Developing a Spatial-ID–Based Web API for Serving 3-D City-Model Attributes and Reviewing the Spatial ID Specification

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Abstract

Three-dimensional city models are essential for urban planning and smart city applications, yet accessing specific attributes from these models remains challenging when integrating diverse spatial datasets. This paper bridges Japan's Spatial ID specification—a universal voxel-based 3D indexing system—with Project PLATEAU's comprehensive 3D city models covering over 250 Japanese cities. We present a Web API framework that enables efficient retrieval of CityGML data through Spatial ID coordinates, achieving median response times of 1 second for spatial queries. The API provides three complementary endpoints for file discovery, feature search, and attribute retrieval, supported by an interactive visual interface that makes abstract Spatial ID strings accessible to users without extensive GIS expertise. Our implementation demonstrates practical applications in real-time navigation, indoor-outdoor data integration, and sensor data fusion for urban analytics. Performance evaluation shows the system scales effectively to national-level deployment whilst identifying opportunities to enhance the Spatial ID specification, particularly regarding vertical reference system consistency. This work establishes critical infrastructure for Japan's digital twin ecosystem, enabling seamless integration of heterogeneous urban datasets through universal spatial referencing as envisioned under the Society 5.0 initiative.

1. Introduction

Three-dimensional city models have become essential infrastructure for urban planning, smart city applications, and emerging digital twin ecosystems (Biljecki et al., 2015). However, accessing specific attributes from these models remains challenging when cross-referencing with other spatial datasets, particularly when data originates from different coordinate systems or standards. This integration challenge has become increasingly critical as cities worldwide pursue comprehensive digital transformation initiatives that require seamless data interoperability across multiple domains.

Japan has pioneered two significant initiatives to address these challenges: the Spatial ID specification and Project PLATEAU. Spatial ID is a three-dimensional spatial reference system that provides a universal voxel-based indexing scheme for any location in real space (IPA, 2025). Project PLATEAU represents Japan's national effort to create comprehensive open 3D city models, providing detailed CityGML-based models covering over 250 Japanese cities (MLIT, 2020).

Despite the potential synergy between these initiatives, a standardised Web API for accessing PLATEAU data through Spatial ID references remains absent, hindering integration across urban datasets. This gap represents a significant barrier to realising the full potential of Japan's digital twin ecosystem, where diverse spatial datasets should be seamlessly accessible through universal spatial referencing.

This paper bridges the gap between these initiatives by presenting a Web API that enables attribute retrieval from PLATEAU using Spatial ID coordinates and evaluates the Spatial ID specification for potential improvements based on practical implementation experience. Our research demonstrates the feasibility of integrating these systems whilst identifying specific areas where the Spatial ID specification could be enhanced to better support real-world applications.

2. Related Work and Research Question

2.1 Spatial ID Specification and Technical Framework

Spatial ID is a three-dimensional spatial reference system proposed by Japan's Information-technology Promotion Agency (IPA) and partners to uniquely identify any location or volume in real space. The system subdivides the world into a hierarchy of cubic cells (voxels) at various scales, assigning each voxel a unique code in the format `Z/F/X/Y` (zoom level, vertical index, tile X, tile Y). In essence, Spatial ID serves as a "3D address": every cubic metre at high zoom levels is given an ID string that encodes its latitude-longitude span and elevation slice (IPA, 2025).

This system extends conventional 2D geospatial indices (like map tiles or geohashes) into the vertical dimension, providing a unified way to index three-dimensional space rather than just the ground surface. The Spatial ID for any location can be computed directly from its latitude, longitude, and altitude using defined formulas, ensuring that any platform can derive the ID on the fly from physical coordinates. The primary intent of Spatial ID is to enable easy integration and interoperability of diverse spatial data in Japan's emerging digital twin ecosystem.

By using a common voxel-based ID as a key, different datasets—from building models and terrain to utility networks, drones, and even real-time sensors—can be cross-referenced and merged seamlessly despite originating from different coordinate systems or standards. This approach is a cornerstone of Japan's smart city and Society 5.0 initiatives, where massive amounts of geospatial information must be efficiently shared across agencies and private services (Japan Cabinet Office, 2025).

