limitations of current pothole detection and management methods, we will use ontologies and semantic web technologies that offer an innovative solution by facilitating the co-construction and sharing of knowledge [11]–[14]. The creation of a pothole-specific ontology allows structuring and standardizing the collected data, thus facilitating their sharing and integration between different systems. By establishing a common framework for categorizing and analyzing pothole-related information, ontologies facilitate more efficient data management and better decision-making. Using ontology [11] in pothole detection, coupled with semantic technologies, optimizes information exchange between citizens, local authorities, and road maintenance management systems, thereby enhancing the responsiveness and effectiveness of repair efforts.

C. Citizen Engagement in Pothole Detection

Citizen engagement is a cornerstone of the proposed pothole detection system, which relies on citizens using mobile applications to report potholes. Public participation not only reduces detection costs but also enhances data coverage, as citizens act as decentralized sensors across the road network. Research in smart city development emphasizes the importance of fostering meaningful citizen engagement to ensure the success of participatory systems [15].

Key factors influencing citizen engagement include:

- Information Availability: Providing accessible, real-time information about the impact and benefits of participation encourages citizens to engage. Studies show that when citizens are well-informed about the value of their contributions, they are more likely to participate actively in civic initiatives [16].
- Perceived Benefits: Demonstrating how citizen reports directly contribute to road safety and reduced maintenance costs fosters trust and motivation to participate. For instance, highlighting how a reported pothole led to faster repairs can inspire broader engagement [17].
- Feedback Mechanisms: Offering timely updates about the status of reported potholes ensures that citizens feel their contributions are valued, further incentivizing participation. Effective feedback loops have been shown to strengthen trust between citizens and governing bodies, leading to sustained engagement[16]

Studies on smart city initiatives highlight the effectiveness of bottom-up approaches, where community members play an active role in co-designing solutions. These approaches promote transparency, accountability, and inclusivity, ensuring that technological advancements address the diverse needs of the population [15], [17]. By integrating these principles, the proposed system aims to empower citizens to contribute to safer and more efficient road networks.

D. Application for Local Authorities

The proposed pothole detection application will be use by local authorities, providing them with a powerful and economical tool to enhance road safety and infrastructure maintenance. By utilizing citizens' smartphones to report potholes, municipalities can gain access to real-time data that aids in repair planning and allows prioritization of interventions in the most critical areas. This collaborative solution not only engages citizens in maintaining the safety of their environment but also provides local authorities with valuable insights to optimize resource allocation and reduce maintenance costs. Integrating this application into their management systems enables local authorities to adopt a proactive and participatory approach to managing road infrastructure.

III. METHODOLOGY

The methodology of this project is centered on integrating accessible technologies and citizen participation to develop a cost-effective and efficient system for pothole detection and management. The proposed system comprises several key steps, ranging from data collection by citizens to the use of advanced technologies for data analysis and processing.

A. Data Collection via Citizens' Smartphones

The core of the methodology is utilizing citizens' smartphones to detect and report potholes. Any citizen equipped with a smartphone can participate in pothole detection by taking a photo of a pothole they encounter and uploading the image through a dedicated mobile application. This application uses the smartphone's built-in GPS to record the precise location of the pothole. Users can also provide additional information, such as the approximate size of the pothole and any other relevant observations.

- **Development of the Mobile Application:** A user-friendly application will be developed to enable citizens to report potholes easily. The app will include features for taking photos, adding descriptions, and sending the data to a central server. It will also have a simple user interface to encourage broad and active participation.
- **Incentives for Citizens:** To motivate active citizen participation, incentives such as reward points or public recognition could be integrated into the application. These incentives will encourage users to report potholes regularly.

B. Data Processing and Validation

Once the data is collected, it is sent to a central server where it will be processed and validated. The integration of semantic web technologies and ontology will facilitate the organization and analysis of the data.

- **Data Filtering and Cleaning:** The collected data will first be filtered to remove duplicates and incorrect reports. Filtering algorithms based on GPS location and image analysis will be used to confirm the existence and position of potholes. This process will reduce noise in the data and increase its reliability.
- **Validation with Pothole Ontology:** A specific ontology will be developed to categorize the data and validate reports. This ontology will define the characteristics of potholes and the relationships between different types of data, enabling more coherent and standardized interpretation of information. Reports will be compared

against the ontology models to verify their validity and relevance.

