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Enhancing Quality Control Standards for Armenia's National Spatial Data Infrastructure: A Python-based Approach with Emphasis on Road Spatial Data Layers

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Abstract:

The effective implementation and sustained operation of a national spatial data infrastructure (NSDI) hinges upon meticulous data QC measures. Standardisation guidelines play a pivotal role in ensuring compliance and consistency across spatial datasets, thereby fostering reliability and usability. Within the realm of spatial data accuracy, both location accuracy (Zanderbergen P., 2008) and attribute accuracy are paramount considerations (Edward F., 2006).

In the Republic of Armenia, while National Spatial Data Standardization Guidelines have addressed attribute accuracy requirements comprehensively, ensuring location accuracy remains a critical yet unaddressed aspect. This research delves into the essentiality of QC measures, particularly focusing on the transport network layers of Armenia's NSDI. While the existing NSDI Layer Standardization Guidelines outline minimum attribute data requirements for road layers, the adequacy of topological data specifications necessitates further scrutiny. Through meticulous examination, this research identifies the fundamental prerequisites for QC in the transport network layers, encompassing both attribute and location accuracy considerations.

Drawing insights from theoretical frameworks and international standards such as those delineated by the International Organization for Standardization (ISO) and the Infrastructure for Spatial Information in the European Community (INSPIRE), the study explores spatial data layer conflicts, distinguishing between horizontal and vertical discrepancies (Yuan and Tao, 1999). Conflation emerges as a pivotal process in reconciling heterogeneous spatial datasets, necessitating innovative methodologies for feature matching and data integration (Wiemann S. and Bernard L., 2010).

To address potential conflations within the spatial data layers of Armenia's road network, a systematic methodology was developed, comprising sequential stages: Requirement Analysis, Tool Design and Prototyping, and Implementation and Testing.

The initial step involved identifying specific issues such as directional inaccuracies of road edges, topological inconsistencies, and discrepancies in data representation and connectivity.

The Tool Design and Prototyping phase encompassed the delineation of functionalities, algorithms, and data structures essential for addressing QC challenges inherent in road spatial data layers. These challenges mandated the development of precise solutions to safeguard the integrity and precision of spatial data. Consequently, a suite of Python-based modules was formulated.

These modules undertake several critical tasks. They analyse directional attributes of road edges to ensure accurate depiction and connectivity, deliver specialised tools customised for the specific demands of transportation infrastructure data, and harmonise road network edges and nodes to uphold topological coherence and reliability. Additionally, they extract features from road network edges for exhaustive analysis and comparison, pinpoint correspondences between road network elements to reconcile conflicts and discrepancies, and facilitate the amalgamation of road network edges to enhance data integrity and consistency. Furthermore, the modules construct graph representations of the road network for both visual examination and analytical inquiry, align road network elements to guarantee uniformity and precision in representation, evaluate correspondences between road network elements to gauge data quality and integrity, and manage

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the construction and upkeep of the road network dataset within the NSDI, focusing rigorously on completeness and accuracy.

Methodologically, the approach involves extracting nodes from the road network for further scrutiny and processing, matching road network nodes to ensure consistent topology and accuracy, and scrutinising the topology of road network nodes to identify and rectify discrepancies.

In the Implementation and Testing phase, the designed toolkit modules were implemented using Python programming language along with relevant libraries and frameworks such as GeoPandas, Shapely, and NetworkX. Each module underwent rigorous testing to ensure functionality, performance, and compatibility with the spatial data infrastructure.

The developed solutions have been published on GitHub (GitHub Repository) and are available for use by interested parties and organisations aiming to enhance the efficiency of the NSDI.

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