The IPA began developing Spatial ID around 2020 as part of a 4D spatio-temporal information infrastructure project in collaboration with METI and MLIT. The specification has evolved through several working group meetings and was published in a beta form (v1.0 beta) by March 2024. Ultimately, Spatial ID is intended to function as a universal spatial reference in Japan, simplifying tasks like data integration, location-based searches, and real-time spatial queries across many applications (IPA, 2025).

2.2 Related Work on Spatial ID Applications

Several government and industry consortia have piloted the use of Spatial ID for seamless coordination between different mapping systems and agents, demonstrating its practical applications in real-world scenarios.

2.2.1 Spatial ID-Enabled Multi-Agent Navigation Dynamic Map Platform et al. (2023) conducted a significant trial in 2023 at Tokyo PortCity Takeshiba, involving delivery-robot and augmented reality (AR) navigation coordination. In this experiment, they deployed an autonomous Cuboid robot that annotated its high-precision 3D map with Spatial IDs for features like elevator shafts and restricted zones. The robot then shared those IDs with an AR smartphone navigation app, enabling both systems to reference the same voxel ”addresses” for seamless coordination.

This demonstration achieved smooth indoor navigation coordination across heterogeneous systems, with human users able to see the robot's planned route and critical points of interest overlaid in real time through AR visualization. The trial demonstrated the power of a common voxel index to merge dynamic robot maps with static building models, whilst highlighting the need for standardised floor-level mappings and boundary-handling flags in the Spatial ID specification.

2.3 Project PLATEAU and Spatial ID Collaboration

Project PLATEAU represents Japan's national effort to create comprehensive open 3D city models, led by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). The initiative provides detailed CityGML-based 3D models covering over 250 Japanese cities, including various types of city objects such as buildings, transportation, vegetation, terrain, etc (MLIT, 2020). These models serve as the foundation for various urban applications ranging from disaster simulation to urban planning analysis.

PLATEAU has conducted several experimental projects exploring integration with Spatial ID. The PLATEAU TwinLink project, launched in 2023, developed a digital-twin platform integrating 3D city models, Building Information Modelling (BIM), and Spatial ID. Built on Unreal Engine, the platform renders 3D CityGML and BIM within a unified Spatial ID grid, visualises real-time population-flow and meteorological data at voxel granularity, and enables path-planning and point-of-interest queries directly via `{z}/{f}/{x}/{y}` IDs (PLATEAU, 2023b). Additionally, PLATEAU has developed voxelisation tools for CityGML data to facilitate Spatial ID integration (PLATEAU, 2023a).

These pilot projects have demonstrated the potential benefits of combining PLATEAU's rich semantic 3D city models with Spatial ID's universal spatial indexing system. However, despite these experimental efforts, significant research gaps remain. A standardised Web API for accessing PLATEAU data through Spatial ID references is still absent from the production ecosystem. This gap hinders systematic integration across urban datasets and represents a significant barrier to realising the full potential of Japan's digital twin ecosystem, where diverse spatial datasets should be seamlessly accessible through universal spatial referencing. Furthermore, the practical implementation of Spatial ID in production environments has revealed areas where the specification itself could be improved to better facilitate real-world integration scenarios.

3. Methodology

Our approach centers on developing a comprehensive Web API framework that enables efficient retrieval of 3D city-model data through Spatial ID referencing, complemented by an interactive interface for visual Spatial ID selection. The methodology comprises two main components: a multi-tiered Web API architecture and a user-friendly spatial selection interface.

3.1 Web API Supporting Spatial ID

We developed three complementary Web API endpoints—two dedicated to Spatial ID–centric queries and one providing a unified attributes call—to enable clients to retrieve 3D city-model data by voxel address. These endpoints are exposed via a common base URL (`https://api.plateauview.mlit.go.jp`), with OpenAPI definitions and interactive documentation available at `/openapi.json` and `/docs/`, respectively.