C. User Notification and Alerts

The system will include an alert feature that notifies nearby drivers of detected potholes.

Real-Time Alerts can be used to alert the users of the application. When a pothole is validated, an alert will be sent to app users in the vicinity. These real-time notifications will allow drivers to adjust their routes or slow down to avoid potential damage. Validated pothole information will also be transmitted to local road maintenance services via an online platform. This platform will provide an overview of reported potholes, facilitating the planning and prioritization of repairs.

D. Integration with Road Maintenance Management Systems

The proposed ontology will not only categorize and validate pothole data but also integrate with existing road maintenance management systems to facilitate efficient pothole repair by local authorities.

- **Ontology-Based Maintenance Integration:** The ontology will include specific concepts and relationships related to pothole maintenance activities. This will allow the system to seamlessly integrate with municipal maintenance workflows, ensuring that pothole reports are translated into actionable tasks for repair crews. The ontology will define key attributes such as severity, urgency, and resource requirements, enabling automated prioritization and scheduling of maintenance activities.
- **Coordination and Communication:** The system will provide a communication interface for maintenance teams, allowing them to update the status of reported potholes in real-time. This interface will facilitate coordination between the data collected through citizen reports and the actions taken by road maintenance teams. By integrating with existing management systems, the ontology-based approach will help streamline the workflow, from detection to repair, ensuring that potholes are addressed efficiently and effectively.
- **Feedback Loop for Continuous Improvement:** The system will include a feedback loop that allows maintenance teams to report back on the completion of repairs. This information will be fed into the ontology to update the status of the potholes and refine the detection and reporting processes. By continuously updating the ontology with real-world data, the system will improve over time, becoming more accurate and responsive to changes in road conditions and maintenance needs.

By integrating smartphone technology, citizen engagement, and advanced data management through ontologies and semantic web technologies, this methodology offers an innovative and cost-effective solution for pothole detection and management. The system will empower local authorities with tools to enhance road safety, optimize maintenance resources, and engage citizens in preserving their environment. The ontology-based integration ensures that pothole detection leads directly to effective maintenance actions, making road management more proactive and data-driven.

IV. System Design

The design of the pothole detection and management system relies on a combination of accessible technologies, service-oriented architecture, and a dedicated ontology to ensure effective data collection, analysis, and management. This system is designed to be both robust and flexible, enabling easy integration with existing local government infrastructures and active citizen participation.

A. System Architecture

The system architecture Fig. 1 is designed to maximize the efficiency of data collection and information management while minimizing operational costs. It includes several interconnected layers that work together to provide real-time services.

- **User Interaction and Data Collection Layer:** This layer encompasses all interfaces and mechanisms through which users interact with the system and provide data. It integrates both the citizen-driven data collection processes and the user interfaces for interacting with the system:
  1. Mobile Application Interface
  Used by Citizens: The mobile application allows citizens to report potholes by capturing photos, recording GPS coordinates, and submitting relevant information. It is designed to be intuitive and user-friendly, providing straightforward options to encourage wide participation. Citizens also receive notifications about nearby potholes, improving road safety by keeping them informed of potential hazards.
  2. Web Portal for Maintenance Teams
  Used by Maintenance Teams: The web portal provides road maintenance teams with access to detailed pothole reports, enabling them to update the repair status, schedule maintenance activities, and plan interventions. The portal offers visual representations of pothole data using maps and charts, facilitating better decision-making and efficient resource allocation.
  3. Data Transmission
  Data collected through both the mobile application and the web portal are transmitted to the central server for processing. This ensures that all pothole reports and maintenance updates are centralized, allowing for integrated management and analysis.
- **Central Server Layer:** The central server acts as the core processing hub for all incoming data. It hosts the ontology and integrates multiple modules to handle various data processing tasks. Functions of this layer include:

  1. **Data Filtering and Cleaning Module:** Cleans and filters the raw data to eliminate duplicates and irrelevant reports.
  2. **Ontology and Knowledge Management:** The pothole ontology is hosted on the central server, serving as the foundation for data validation, classification, and standardization. The ontology

defines the relationships and attributes related to potholes and their maintenance, ensuring that data is processed consistently and accurately.

