Cut Pursuit and Geometric Applications

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We present an overview of the cut pursuit algorithm [1], together with different applications for image processing and 3D data analysis.

We consider the problem of minimizing functionals defined with respect to an undirected weighted graph $G = (V, E, w)$ with $w \in \mathbb{R}_+^E$ and with the following form:

$$F : \Omega^V \to \mathbb{R} : x \mapsto f(x) + \sum_{\{u,v\} \in E} w_{\{u,v\}} h(x_u, x_v) \ ,$$

where $f : \Omega^V \to \mathbb{R}$ is a function of interest depending on the context, and $h : \Omega^2 \to \mathbb{R}$ is a function that reaches its minimum only when $x_u = x_v$. More precisely, we are interested in functions h that encourage equality between x_u and x_v.

Such functionals, commonly encountered when handling spatial data, encourage their solutions to exhibit a particular kind of graph-structured sparsity. The motivation behind cut pursuit is to exploit this regularity to accelerate the minimization of F with a working-set iterative scheme.

Thanks to parsimonious computations and efficient parallelization [3], cut pursuit can be several orders of magnitude faster than other widely used optimization algorithms such as first-order proximal methods, or graph cut-based approaches. It can be used to minimize a large class of functionals and provides theoretical convergence guarantees in some settings without requiring convexity or differentiability of f [2].

Its principle can also be adapted to handle a variety of problems with a spatial structure, from inverse brain imaging to large-scale surface reconstruction [6]. Cut pursuit is also at the center of the SuperPoint Graph approach [4, 5], a state-of-the-art deep learning-based algorithm for the automated analysis of very large 3D point clouds.

Joint work with: Loïc Landrieu, IGN LaSTIG, Grand-Est University.

References

[1] Loïc Landrieu and Guillaume Obozinski. Cut pursuit: Fast algorithms to learn piecewise constant functions on general weighted graphs. *SIAM Journal on Imaging Sciences*, 10(4):1724–1766, 2017.

[2] Hugo Raguet and Loïc Landrieu. Cut-pursuit algorithm for regularizing nonsmooth functionals with graph total variation. *International Conference on Machine Learning*, 80:4244–4253, 2018.

[3] Hugo Raguet and Loïc Landrieu. Parallel Cut Pursuit For Minimization of the Graph Total Variation. *International Conference on Machine Learning*, Workshop on Learning and Reasoning with Graph-Structured Data, 2019.

[4] Loïc Landrieu and Martin Simonovsky. Large-scale Point Cloud Semantic Segmentation with Superpoint Graphs. *IEEE Conference on Computer Vision and Pattern Recognition*, 2018.

[5] Loïc Landrieu and Mohamed Boussaha. Point Cloud Oversegmentation with Graph-Structured Deep Metric Learning. *IEEE Conference on Computer Vision and Pattern Recognition*, 2019.

[6] Loïc Landrieu, Stéphane Guinard, Laurent Caraffa and Bruno Vallet. Piecewise-Planar Approximation of Large 3D Data as Graph-Structured Optimization. *ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences*, IV-2/W5:365–372, 2019.