3.1.1 CityGML Files API with Spatial ID Conditions We extended the generic CityGML Files API to accept Spatial ID as a filter condition, enabling clients to request all CityGML file URLs intersecting one or more voxels:

```
GET /datacatalog/citygml/s:<SpatialID>,<
    SpatialID>,...
```

Listing 1. CityGML Files API endpoint

The Spatial ID syntax supports both `z/x/y` and `z/f/x/y` forms, as well as leading slashes or tile-hash notation. For example:

```
GET https://api.plateauview.mlit.go.jp/
    datacatalog/citygml/s:18/1/232853/103220
```

This endpoint returns a JSON list of cloud-hosted CityGML URLs whose geometries intersect the specified voxel(s).

3.1.2 CityGML Spatial ID Search API To obtain identifiers of all CityGML objects within given voxels without first fetching entire files, we designed a lightweight features endpoint:

```
GET /citygml/features?sid=<SpatialID1>,<
    SpatialID2>,...
```

Listing 2. Features search endpoint

The response provides a JSON array of feature identifiers:

```
{
  "featureIds": [
    "bldg_09f2c415-e668-4de4-880a-40
    cfd91a57b1",
    "bldg_1d1c7c3d-65b0-4228-a4a7-041
    a5a960bc4"
  ]
}
```

Listing 3. JSON response format

This call avoids full-GML downloads and allows clients to efficiently enumerate CityObjectMember `gml:id` values by voxel.

3.1.3 CityGML Spatial ID Attributes API To streamline client workflows, we combined the previous two steps into a single call that returns attribute JSON for all features in one or more voxels:

```
GET /citygml/spatialid_attributes?sid=<
    SpatialID>&type=<FeatureType>&
    skip_code_list_fetch=<bool>
```

Listing 4. Consolidated attributes endpoint

Parameters include:

- `sid`: comma-separated voxel IDs (required)
- `type`: comma-separated CityGML feature types (e.g.`bldg,veg,tran`) (required)
- `skip_code_list_fetch`: if true, returns raw code values without fetching taxonomy lists

The response provides a JSON array of attribute objects keyed by `gml:id`, matching the schema of the standalone Attributes API but scoped to the specified voxels.

3.2 Interactive Spatial ID Selection Interface

To address the challenge of conceptualising abstract Spatial ID strings, we developed a web interface that allows users to visually select Spatial IDs through intuitive interaction methods. The interface provides three complementary selection approaches to accommodate different user needs and spatial scales.

3.2.1 Multi-Scale Zoom Selection The interface implements a hierarchical zoom-based selection system that leverages the octree structure of Spatial ID. Users can navigate through different resolution levels, with each zoom level corresponding to a specific `z` value in the Spatial ID format. This approach enables users to select voxels at appropriate scales for their analysis, from regional-level studies to building-specific simulations.

3.2.2 Horizontal Grid Selection A horizontal grid overlay allows users to select specific `x` and `y` coordinates within the current zoom level. The grid visualization provides immediate spatial context, enabling users to understand the geographic extent of their selected voxels. This method is particularly effective for area-based selections and spatial pattern analysis.

3.2.3 Vertical Level Selection The interface includes vertical level controls that allow users to specify the `f` parameter, corresponding to height slices above the geoid. This three-dimensional selection capability is essential for applications involving multi-story buildings, atmospheric analysis, or underground infrastructure management.

3.2.4 Visualization and Feedback Selected voxels are visualised as 3D cubes overlaid on the city model, providing immediate visual feedback about the spatial extent of the selection. The interface displays returned feature attributes in real-time, allowing users to confirm feature correspondence and explore the hierarchical relationships between different resolution levels. This visualization approach bridges the gap between abstract ID strings and their physical spatial representation, making Spatial ID more accessible to users without extensive GIS expertise.