3. **Data Analysis Module:** Performs analysis on the validated data to identify patterns, such as pothole hotspots, and to prioritize maintenance efforts. This analysis helps in making informed decisions regarding road maintenance and resource allocation.

- **Notification System Layer:** This system generates real-time alerts for drivers based on validated pothole data. Alerts are sent to citizens' smartphones to warn them about nearby potholes, enhancing road safety. This layer is closely integrated with the central server to ensure timely and accurate notifications.

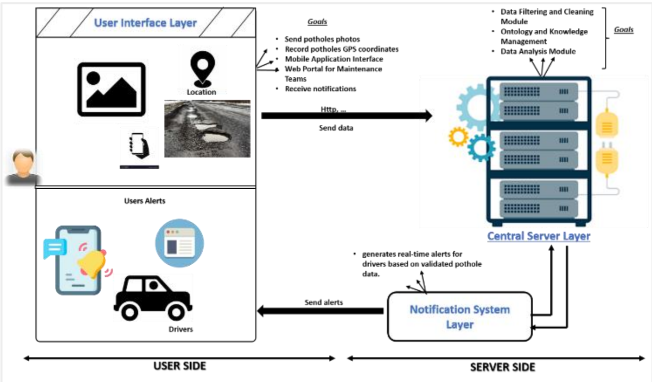

Fig. 1: System architecture

B. Modeling Approach for Pothole Management Ontology

1) Top-Down Ontology Development.

. In this section, we model the pothole ontology, providing a structured framework for organizing and interpreting data related to pothole detection, reporting, verification, and maintenance. By leveraging a lightweight implementation of the Unified Foundational Ontology (gUFO) [2], [3], we ensure that the ontology is both comprehensive and adaptable to the specific needs of pothole management.

The ontology development begins by defining high-level concepts such as Object, Event, and Role from gUFO. These foundational concepts form the core structure of the ontology, allowing it to be scalable and organized. From these foundational concepts, we then specialize into more detailed sub-concepts specific to the domain of pothole management, such as Pothole, Citizen, MaintenanceEvent, ReportEvent, and roles like Reporter and Maintainer.

2) Definition of Core Classes

Here we defined the structure of the Ontology

- Object:
  - ✓ Pothole: Represents the physical potholes that are detected and reported. This class includes attributes such as geographic location (latitude, longitude), size, condition, and status (e.g., "Reported", "In Progress").
  - ✓ Citizen: Represents individuals who detect and report potholes. This class includes attributes like name and contact information, facilitating communication and follow-up.
  - ✓ Team: Represents groups of employees organized to conduct maintenance and repair activities. Attributes may include team name and the number of members.
- Event:
  - ✓ ReportEvent: Captures the action of a pothole being reported by a citizen. This event includes details such as the reporting date and the involved pothole, linking the reporter to the pothole.
  - ✓ VerificationEvent: Represents the event where a pothole report is verified by an employee. This event ensures that reported potholes are evaluated before being scheduled for maintenance.
  - ✓ MaintenanceEvent: Represents activities related to the maintenance and repair of potholes. This event includes the scheduling, execution, and completion of maintenance tasks, specifying the type of maintenance and the personnel or team involved.
- Role:
  - ✓ Reporter: A role that a Citizen assumes when they report a pothole. This role is critical for initiating the maintenance workflow.
  - ✓ Supervisor: A role that an Employee may take on, overseeing the verification of reports and the coordination of maintenance activities.
  - ✓ Maintainer: A role that a Team or Employee undertakes during the MaintenanceEvent, responsible for carrying out maintenance tasks.

