MONOCULAR EXTRACTION OF 2.1D SKETCH

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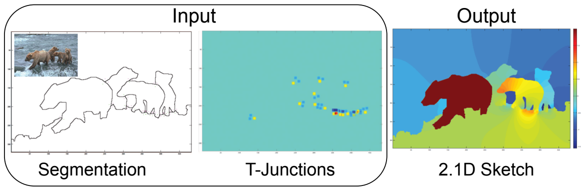
Problem Statement

Given an image and its:

- Segmentation,
- T-junctions,

Estimate a layered representation of the scene.



Rationale

The 2.1D sketch should be:

- Smooth within every region in the image, and
- Discontinuous at region boundaries.

Approach

- Smoothness:
  Zero Laplacian of the 2.1D sketch within each region
- Discontinuity:
  Increments of the sketch at the "caps" of the T-junctions

Contributions

- A regularized quadratic-optimization formulation
- The algorithm that resolves:
  - Global consistency, and
  - Produces a consistent layered depth map.

Problem Formulation

Notation:

$\boldsymbol{d}$: 2.1D Sketch

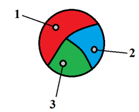
$\boldsymbol{D}_x$: Derivative in x direction

$\boldsymbol{m}$: Segmentation mask

$\boldsymbol{m}_{xy} = 0$ at boundaries, and 1, o.w.

$\boldsymbol{L}$: Laplacian $\boldsymbol{L} = \boldsymbol{D}_x^{\mathrm{T}}\mathrm{diag}(\boldsymbol{m})\boldsymbol{D}_x + \boldsymbol{D}_y^{\mathrm{T}}\mathrm{diag}(\boldsymbol{m})\boldsymbol{D}_y$

$$\min_{\boldsymbol{d}} \; \boldsymbol{d}^{\mathrm{T}}\boldsymbol{L}\boldsymbol{d} + 2\lambda \sum_i \sum_{j=1}^{2} f(\boldsymbol{a}_{ij}^{\mathrm{T}}\boldsymbol{d})$$



index of T-Junctions

enforces T-Junction constraints hinge-loss

index of two seeds (1,2) and (1,3) per T-Junction

Solution: Optimization Transfer

Goal: find a convex bound of the QP

We bound hinge loss as: $f(x) \leq \frac{x^2}{4} + (1-x)\mathbf{1}(x<1)$

$$\min_{\boldsymbol{d}} \; \boldsymbol{d}^{\mathrm{T}}\boldsymbol{L}\boldsymbol{d} + \lambda \left(\sum_i \sum_{j=1}^{2} \frac{\boldsymbol{a}_{ij}^{\mathrm{T}}(\boldsymbol{d}-\boldsymbol{d}')^2}{2|1-\boldsymbol{a}_{ij}^{\mathrm{T}}\boldsymbol{d}'|} + 2(1-\boldsymbol{a}_{ij}^{\mathrm{T}}\boldsymbol{d})\mathbf{1}(1-\boldsymbol{a}_{ij}^{\mathrm{T}}\boldsymbol{d}'<1) \right)$$

Solution = Accelerated Landweber iterations

$\boldsymbol{d}^{(t)}$ current estimate of the 2.1D sketch

$\boldsymbol{\delta}^{(\tau)}$ auxiliary updates

$\boldsymbol{A}, \boldsymbol{b}$ auxiliary quadratic-form coefficients

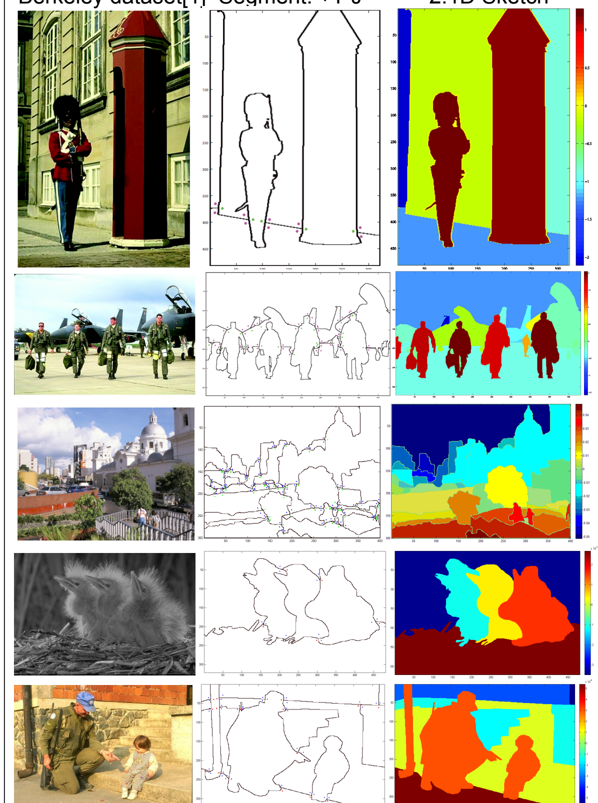
$$\boldsymbol{\delta}^{(\tau+1)} = \boldsymbol{\delta}^{(\tau)} + \alpha_t \left(\boldsymbol{\delta}^{(\tau-1)} - \boldsymbol{\delta}^{(\tau+1)}\right) + \beta_t \left(\boldsymbol{b}(\boldsymbol{d}^{(t)}) - \boldsymbol{A}(\boldsymbol{d}^{(t)})\boldsymbol{\delta}^{(\tau)}\right)$$

$$\tau = 1, 2, \ldots, T$$

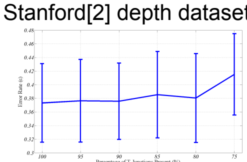
$$\boldsymbol{d}^{(t+1)} = \boldsymbol{\delta}^{(T)}$$

Results

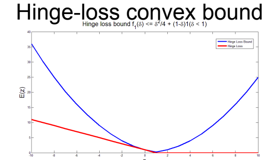
Berkeley dataset[1] | Segment. +T-J | 2.1D Sketch



Stanford[2] depth dataset



Hinge-loss convex bound



References:

[1] D.Martin, C. Fowlkes, D. Tal, and J.Malik, "A database of human segmented natural images and its application to evaluating segmentation algorithms and measuring ecological statistics," in *ICCV, 2001.*

[2] A. Saxena, M. Sun, and A. Y. Ng, "Make3D: Learning 3D scene structure from a single still image," *IEEE TPAMI, vol.* 31, no. 5, pp. 824–840, 2009.