A Computational Approach to Edge Detection

A Summarized Report

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Organization of the paper

- Introduction
- Mathematical formulation
  - Detection, Localization and Multiple responses
- Optimal Detectors by Numerical Optimization
- Detector for Step Edges
- An efficient approximation
Organization of the paper (contd.)

- Noise estimation and thresholding
- Multi dimensions
- Need for multiple widths
- Need for directional operators
One dimensional formulation

- Identification of the performance criteria.
  - Detection
  - Localization
  - Single response to an edge

- Mathematical formulation
Mathematical Formulation

- Detection analogous to SNR.
- Localization formulated as the reciprocal of the deviation of point marked as edge from the center of *true edge*.
- Trivial maximization of the SNR-Localization product.
- Elimination of maxima in the vicinity of the edge; spatial scaling.
Optimal Detectors by Numerical Optimization

- Difficult to find closed form for the operator that satisfies all the performance criteria.
- Hence, necessary to numerically optimize the sampled operator impulse response.
- Maximization of SNR-Localization product subject to constraints.
- Procedure applied to develop optimal detectors for ridge and roof profiles.
A Detector for Step Edges

- Formulation of the SNR and Localization criteria.
- Definition of the $\Sigma \Lambda$ product.
- The uncertainty principle.
- Maximizing the $\Sigma \Lambda$ product.
- Comparison of different filters.
An Efficient Approximation

- The optimal operator is similar to the first derivative of a Gaussian.
- Theoretical performance comparison.
- Comparison with the Marr-Hildreth LoG operator.
- Edge detection between textured regions.
Noise estimation

- Wiener filtering is used to estimate the noise component in the image.
- Derivation of the optimal Wiener filter.
- Global histogram estimation.
- Averaging is not used because the noise estimate is heavily colored by the density and strength of the edges.
Thresholding

- Broken edge contours
- Streaking
- Twin threshold scheme
Two or more dimensions

- Definition of edge direction.
- The Gaussian projection function.
- Derivation of the directional operator.
- Reasons why a Gaussian projection function is used – efficient convolution due to separability of the 2-D filter, smooth window function.
Need for multiple widths

- SNR will be different for each edge in the image.
- Thresholding based on the probability of error and not on the magnitude of response. Corresponding minimum acceptable SNR is determined. Operator with smallest width having SNR above minimum limit is chosen.
- Trade off between SNR and localization remains.
Feature Synthesis

- Mark edges from smallest operators.
- Synthesize large operator outputs from these edges (Convolve with a Gaussian normal to the edge direction).
- Compare the actual (large) operator outputs with these synthesized outputs.
- Additional edges are marked only if the large operator has significantly larger response.
Need for Directional Operators

- Detection and localization of the operator improves as the length of the projection function increases.
- Practical limitations on this increase. Hence the need for directional operators.
Forming directional masks

- To estimate the goodness of fit of a directional mask, the output of non-elongated masks is sampled in a direction parallel to the edge.
- If the samples are close together (< 2σ apart), the resulting masks is flat over most of its range in the edge direction and falls off smoothly to zero.
Summary

- Identifying the edge detection criteria and mathematically formulating these.
- Numerical optimization to find optimal operators.
- Tradeoff between detection and localization determined by spatial width.
- Impulse response of the optimal operator – first derivative of Gaussian.
Summary (contd.)

- Adaptive thresholding with hysteresis. Thresholds set according to noise estimate.
- Feature synthesis.
- Directional masks.
- Extension of this work – integration of different edge detector outputs into a single description.