**PhD title:**
3D modeling from Lidar data for Radar simulation

**Keywords:** Radar simulation, 3D reconstruction, digital twin
**Supervision:**

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# Context

Scene simulation in the electromagnetic domain requires a digital representation of the environment describing in three dimensions the different constituent elements (terrain, vegetation, infrastructure, street furniture, vehicles, etc.). In the case of a study on a real environment, corresponding to a geographical situation likely to be measured, the construction of this digital representation is generally done using a combination of different remote sensing products.
Among these products, the first sources are those with two dimensions or images, which provide information on the nature of the elements that make up the scene. These images can come from different viewing angles and from various areas of the electromagnetic spectrum (infrared, visible, microwave). The second type of source, obtained either directly by specific measurement methods or by the combination of several images (interferometric or stereoscopic), makes it possible to provide information on the third dimension of the observed scenes.

The methodology currently used by ONERA for the construction of virtual scenes for simulation is based on sources which do not yet contain all of the 3D information. In fact, digital terrain or surface models from SRTM data, WorldDEM data, or for France RGE Alti are only elevation maps which only give a single altitude for each pixel of an image. It is ultimately only 2.5D information. For example, it is impossible to correctly represent the geometry of a building facade, the low structure of a tree, or to observe small vertical objects such as electrical poles or elements of street furniture. LIDAR data, particularly those produced as part of the IGN LIDAR HD project, will soon be available throughout France and offer a point cloud representation measured from a certain angular variety. Such LIDAR data have the potential to resolve the limitations of existing strategies and algorithms but require a complete revisit of information exploitation and extraction strategies.

*Rendering of a 3D model used for RADAR simulation*

# Goals

The objective of this thesis is therefore to develop a first algorithmic base for exploiting data available in the form of a 3D point cloud to construct virtual environments dedicated to electromagnetic simulation. Numerous point clouds processing methods, particularly for constructing meshes, exist in the literature as well as in commercial or open source software. However, these tools are not currently adapted to the challenges of electromagnetic simulation.

Indeed the constraints are linked to the need to calculate the interaction between the scene and a centimeter wavelength most often in backscattering configurations (that is to say when the transmission and reception are located at the same point). This in particular induces a need for significant detail since it is the small elements of the order of the wavelength which mainly interact with the incident wave. The notable particular effects are:

- Very high sensitivity to normals and roughness of the facets. Thus, the meshing artifacts of usual methods most often restore “bumpy” surfaces which completely distort the calculation of the interaction with the electromagnetic wave.
- A very important need for fidelity regarding the orthogonality of the plans. Due to backscattering, the most significant effects on the signal perceived by the sensor come from multiple reflections between perpendicular faces: double reflection for example between the ground and a facade or triple reflection (“cube corner” effect).
- A need to properly represent long linear or periodic elements (roof edges, walls, slides) in the context of coherent imagery likely to form constructive interferences in particular observation directions.

Conversely, the particular need for electromagnetic simulation can relax certain constraints usually linked to the problem of 3D scene reconstruction.
It is therefore not necessary to maintain a capacity for projection of the “optical” texture or for consistency with the optical view since this will not be used by the simulation. Furthermore, the confusion between certain optically contrasting elements but very close from a structural

point of view (for example between two different traffic signs) is not significant for the intended application.
Generally speaking, the objective is to produce realistic reconstructions of 3D scenes; details sensitive to electromagnetism but not directly observable from the input data can be added in a statistically representative manner.
Finally, the algorithms developed will be intended to replace tasks currently carried out mainly manually. Thus an error rate can be maintained to the extent that the algorithm can self-qualify and guide the human operator so that he only works on the areas really necessary while offering him simplified modification capabilities if possible.

# Work description

We propose to explore two main avenues:

- The first consists of exploiting the principle of instantiation. From object databases already prepared in advance, presenting levels of detail and faceting quality compatible with electromagnetic calculation, each element encountered in the point cloud is associated with one of the objects in the catalog as well as position parameters, orientation and possibly scale factor. This strategy is naturally optimal for similar generic objects encountered in large numbers in the scenes: street furniture, poles, vegetation, vehicles, barriers, etc. The algorithms implemented may draw inspiration from the solutions proposed in the classification/recognition problems which will remain to be adapted to the particular nature of the data.
- The second consists of exploiting existing procedural generation algorithms. These algorithms make it possible, based on their derivation parameters, to automatically generate realistic meshes of objects. These meshes can be, by construction, adapted to electromagnetic calculation. This sector is most naturally suited to objects whose overall structure can vary very significantly from one occurrence to another and for which the use of scale factors is therefore not suitable. This mainly concerns buildings which can be properly reconstructed in 3D based on simplified descriptions (roof type, number of floors, presence or absence of windows, size and spacing, base polygon, etc.).

# Candidate profile

- M2 student in computer vision, photogrammetry, remote sensing, physics.
- Knowledge of 3D geometry and continuous and discrete optimization would be appreciated.
- Mastery of C++ and Python
- Fluent English
- (Optional) Knowledge of electromagnetism or radar

# Application

Send an email to bruno.vallet@ign.fr and nicolas.trouve@onera.fr with:

- Your resume

- A cover letter
- A record of your master’s grades
- One or more letters of recommendation (if applicable)