The interface serves both as a practical tool for spatial data exploration and as a validation mechanism for the underlying API functionality, ensuring that the theoretical benefits of Spatial ID-based indexing translate into tangible user benefits.

4. Results

4.1 Web API Implementation and Performance

Our Spatial ID-based Web API has been successfully deployed and tested across Japan's national 3D city model dataset. The implementation demonstrates both scalability and performance capabilities necessary for production-level applications.

4.1.1 Dataset Coverage and Indexing The API currently indexes PLATEAU data covering over 250 Japanese cities, representing comprehensive national coverage of Japan's major urban areas. This extensive dataset includes diverse urban environments ranging from dense metropolitan areas like Tokyo and Osaka to smaller regional cities, providing a robust foundation for testing API performance across varied spatial scales and data densities.

The indexing process successfully voxelised millions of CityGML objects at multiple resolution levels, with each geometric feature mapped to its corresponding Spatial ID coordinates. The resulting spatial index enables efficient querying across different zoom levels, from regional-scale analysis to building-specific queries.

4.1.2 Query Performance Analysis Performance testing reveals that the median query response time for the `spatialid_attributes` endpoint is approximately 1 second across the indexed dataset. This response time includes the complete workflow from Spatial ID resolution to attribute retrieval and JSON serialisation, demonstrating the system's capability to handle real-time applications.

4.2 Interactive Spatial ID Selection Interface

The visual interface successfully demonstrates the practical application of Spatial ID concepts and provides an intuitive method for users to understand and interact with the voxel-based spatial indexing system.

4.2.1 Spatial ID Visualisation The interface effectively addresses the challenge of conceptualising abstract Spatial ID strings by providing immediate visual feedback, as shown in Figure 1. Users can observe how the hierarchical octree structure translates into physical space, with selected voxels rendered as 3D cubes overlaid on the city model. This visualisation bridges the gap between the mathematical representation of Spatial ID and its spatial meaning.

The multi-scale zoom functionality demonstrates the hierarchical nature of the Spatial ID system, allowing users to navigate seamlessly between different resolution levels. Users can observe how parent voxels subdivide into child voxels, providing intuitive understanding of the octree structure that underlies the Spatial ID specification.

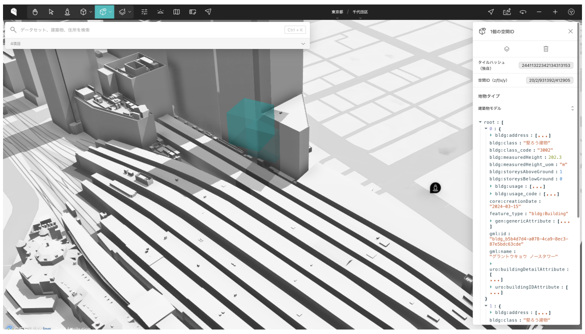

Figure 1. Interactive Spatial ID selection interface showing voxel visualization overlaid on 3D city model with attribute display panel. The interface demonstrates multi-scale zoom selection, horizontal grid overlay, and real-time attribute retrieval for selected voxels.

5. Discussion

5.1 API Use Cases and Applications

The Spatial ID specification was designed to serve as a universal spatial index for integrating diverse datasets across different standards and domains. Our implementation of a Spatial ID-indexed PLATEAU Web API demonstrates this integration potential and opens numerous application possibilities that leverage the common spatial reference system.

5.1.1 Real-Time Navigation and Routing Applications The integration of Spatial ID with navigation systems represents a particularly promising application domain. As demonstrated by Dynamic Map Platform and partners in their delivery robot and AR navigation experiments (Dynamic Map Platform et al., 2023), Spatial ID provides a common spatial framework that enables seamless data sharing between autonomous systems and mapping platforms.

Our API's sub-second response times for spatial queries make it suitable for real-time navigation applications. Navigation systems can query PLATEAU data using Spatial ID coordinates to obtain detailed urban context information, including building heights, road geometries, and obstacle locations. This capability is essential for applications such as drone path planning, where precise 3D environmental awareness is critical for safe autonomous navigation.

