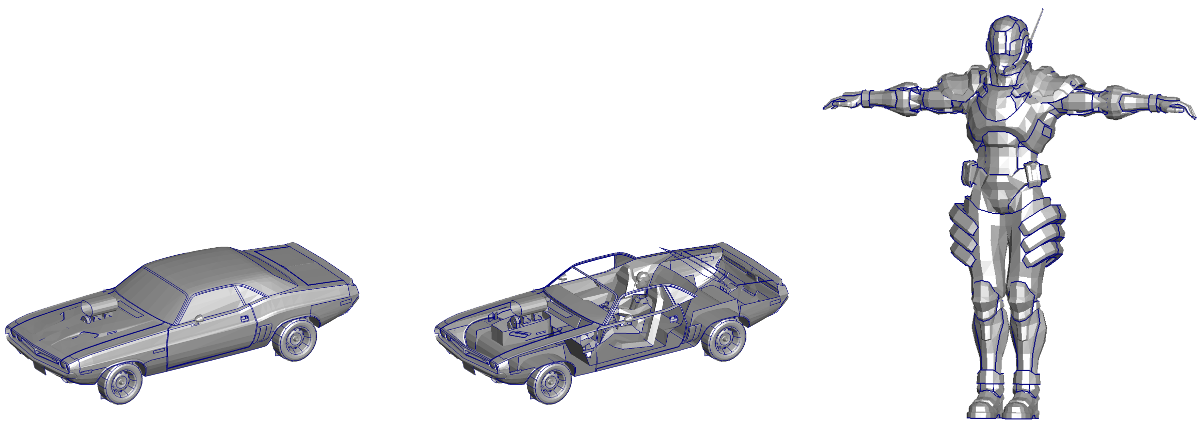
Geometrical and topological mesh filtering for fabrication

- **Titre :** Geometrical and topological mesh filtering for fabrication
- **Thématique :** Computer graphics, 3D printing
- **Laboratoire, institution et université :** LORIA, Inria, Université de Lorraine
- **Ville et pays :** Nancy, France.
- **Equipe ou projet dans le labo :** PIXEL (http ://pixel.inria.fr/) and MFX (http ://mfx.loria.fr/)
- **Encadrants de stage :** Dobrina Boltcheva (dobrina.boltcheva@univ-lorraine.fr) et Cédric Zanni (cedric.zanni@loria.fr)
- **Directeur du laboratoire :** Jean-Yves Marion (jean-yves.marion@loria.fr)

- **Field description :**
3D printing, also called Additive Manufacturing, has become many peoples hobby at home, thanks to the fast development in the past decades [1]. Today fabricating an appropriate 3D model using a low-cost 3D printer is nearly as easy as printing a textual document, but creating a 3D model which is actually "appropriate" for printing is definitely *complicated*.



(a) (b) (c)

FIGURE 1 – (a) A 3D model of a car. (b) Interior view after removing some external sheets. (c) A model containing many disconnected sheets.

Indeed, the 3D models flooding Internet are usually not meant to be fabricated, and can therefore reveal many defects and flaws that make them unsuitable for printing, such as open boundaries, self-intersections, zero-thickness walls, incomplete geometry, many high frequency small details, etc. But which of them can really be printed ? How to repair and filter the unprintable models to adapt them to the fabrication requirements ? See, for example, some unprintable models on Fig.1.
In reality, users of domestic 3D printers have to make extremely hard effort to get a printing project done, starting from *any* STL file. They usually suffer from the lack of 3D printing engineering knowledge and insufficient automation of the software tools [2].
The situation is the same for professional users such as architects who usually work with extremely detailed building models which are unprintable. Currently, if a printed prototype is required, these users have to build a second 3D model which is extremely costly. They need automatic tools allowing to convert the working model into a coarser but accurate one and suitable for 3D printing. How to scale the detailed model while preserving all the visible surfaces with no or minimal distortions ?
Moreover, the input models do not contain only geometrical and topological information (vertex positions and connections) but also material properties (color, texture, elasticity,...) and domain-specific information (wall, window, chair, kitchen sink,...) that have to be taken into account during the mesh filtering.
- **Internship goals :**
We currently miss a geometrical and topological mesh filtering approach that can cope with any STL file

while preserving all visible surfaces with no or minimal distortions and managing material properties and domain-specific information contained into the input model. The goal of this project is to design such a framework.
There are numerous possible research strategies to tackle this broad and difficult problem.
One of the first attempts will be to design a robust and efficient automatic approach to define and compute a *signed distance field* for models for which the notion of inside/outside is mathematically ill-defined (non-manifoldness, self-intersections,...). The idea is to take advantage from the notion of generalized winding numbers [3, 4] while integrating the notion of multiple materials.
We are also planning to investigate how the Scale-Space theory [5] can be, first, adapted to filter out high-frequency small details of a single-material mesh. This is a framework for multi-scale signal representation developed by the image and signal processing communities. It is a formal theory for handling image structures at different scales, by representing an image as a one-parameter family of smoothed images, the *scale-space representation*, parametrized by the size of the smoothing kernel used for suppressing fine-scale structures. Secondly, we will try to extend the framework in order to integrate fabrication constraints and multi-material properties.

— **Required skills :**
The main quality is the desire to learn and work as a team. It is not necessary to have prior knowledge of 3D printing, it could be acquired during the internship. However, a good level on mathematics and a good geometric intuition in $3D$ will be needed.

Références

[1] M.Livesu, S.Ellero, J.Martinez, S.Lefebvre, M.Attene, "From 3D models to 3D prints : an overview of the processing pipeline", Computer Graphics Forum 36 :2, Eurographics 2017.

[2] M.Attene, "As-exact-as-possible repair of unprintable STL files", arXiv :1605.07829, 2016

[3] A.Jacobson, L.Kavan, O.Sorkin-Hornung. "Robust inside-outside segmentation using generalized winding numbers". ACM Transactions on Graphics 32, 4. 2013.

[4] Barill et al. "Fast Winding Numbers for Soups and Clouds", SIGGRAPH 2018.

[5] T. Lindeberg. "Scale-space theory : A basic tool for analysing structures at different scales". J. of Applied Statistics 21(2), 1994.