Thesis topic

Change detection and updating of 3D territorial models

ACTE Team /LaSTIG Laboratory / Géodata Paris

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- **Discipline** : Computer science
- **Speciality:** Geographic Information Science
- **Research Structure**: DIFFICULT/IGN
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- **Short description**: Development of a data model to represent a territory in a hierarchical and structured way, as well as its evolution over time. Detection of changes between this type of model and more recently acquired data, and its update.
- **Keywords:**3D computer vision, algorithmic geometry, change detection, updating, geometric data structures
- **Desired profile.**The candidate should have a strong background in mathematics, particularly 3D geometry, and in computer science (especially proficiency in Python and C/C++ programming). They must have a keen interest in scientific research and demonstrate autonomy, rigor, and creativity.

General context and IGN context

The French National Institute of Geographic and Forest Information (IGN) is the leading operator for geographic and forest information in France. LASTIG (Laboratory for Geographic Information Science and Technology for Smart Cities and Sustainable Territories) conducts applied research in geographic information science and technology. The unit's research covers the entire lifecycle of geographic or spatial data, from acquisition to visualization, including modeling, integration, and analysis. LASTIG is particularly interested in spatiotemporal geographic reference systems, which are central to the IGN's missions. LASTIG comprises four research teams, including the ACTE (Acquisition and Processing)

team, which focuses on the collection and processing of remote sensing data (imagery, lidar, radar) gathered from satellite, airborne, or ground-based platforms.
IGN and INRIA are participating in the JUNN (National Digital Twin) project, which aims to produce a digital twin of the French territory, maintain it, and use it to address numerous use cases (urban planning, visualization/communication/consultation, simulation, etc.). One of JUNN's components is a structured 3D model of the entire territory. A model is considered structured if it offers a hierarchical representation of all objects present on the territory, and if each final object (at the lowest level of the hierarchy) has a geometry that is faithful to reality and consistent with the geometry of other objects in the scene. For example, a building is composed of final geometries (facades, roof sections, superstructures) that must be adjacent to each other but also to other objects in the scene, such as the ground on which the building is situated and adjacent buildings.
Within the JUNN project, these structured 3D models will be produced from lidar data from the IGN's LidarHD campaign between 2021 and 2026, and from object-based automatic reconstruction techniques [1, 2] enabling the production of a structured representation in the CityGML data model [3]. A key challenge of the LidarHD project will be updating this structured 3D model using aerial or satellite imagery, acquired more frequently than lidar but of lower quality.

