

PhD: Structured 3D city reconstruction from heterogeneous data

Key Words: Reconstruction, classification, semantics, Lidar, Image

1 Context

The Building Indoor/Outdoor Modeling (BIOM) project aims at automatic, simultaneous indoor and outdoor modeling of buildings from images and dense point clouds. We want to achieve a complete, geometrically accurate, semantically annotated but nonetheless lean 3D CAD representation of buildings and objects they contain in the form of a Building Information Models (BIM) that will help manage buildings in all their life cycle (renovation, simulation, deconstruction). We view indoor and outdoor building modeling as a joint process where both worlds fruitfully cooperate and benefit one another both in terms of semantics and geometry. This holistic scene understanding and reconstruction approach should lead to more complete, correct, and geometrically accurate building models.

The first challenge will be to accommodate for heterogeneous data as full building modeling calls for data acquisition both inside and outside the building, but also from an aerial point of view to model the roof. The BIOM project will also aim at exploiting the complementarity of image and LiDAR data. Another challenge is coping with incomplete data due to occlusions by furniture inside, and urban and mobile objects outside. Last but not least, BIOM aims at modeling a large variety of architectural styles, different interior scene layouts, and the large amount of different objects that may be contained within each scene.

State-of-the-art approaches currently treat outdoor and indoor worlds separately: most indoor reconstruction approaches focus on the detailed modeling of single rooms, and only rarely deals with 3D modeling of complete floors, and when they do, they often rely on simplifying hypotheses, such as a Manhattan world assumption. To the best of our knowledge, no works have yet been proposed to model buildings outdoor and indoor simultaneously within one single comprehensive framework. After a separate analysis of indoor and outdoor data and their registration, we propose to formalize complex priors about the structure of buildings and included objects in a probabilistic fashion. A crucial unsolved problem in probabilistic modeling of dense, textured point clouds is how



Inside scan (left, from Stanford 2D-3D-S dataset) and outside scan (right, IGN dataset)

to take into account object-level context and topology of large, complex, cluttered 3D scenes. In this regard, our research shall investigate where the sweet spot lies between generative, procedural modeling and discriminative object labeling, and generalization or primitives based reconstruction. What is more, a good compromise of fast unsupervised and expressive, precise supervised modeling and object recognition from structured deep networks will be a major part of our research.

The BIOM project will investigate multi-scale application use cases and their specific modeling needs and develop operational methodologies for producing *Application/Domain Ready* BIM models in the standard CityGML/IFC formats. Use cases and proofs of concept covering different phases and aspects of the urban project will be experimented over two sites and industrialized through dedicated web services.

The development of new methodologies and services (such as simulations and optimizations) based on virtual clones of buildings can only address the very limited fragment of the stock for which a BIM model exists. The BIOM project will address this issue by providing a robust, comprehensive and reference methodology for data acquisition and reliable BIM modeling to address a broad range of applications: inventory and urban studies, life-cycle management, construction works, occupancy phase, consultancy and communication of urban information. We expect the BIOM project to have a significant potential of transmission of outcomes to industry products. IGN and CSTB will work with industrial partners, existing spin-offs, and public authorities on the increased valuation of the produced reference. An open call for initiatives stemming from such a reference will be released in direction of SME and start-ups in order to raise interest of new actors in the domain and generate innovating services.

2 Objectives

A crucial step of the BIOM project is reconstructing a structured 3D representation of all the data acquired from the outside of buildings at city scale. This data can be either from a RGB imaging sensor or from a Lidar sensor mounted on any platform (fixed or mobile at street-level, drone, helicopter, plane). From this data, the ambitious goal of the PhD is to reconstruct a structured semantic 3D model, containing a hierarchy of semantic parts (block, building, facade, window, ...) and a textured 3D geometry for each part. Ideally, this geometry should be as compact as possible (respecting the geometric structure of the parts) and topologically correct (the parts should fit without holes).

A possible work-flow to achieve this goal would be:

- Merge all geometric information sources into a single surface mesh [Caraffa et al., 2016]
- Semantize the surface mesh exploiting both its geometry and the radiometry of the images [Boulch et al., 2013, Boussaha et al., 2018] possibly exploiting the global context with a structured deep network [Landrieu and Simonovsky, 2018].
- Hierarchically segment the mesh into semantic parts as in [Chauve et al., 2009, Gadde et al., 2017, Koziński et al., 2015] for instance.
- Generalize the geometry of each part depending on its type [Boulch et al., 2014, Demantké et al., 2014, Lafarge et al., 2013, Lafarge and Alliez, 2014, Oesau et al., 2014, Salinas et al., 2015], possibly inventing geometry in occlusions [Chauve et al., 2010, Fan et al., 2014, Koziński et al., 2015]
- Texture the resulting geometries with the images with occlusion handling and radiometric equalization [Waechter et al., 2014]

Some of these steps may benefit from one another, and possibly be performed jointly [Boussaha et al., 2018]. The developed method should benefit from the complementarity of images and Lidar data [Cheng et al., 2013] and operate at large scale [Duan and Lafarge, 2016].

3 Profile

- Student in a Research oriented Masters degree

- Specialization in Computer Vision, machine learning, pattern recognition, image processing, or optimization.
- Familiarity with deep learning theory and framework preferable but not required
- Good skills in C++
- Autonomy, rigor, pragmatism
- Strong taste for scientific research

4 Environment

The contacts for this PhD are:

- Director: Bruno VALLET, MATIS Team, bruno.vallet@ign.fr
- Co-director: Renaud MARLET, IMAGINE Team, renaud.marlet@enpc.fr
- Advisor: Sven OESAU, CSTB, sven.oesau@cstb.fr

Bruno VALLET is full time researcher at the MATIS Team¹ and coordinator of the BIOM project. Renaud MARLET is with the IMAGINE Team² and leads the BIOM work package on registration. Sven OESAU is a researcher at CSTB and member of the BIOM project.

The PhD will take place in the MATIS Team from the LaSTIG Lab of IGN (Institut National de l'Information Géographique et Forestière), located at Saint-Mandé (close to Paris, metro line 1, Saint-Mandé station). It will last 3 years starting September to November 2018.

The MATIS team is located at Saint-Mandé, bordering Paris in France. It depends on the Research Unit in Geo-Information Science of the French Mapping Agency (IGN), which itself belongs to the Research and Teaching Department of IGN. The MATIS team leads research activities in the fields of mathematics and computer science applied to photogrammetry, computer vision and remote sensing dedicated to ground-based, aerial and satellite multi-sensor imagery (optical, LiDAR, radar, etc.)

IMAGINE is a research group in computer vision, machine learning and optimization of the École des Ponts ParisTech (a.k.a. ENPC). It is affiliated to the Gaspard Monge Computer Science Lab (LIGM) of the University Paris-Est (UPE).

The CSTB is the french scientific and technical agency for buildings and the reference for all construction works in France.

5 Application

Interested candidates must send to the contacts, **in a single pdf before September 1st 2018**:

- a detailed résumé,
- a motivation letter explaining the interest in the topic and suggesting ideas for solutions,
- the names and contacts of at least two references.

References

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¹Web page: <http://recherche.ign.fr/labos/matis/accueilMATIS.php>

²Web page: <http://imagine.enpc.fr/>

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