Voxelization and Spatial Data Cube Construction of Administrative Big Data Based on a 3D Grid System

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Abstract

Digital twin-based national spatial information requires a framework that can integrate administrative big data generated across above-ground, underground, and aerial spaces. However, heterogeneous location representations, spatial data types, and attribute structures limit data overlay and multidimensional analysis. This study proposes a method for converting administrative big data into voxels and constructing and visualizing spatial data cubes using a three-dimensional (3D) grid system as a common spatial reference.

Administrative big data APIs from public data platforms were reviewed to identify datasets containing spatial information and suitable for spatial data cube construction. Location and attribute information were extracted and transformed into 3D grid units to construct Basic Cubes, which were then combined into Application Cubes for analytical purposes. In the second project year, 28 administrative datasets were selected, including road freezing and traffic accidents, meteorological data, borehole and geotechnical information, transportation facilities, Asian dust, earthquakes, lightning, and wave information.

For application cases, road-freezing sections and meteorological information were integrated in the same voxel space to represent freezing risk according to temperature and humidity conditions. Borehole and geotechnical attributes, including location, strata, standard penetration test results, and groundwater levels, were also voxelized to construct a subsurface spatial data cube. The results demonstrate that heterogeneous administrative big data can be overlaid and integrated within a common 3D grid framework for spatial relationship analysis.

To support integrated analysis, source-specific spatial and attribute information was preserved during voxel conversion. Point-, line-, and area-based administrative data were mapped to corresponding 3D grid units, enabling heterogeneous datasets to be handled within a common discrete spatial framework. Basic Cubes retain the attributes of individual datasets, while Application Cubes combine multiple layers for analysis. This structure also enables updated administrative information to be reflected without repeatedly reconstructing conventional 3D models.

Future work will expand administrative big data cube construction and link the cubes with status-change detection models to support spatiotemporal analysis and visualization in a 3D grid-based digital twin environment.

Keywords

3D Grid System, Administrative Big Data, Voxel, Spatial Data Cube, Digital Twin.

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