3) Object Properties (Relationships)

We define the relationships between these concepts here to capture the interactions and dependencies essential for efficient pothole management:

- reports: Links a Citizen to a Pothole, indicating the action of reporting a pothole.
- verifiedBy: Connects a Pothole to an Employee (acting as Supervisor), indicating that the pothole report has been verified.
- plannedBy: Associates a MaintenanceEvent with an Employee (acting as Supervisor), highlighting who is responsible for planning the maintenance.
- conductedBy: Relates a MaintenanceEvent to a Team or Employee (acting as Maintainer), indicating who performed the maintenance.
- relatedPothole: this relation Links ReportEvent, VerificationEvent, and MaintenanceEvent to the specific Pothole they address.

4) Semantic Web Standards

We use Protégé[18] to implement the ontology. Protégé provides a user-friendly interface for building, visualizing, and managing ontologies. It allows ontology developers to define classes, properties, and relationships easily, leveraging RDF and OWL[19] for creating machine-readable semantic annotations.

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5) Visual Representation

We illustrate the concepts, relationships and data properties defined in the ontology in Fig. 2, Fig. 3 and Fig. 4:

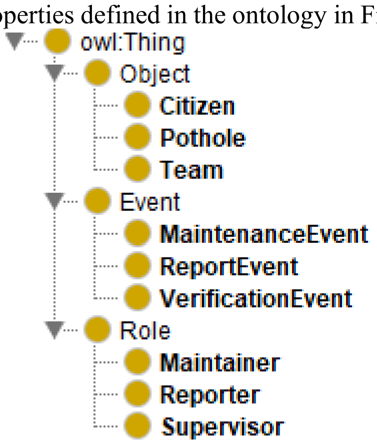

Fig. 2: Ontology Class Diagram Based on gUFO

Fig. 2 visually represents the main classes (Object, Event, Role) and their hierarchical relationships, demonstrating how the ontology aligns with gUFO's foundational structure.

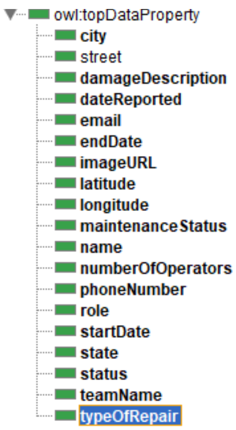

Fig. 3: Data Properties of Key Classes

Fig. 3 outlines the data properties associated with each class, such as latitude, longitude, state, and imageURL …, highlighting the specific attributes captured within the ontology. These data properties allow the ontology to represent detailed information about each entity in the domain of pothole management.

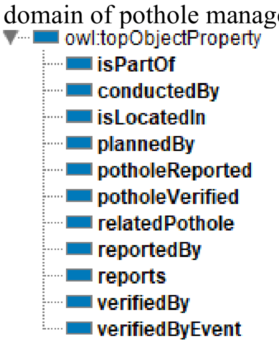

Fig. 4:Object Property Relationships

Fig. 4 shows the object properties that define relationships between classes, such as reportedBy, plannedFor, repairs, and performedBy, illustrating how entities interact in the gUFO-based ontology.

C. User Interface and Experience

The design of the user interface is crucial to ensuring successful adoption and use of the system by citizens and maintenance teams.

- **Mobile Application for Citizens:** The mobile application must be intuitive and easy to use, allowing users to report potholes quickly and easily. The interface will include options to capture photos, add descriptions, and submit reports. Push notifications can be used to remind users to report potholes and to inform them of nearby alerts.
- **Web Portal for Local Authorities:** The web portal will provide maintenance teams with an overview of reported potholes, including details such as location, size, and repair status. The portal will also allow for updating pothole status and planning interventions. Data will be presented visually, with interactive maps and charts to facilitate decision-making.
- **Real-Time Notifications:** Real-time notifications will be sent to drivers near detected potholes, allowing them to take preventive measures. Notifications will be based on GPS data and validated reports, ensuring maximum accuracy and relevance.

D. Data Security and Privacy

Data security and privacy are critical considerations in the system design, given the sensitive nature of the information collected.

- **Data Encryption:** All collected data, including photos, GPS coordinates, and users' personal information, will be encrypted during transmission and storage. This will ensure that data remains protected from unauthorized access.
- **Access Control:** The system will include strict access controls to ensure that only authorized personnel, such as maintenance teams and system administrators, can access sensitive data and system features.
- **Data Anonymization:** Citizen data will be anonymized before being analyzed or shared with local authorities to minimize the risk of privacy breaches.

