Fast Semi-Supervised Image Segmentation Using Novelty Selection

Antonio R. C. Paiva, Tolga Tasdizen, Scientific Computing and Imaging Institute

THE UNIVERSITY OF UTAH

SCI www.sci.utah.edu

Introduction

- Semi-supervised image segmentation concerns how to obtain the segmentation from a partially labeled image.
- Semi-supervised learning methods are particularly interesting for image segmentation because they use the image manifold structure to propagate labels.
- The major limitation of semi-supervised learning methods is that the computation complexity and memory requirements scales with the square of the number of points.
- We propose the use of *novelty selection* to to reduce the number of points that one needs to be processed, leading to reduced computation time and memory usage.

Novelty Selection

- The goal is to use the least number of points while preserving the underlying manifold structure, as in resource-allocating networks [1].
- A point is added to a representative set only if the distance to all points in the representative set is greater than δ.
- Key advantages:
- Very fast and memory efficient;
- The numbers of points needed is determined from directly from data.

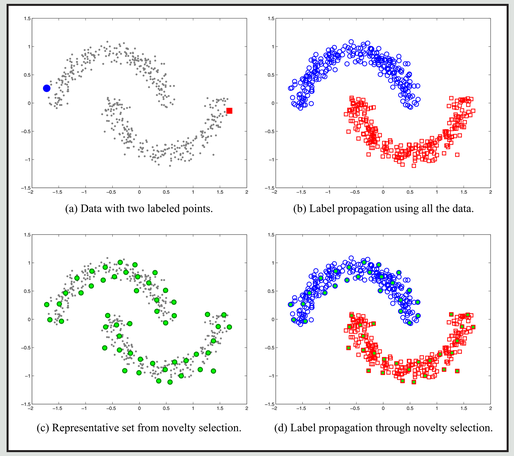

Fig. 1: Illustration of novelty selection and semi-supervised learning.

Algorithm

Consider N data points in $X=\{x_1,...,x_N\}$ and denote the representative set by Y. Also, let $I_X = \{j_1,...,j_N\}$ denote the set of indices of the nearest neighbor in Y for each x_i in X.

The novelty selection algorithm proceeds as follows:

- Initialize $Y=\{x_1\}$ and $I_X=\{1\}$.
- For each x_i in X,
  - Compute distances $d(x_i,Y)$ of x_i to all elements in Y,
  - If min $d(x_i,y_n) > \delta$,
    - Add x_i to Y and set $j_i = i$,

    else,
    - Set j_i = argminn $d(x_i,y_n)$, y_n in Y.

The final image segmentation results are obtained with:

1. Apply novelty selection to all the data,
2. Ensure all labeled points are in the representative set,
3. Propagate labels using SSL,
4. Label remaining point using I_X.

Image	Dimensions (pixels)	With novelty selection	Without novelty selection	Speedup
Tree	110x122	24.5	392.1	16x
Beach	150x150	4.6	2857.8	621x
House	128x128	18.2	639.4	35x
Tulips	300x200	640.6	12351.4	19x

Table 1: Comparison of computation times.

Results

- Used semi-supervised learning method proposed by Zhou et al. [2].
- Tested the proposed method on the “two moons” dataset, shown in Fig. 1, having achieved a speedup of 22x.
- Experiments for segmentation of several images (Fig. 2) yields results as accurate as using all the data.
- Reduction of computation time ranges from 16 to 621 times!

Conclusions

- Novelty selection speeds-up and reduces memory needs for semi-supervised image segmentation with same accuracy.
- Semi-supervised image segmentation uses user input to direct the algorithm towards the “correct” segmentation.
- Use of novelty selection may be applied to other semi-supervised learning applications.
- Future work will focus on automatically determining the novelty selection parameter.

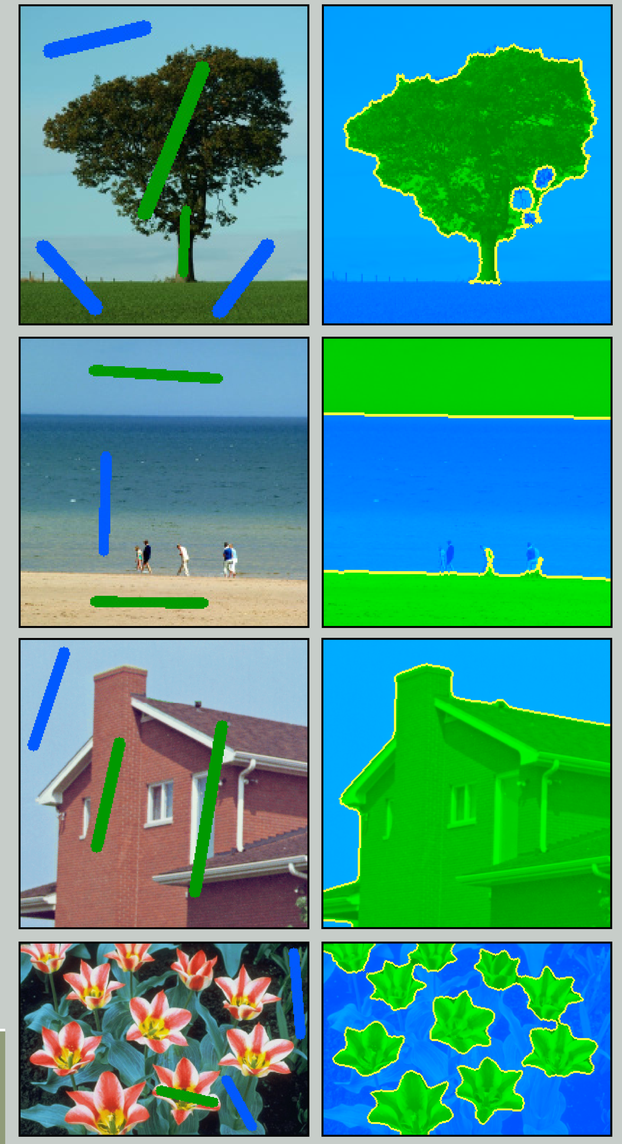

Fig. 2: Image segmentation results.

References

[1] J. Platt, “A resource-allocating network for function interpolation,” Neural Computation, 3(2), 1991

[2] D. Zhou, O. Bousquet, T.N. Lal, J. Weston and B. Scholkopf, “Learning with local and global consistency,” in NIPS, 2003

Acknowledgements: This work was supported in by NIH NIBIB under grant RO1EB005832.