Fast Detection of Curved Edges at Low SNR

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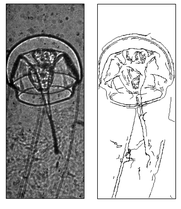
Objective:

- Efficient (near linear time) detection of faint curved edges in noisy images



Motivation:

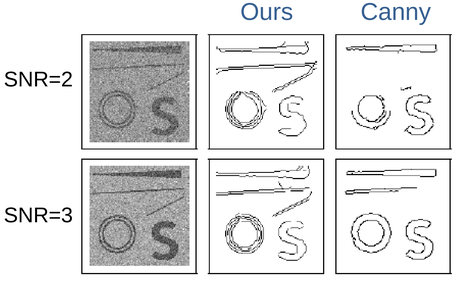
- Longer curves are perceived in lower SNR than short ones

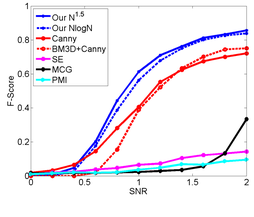
SNR = 1 | SNR = 2 | Clean Pattern

- Long is good: noise can be averaged out by smoothing along the curve (while maintaining contrast across the curve) by using a *matched filter*
- But where are those curves and what are their shapes? curves can appear in any of an exponential number of shapes

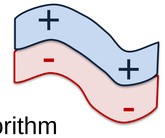
Our solution:

- An efficient hierarchical algorithm to examine an exponential number of candidate curved edges
- Use statistically rigorous adaptive threshold to detect edges at very low SNRs



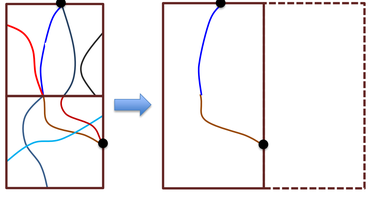


Approach:

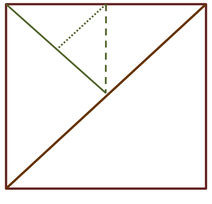


- Examine each potential edge curve using its "custom tailored" matched filter
- Do this efficiently using a dynamic programming-like algorithm on a hierarchical, binary-split tree of the image (keep best curve for each two points on the boundary of a tile)

Rectangle/square split



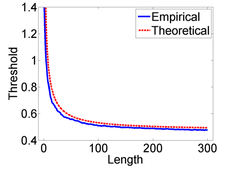
Triangle-split tree



Limits of detectability:

$T(L) = \sigma\sqrt{\frac{2\ln K_L}{wL}}$, where $K_L = 6N(2^{\beta L})$

(number of considered curves, K_L, grows exponentially with L)



$T(L \to \infty) = \Omega(\frac{\sigma}{\sqrt{w}})$

(Notation: N-image size; L, w-filter size; σ-noise level, β-constant)

Computational complexity:

- Stringent: $O(N^{1.5})$ - examine all contact points in the interface between tiles
- Greedy: $O(N \log N)$ - contact points are sorted by score; only curves through highest scoring points are examined
- Runtime:0.9 (0.6) secs on 129×129.