E. Integration with Road Maintenance Management Systems

The proposed ontology will not only categorize and validate pothole data but also integrate seamlessly with existing road maintenance management systems to facilitate efficient pothole repair by local authorities.

- **Ontology-Based Maintenance Integration:** The ontology will include specific concepts and relationships related to pothole maintenance activities. This will allow the system to seamlessly integrate with municipal maintenance workflows, ensuring that pothole reports are translated into actionable tasks for repair crews. The ontology will define key attributes such as severity, urgency, and resource requirements, enabling automated prioritization and scheduling of maintenance activities.

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- **Feedback Loop for Continuous Improvement:** The system will include a feedback loop that allows maintenance teams to report back on the completion of repairs. This information will be fed into the ontology to update the status of the potholes and refine the detection and reporting processes. By continuously updating the ontology with real-world data, the system will improve over time, becoming more accurate and responsive to changes in road conditions and maintenance needs.

V. RESULTS

A. Summary of Outcomes from Ontology Design

The primary outcome of this research is the development of a structured ontology specifically designed for pothole detection and management, integrating citizen reports with municipal maintenance workflows. The ontology includes key classes such as Pothole, Report, Repair, and Reporter, along with properties that define relationships and attributes, including severity, location (latitude and longitude), and repair status. This structure facilitates standardized data collection and allows for seamless integration with external road maintenance systems [20].

The ontology's design emphasizes data organization and interoperability, which are essential for efficient pothole management. By standardizing how pothole information is categorized and shared, the ontology ensures that reports are uniformly represented, regardless of the source. This structure makes it easier to prioritize repair tasks, as potholes can be assessed and sorted based on severity, urgency, and location. In practice, the ontology is expected to support more accurate data flow and improve coordination among citizens, maintenance teams, and local authorities.

B. Projected System Performance Analysis

Although the full system has not yet been deployed, we can anticipate several performance outcomes based on the ontology's structure and similar implementations in the literature.

- Accuracy and Data Validation: The ontology is structured to validate and refine data by using specific data properties, such as severity levels and GPS coordinates, associated with each Pothole instance. By categorizing reports based on defined attributes, the ontology could help filter out erroneous or redundant data, increasing the accuracy of citizen-reported information before it is processed by maintenance teams. Future system implementations may also incorporate additional data sources, such as vehicle-mounted sensors, to further enhance data validation.
- Citizen Engagement and Reporting Efficiency: Based on findings from comparable systems, it is anticipated that an ontology-based reporting system with an intuitive mobile application will enhance citizen engagement. By providing a simple interface for reporting potholes and tracking the status of repairs, the system encourages consistent participation from citizens. This engagement model is expected to improve reporting frequency, especially if citizens receive feedback on the actions taken based on their reports [16], [17].
- Anticipated System Responsiveness and Data Flow: The ontology's structured data flow enables real-time report processing and integration with municipal maintenance workflows. In comparison to traditional pothole reporting methods, which often rely on delayed manual entries, this ontology-based system is expected to speed up data submission, prioritization, and repair. The system's responsiveness is anticipated to improve resource allocation, allowing maintenance teams to address high-priority issues faster and more effectively[15].

VI. DISCUSSION

The proposed ontology-based pothole management system combines semantic technologies and community-driven participation to address critical challenges in road infrastructure maintenance. This section evaluates the system's contributions, compares it with related works, and discusses its limitations.

A. Contributions of the Ontology

The ontology is the central innovation of this study, providing a standardized framework for organizing and sharing pothole-related data. Unlike traditional detection systems that rely heavily on machine learning or sensor-based methods [7], the proposed ontology ensures interoperability with municipal road maintenance systems by structuring data systematically.

Related works in [21], applied semantic modeling in vehicular networks to represent ride quality knowledge but focused primarily on assisted driving scenarios. While their study demonstrated the potential of semantic technologies for intelligent transportation systems, it did not address the specific challenges of road maintenance or pothole management. By contrast, the proposed ontology emphasizes structured data representation tailored to the unique requirements of pothole detection, repair prioritization, and integration with municipal workflows.

