

# Discrete Optimization and Machine Learning for Line Drawing 3D Reconstruction

## Advisor

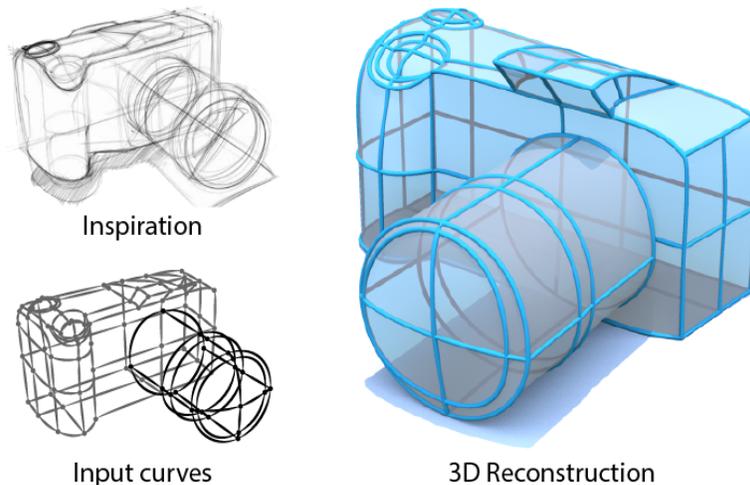
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## Context and Research Goal

Designers draw extensively to externalize their ideas and communicate with others. However, drawings are currently not directly interpretable by computers. To test their ideas against physical reality, designers have to create 3D models suitable for simulation and 3D printing. A long-term ambition of our research group is to bring the power of 3D engineering tools to the creative phase of design by automatically reconstructing 3D models from drawings (Figure 1).



*Figure 1: Our ambition is to automatically reconstruct 3D models from design drawings. Our preliminary solution [2] requires the presence of cross-section lines, which are assumed to be mutually orthogonal.*

However, reconstructing 3D models from drawings is an ill-posed problem: a point in the drawing can lie anywhere in depth. In addition, line drawings are often drawn quickly and do not represent a perfect projection of a 3D object. We thus need additional constraints on the solution to reduce ambiguity and correct for drawing inaccuracy.

## Approach

While line drawing reconstruction remains an open problem, several methods have been proposed for specific shapes (see [1] for polyhedrons) and drawing techniques (see our work [2] that exploits a technique called cross-sections). The main idea behind these approaches is to impose geometric constraints between the lines in the drawing. For instance, two lines that are parallel in the drawing are constrained to be parallel in 3D. However, existing methods often

rely on heuristics to detect these constraints, such as thresholds to identify parallel lines. While these heuristics work well on simple examples, they are not sufficiently robust to handle real-world design drawings.

The goal of this PhD is to design a novel optimization method capable of *jointly identifying constraints in a drawing and reconstructing the corresponding 3D shape*. To do so, we need to consider a number of candidate constraints in the drawing (parallelism, orthogonality, symmetry) and associate each constraint with a binary variable that indicates if the constraint is active. These additional discrete variables make the problem a so-called Mixed-Integer formulation, which is NP-hard since finding the optimal solution would require testing all potential combinations of constraints. Instead, we need to devise efficient strategies to only evaluate a subset of high-quality configurations.

Several optimization strategies have been proposed for generic mixed-integer problems. For instance, the “branch-and-bound” algorithm explores the solution space by progressively estimating upper and lower bounds on the cost of subsets of solutions [3]. These bounds allow the algorithm to ignore solutions that cannot be better than the ones already evaluated. Other approaches such as Markov Chain Monte Carlo start from an initial solution and generate new ones by randomly changing the values of its variables, keeping the change if it yields a better solution. The first part of the PhD will be to study these methods and adapt them to our context.

However, while more efficient than an exhaustive search, existing methods often require many steps before converging to a good solution, especially if they start from a bad initialization. A second part of the PhD will be to exploit machine learning to speed up the optimization. In particular, deep learning has shown great success in predicting approximate 3D information from images [4,5]. Our plan is to build on such approaches to initialize the optimization with a good solution, or to quickly predict the quality of intermediate solutions during the exploration of the solution space.

### **Location**

The PhD will take place at Inria Sophia Antipolis, on the beautiful French riviera. The research will be conducted in the GraphDeco group (<https://team.inria.fr/graphdeco/>). The group does research on image synthesis and computer-aided design.

### **Requirements**

The successful candidate should have taken courses in numerical optimization, computer graphics, computer vision, geometry processing. The candidate must have experience in C++ programming.

### **References**

- [1] H. Lipson and M. Shpitalni  
Optimization-based reconstruction of a 3d object from a single freehand line drawing  
Computer-Aided Design 28, 651–663. 1996  
<http://dl.acm.org/citation.cfm?id=1281556>

[2] Baoxuan Xu, William Chang, Alla Sheffer, Adrien Bousseau, James McCrae, Karan Singh  
True2Form: 3D Curve Networks from 2D Sketches via Selective Regularization  
ACM Transactions on Graphics (Proc. SIGGRAPH) 2014  
<http://www.cs.ubc.ca/labs/imager/tr/2014/True2Form/index.htm>

[3] [https://en.wikipedia.org/wiki/Branch\\_and\\_bound](https://en.wikipedia.org/wiki/Branch_and_bound)

[4] David Eigen and Rob Fergus  
Predicting Depth, Surface Normals and Semantic Labels with a Common Multi-Scale  
Convolutional Architecture  
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[5] Learning Shape Abstractions by Assembling Volumetric Primitives  
Shubham Tulsiani, Hao Su, Leonidas J. Guibas, Alexei A. Efros, Jitendra Malik  
<https://arxiv.org/pdf/1612.00404.pdf>