The hierarchical nature of Spatial ID particularly benefits navigation applications by enabling multi-resolution path planning. Coarse-resolution voxels can be used for regional route planning, while fine-resolution voxels provide detailed local navigation information. This multi-scale approach optimises computational efficiency whilst maintaining the spatial detail necessary for safe autonomous operation.

5.1.2 Indoor-Outdoor Spatial Data Integration PLATEAU data includes indoor spatial information for many buildings, and CityGML's semantic structure supports both city-scale and indoor-scale data representation. The Spatial ID indexing system enables seamless integration of indoor and outdoor spatial data through a unified coordinate system, addressing a significant challenge in current spatial data management.

Our API supports this integration by providing consistent spatial referencing across indoor and outdoor environments. Applications can query spatial information using the same Spatial ID coordinates regardless of whether the data represents outdoor urban features or indoor building components. This consistency is particularly valuable for applications such as emergency response planning, where responders need seamless access to both outdoor approach routes and indoor building layouts.

The vertical component of Spatial ID (`f` parameter) is especially important for indoor-outdoor integration, as it enables precise floor-level referencing within buildings whilst maintaining consistency with outdoor elevation data. This capability supports applications such as indoor navigation systems that need to coordinate with outdoor mapping platforms, or building management systems that integrate with city-wide infrastructure monitoring.

5.1.3 Sensor Data Integration and Urban Analytics The combination of Spatial ID-indexed PLATEAU data with sensor-derived datasets represents a significant opportunity for urban analytics applications. As demonstrated in the PLATEAU TwinLink project's population flow analysis (PLATEAU, 2023b), Spatial ID provides a common spatial framework for integrating diverse urban datasets.

Sensor data can be spatially indexed using Spatial ID coordinates, enabling direct integration with PLATEAU's semantic urban models. For example, air quality sensors associated with specific voxels can be combined with PLATEAU building data to analyse relationships between urban morphology and environmental conditions.

Our API facilitates this integration by providing rapid access to PLATEAU attributes for any given Spatial ID coordinate. Analytics applications can query building characteristics or infrastructure for specific voxels and combine this information with real-time sensor data to support urban planning decisions.

5.2 Limitations and Future Work

While our implementation demonstrates the technical feasibility of Spatial ID-PLATEAU integration, several limitations suggest directions for future development. The current median response time of 1 second, whilst suitable for many applications, may need optimisation for applications requiring sub-second response times, such as real-time autonomous vehicle navigation.

The vertical referencing system used in Spatial ID presents ongoing challenges for integration with certain applications, particularly those using ellipsoidal height references common in GNSS systems. Future work should address these reference system inconsistencies to improve interoperability with existing spatial technologies.

Additionally, the current implementation focuses on static PLATEAU data. Future development should explore temporal extensions that enable time-aware queries and support for dynamic urban data that changes over time. This temporal capability would significantly expand the range of applications that can benefit from Spatial ID-based data integration.

6. Conclusion

This research successfully demonstrated the feasibility of integrating Japan's Spatial ID specification with Project PLATEAU's 3D city models through a comprehensive Web API framework.

Our implementation addresses a critical gap in Japan's digital twin ecosystem by providing standardised access to semantic urban data through universal spatial coordinates.

The developed Web API, covering over 250 Japanese cities with median response times of 1 second, proves that Spatial ID-based data integration can scale to national-level implementations. The interactive interface makes Spatial ID technology accessible to users without extensive GIS expertise, facilitating broader adoption across diverse user communities.

Our analysis demonstrates significant opportunities for urban analytics, autonomous navigation, and sensor data fusion through Spatial ID-PLATEAU integration. The implementation experience also revealed areas where the Spatial ID specification could be enhanced, particularly regarding vertical reference system consistency.

This work advances Japan's digital twin infrastructure by providing both a technical solution and empirical evidence of Spatial ID's practical viability, establishing a foundation for the seamless spatial data ecosystem envisioned under Japan's Society 5.0 initiative.

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