B. Enhancing Citizen Engagement

While secondary to the ontology, citizen engagement adds significant value to the proposed system. By enabling citizens to report potholes via a mobile application, the system capitalizes on community participation to expand data coverage and reduce operational costs. This participatory approach aligns with findings in smart city research, which emphasize the importance of bottom-up strategies for successful urban solutions [15]

Moreover, the inclusion of feedback mechanisms, such as real-time status updates on reported potholes, encourages sustained participation by creating a sense of accountability and empowerment among users. This engagement not only broadens the data collection network but also fosters stronger citizen-government collaboration, an essential factor in urban infrastructure management.

C. Addressing System Limitations

While the ontology provides a robust framework for data integration and standardization, its effectiveness depends on the consistency and quality of citizen reports. Variability in reporting behavior, such as underreporting in less engaged communities or inconsistencies in data submission, could affect the system's overall performance. To address this, implementing incentive mechanisms such as gamification, recognition programs, or tangible rewards could help encourage sustained participation.

Additionally, future enhancements could explore incorporating feedback loops that provide citizens with real-time updates on their reports, fostering trust and encouraging continued engagement. By addressing these limitations, the system can better support real-world applications and adapt to diverse urban contexts.

D. Major Contributions

This study makes two primary contributions to the field of pothole management and urban infrastructure:

Ontology-Based Framework: The structured, interoperable ontology addresses gaps in data standardization and integration, providing a scalable solution for road maintenance workflows.

Citizen Engagement Integration: By leveraging community participation, the system achieves broader data coverage and reduces detection costs, making it a cost-effective and practical solution for municipalities with limited resources.

By combining these elements, the proposed system represents a significant step toward more proactive, efficient, and participatory road infrastructure management. Future research could expand the ontology's capabilities to include predictive analytics, enabling data-driven, proactive maintenance strategies.

VII. Conclusion

The development of a pothole detection system that leverages citizen participation, semantic web technologies, and ontology offers a promising and cost-effective approach to enhancing road safety and infrastructure management. By prompting citizens to report potholes using their smartphones, the system leverages community participation to provide real-time data on pothole locations.

The use of semantic technologies facilitates seamless data sharing and interoperability, enabling local authorities to respond more effectively to reported potholes. By optimizing maintenance schedules and resource allocation, this approach not only improves the responsiveness of road maintenance but also reduces overall costs.

This system represents a shift towards a more proactive and participatory model of urban infrastructure management, where citizens play an active role in maintaining the safety and quality of their environment. By combining the power of ontology with citizen engagement, the proposed solution provides a scalable, efficient, and user-friendly way to address the ongoing challenge of pothole detection and repair, contributing to safer and more resilient road networks.

References

[1] F. Zarei et M. Nik-Bakht, « Citizen engagement body of knowledge – A fuzzy decision maker for index-term selection in built environment projects », *Cities*, vol. 112, p. 103137, mai 2021, doi: 10.1016/j.cities.2021.103137.

[2] J. P. A. Almeida, G. Guizzardi, T. P. Sales, et R. A. Falbo, « gUFO: A Lightweight Implementation of the Unified Foundational Ontology (UFO) », *AO*, 2019, Consulté le: 2 septembre 2024. [En ligne]. Disponible sur: http://purl.org/nemo/doc/gufo

[3] G. Guizzardi, G. Wagner, J. P. A. Almeida, et R. S. S. Guizzardi, « Towards ontological foundations for conceptual modeling: The unified foundational ontology (UFO) story », *Appl. Ontol.*, vol. 10, nº 3-4, p. 259-271, déc. 2015, doi: 10.3233/AO-150157.

[4] T. Berners-Lee et J. Hendler, « Publishing on the semantic web », *Nature*, vol. 410, p. 1023-1024, avr. 2001, doi: 10.1038/35074206.

[5] J. Euzenat et M.-C. Rousset, « Semantic web », in *A guided tour of artificial intelligence research*, P. Marquis, O. Papini, et H. Prade, Éd., Springer, 2020, p. 181-207. doi: 10.1007/978-3-030-06170-8_6.