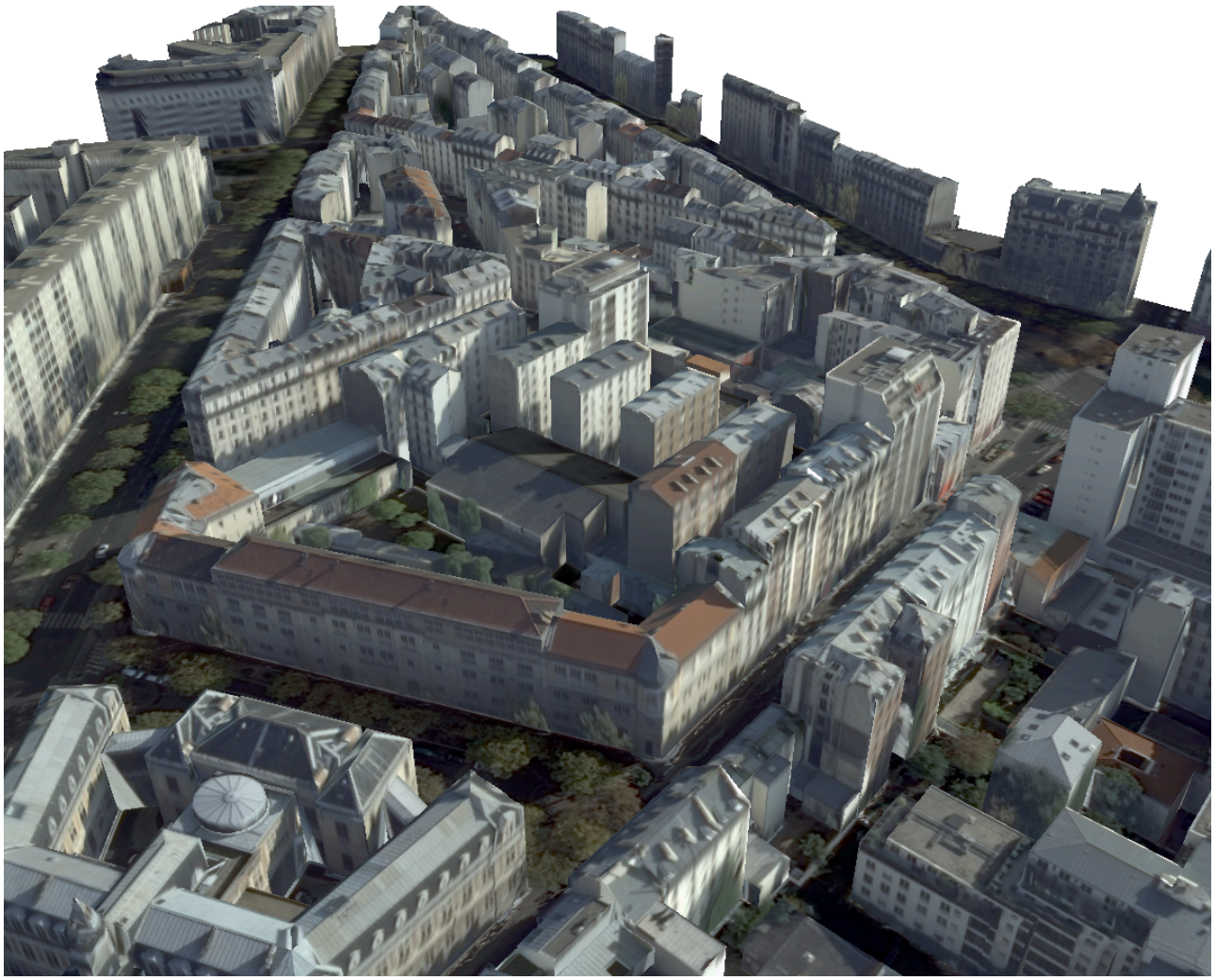

Figure 1: A structured 3D model of the town hall district of the 13th arrondissement produced by the IGN.

Scientific objectives

There are several scientific obstacles to this update:

- CityGML models do not explicitly model the adjacencies of objects whose 3D representations are defined independently. This can cause problems when updating objects (or parts of objects) adjacent to objects (or parts of objects) that have not changed, which necessitates explicitly modeling these adjacencies.
- On the other hand, the CityGML model provides a view of a 3D scene at a given moment and does not allow for explicit modeling of all the changes that may affect the objects in that scene over time: appearances/disappearances, merging, splitting, structural modifications, deformations, etc.
- Being able to detect all these different types of changes at the level of objects in a structured 3D model from new aerial or satellite imagery and apply them to a 3D representation while maintaining its consistency are still very open problems.

The thesis proposes to address these problems in 3 stages:

1. Finding a representation for structured 3D models that allows for the representation of the evolution of the objects composing it while maintaining the overall coherence of the scene and in particular the adjacencies of objects [3], possibly through a 3D triangulation of all the objects allowing for geometry sharing [4, 5]. The idea is then to represent all the geometry of the scene by a single mesh (surface or volume) in which all objects are defined as subsets.
2. Convert the usual representations (of the CityGML type) to this richer representation.
3. Detect changes of the types listed above from an existing model and more recent aerial or satellite imagery data. A method based directly on the new images [6], on a description of the new geometry [7] or by classification of change types [8] can be used.
4. Apply the corresponding changes to the representation proposed in 1 in order to obtain a unique 3D representation maximizing both timeliness and quality as proposed by [9] for 3D meshes.

A major challenge will be to propose a robust, precise method that can be scaled up across the entire French territory.

Work program

The proposed thesis topic concerns the implementation of a complete chain for updating structured 3D territorial models. The work will be broken down into:

- A state of the art of current methods for detecting hybrid changes (between data of different types) and for qualifying 3D models.
- Study of the CityGML format and other types of representations of structured 3D territorial models.
- The appropriation of input data from the chain: oriented images, Lidar point clouds and structured 3D models.
- Proposal for a representation (possibly already existing) allowing for a structured modeling of a territory in 3D and its evolutions.
- Proposal of a method for detecting changes from a structured model and/or the LidarHD used in its construction and more recent aerial and/or satellite imagery.

- Proposal of a method for updating the 3D model for detected changes.
- Evaluation of the complete chain over sufficiently large and varied areas to ensure its ability to scale up and address diverse landscape types.

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