[6] G. Yangsong, L. Yuandong, L. Diyi, et D. H. Lee, « Spatiotemporal kernel density clustering for wide area near Real-Time pothole detection », *Adv. Eng. Inform.*, vol. 60, p. 102351, avr. 2024, doi: 10.1016/j.aei.2023.102351.

[7] U. Bhatt, S. Mani, E. Xi, et J. Z. Kolter, « Intelligent Pothole Detection and Road Condition Assessment », 10 octobre 2017, *arXiv*: arXiv:1710.02595. doi: 10.48550/arXiv.1710.02595.

[8] A. A. Shaghouri, R. Alkhatib, et S. Berjaoui, « Real-Time Pothole Detection Using Deep Learning », 13 juillet 2021, *arXiv*: arXiv:2107.06356. doi: 10.48550/arXiv.2107.06356.

[9] R. G. G et R. G. P, « Real Time Pothole Detection using Machine Learning and Edge Computing », in *2023 IEEE Fifth International Conference on Advances in Electronics, Computers and Communications (ICAECC)*, sept. 2023, p. 1-8. doi: 10.1109/ICAECC59324.2023.10560282.

[10] R. R, A. K, Sankalp, S. B K, et Shashank, « Detection of Real Time Pothole System using Edge Detection », in *2024 4th International Conference on Pervasive Computing and Social Networking (ICPCSN)*, mai 2024, p. 1049-1052. doi: 10.1109/ICPCSN62568.2024.00174.

[11] S. Staab et R. Studer, Éd., *Handbook on Ontologies*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2009. doi: 10.1007/978-3-540-92673-3.

[12] P. F. Diallo, O. Corby, I. Mirbel, M. Lo, et S. Ndiaye, « Ontologies-Based Platform for Sociocultural Knowledge Management », *J. Data Semant.*, vol. 5, nº 3, p. 117-139, sept. 2016, doi: 10.1007/s13740-016-0065-4.

[13] C. Brewster et K. O'Hara, « Knowledge representation with ontologies: the present and future », *IEEE Intell. Syst.*, vol. 19, nº 1, p. 72-81, janv. 2004, doi: 10.1109/MIS.2004.1265889.

[14] M. Da Silveira, L. Deladiennee, E. Scolan, et C. Pruski, « A knowledge-sharing platform for space resources », *Data Knowl. Eng.*, vol. 151, p. 102286, mai 2024, doi: 10.1016/j.datak.2024.102286.

[15] « How to Encourage Public Engagement in Smart City Development—Learning from Saudi Arabia ». Consulté le: 15 novembre 2024. [En ligne]. Disponible sur: https://www.mdpi.com/2073-445X/12/10/1851

[16] S. Bvuma, *Understanding Citizen Engagement in the Era of Smart Cities*. IntechOpen, 2024. doi: 10.5772/intechopen.1005673.

[17] « Facilitating Citizen Engagement in Smart City Mobility ». Consulté le: 15 novembre 2024. [En ligne]. Disponible sur: https://ieeexplore.ieee.org/document/10717973

[18] M. A. Musen, « The Protégé Project: A Look Back and a Look Forward », *AI Matters*, vol. 1, nº 4, p. 4-12, juin 2015, doi: 10.1145/2757001.2757003.

[19] M. Dean et S. GUUS, « OWL Web Ontology Language Reference », W3C Recommendation. Consulté le: 15 janvier 2022. [En ligne]. Disponible sur: http://www.w3.org/TR/2004/REC-owl-ref-20040210/

[20] N. Guarino, D. Oberle, et S. Staab, « What Is an Ontology? », Springer, International Handbooks on Information Systems, 2009. Consulté le: 16 novembre 2024. [En ligne]. Disponible sur: https://econpapers.repec.org/bookchap/sprihichp/978-3-540-92673-3_5f0.htm

[21] V. J. Patel, « Towards Semantic Modeling for Assisted Driving: BFO-Compliant Ontology to Represent Ride Quality Knowledge », *J. Electr. Syst.*, vol. 20, nº 3, Art. nº 3, avr. 2024.