Edge Detection Evaluation: A New Normalized Figure of Merit

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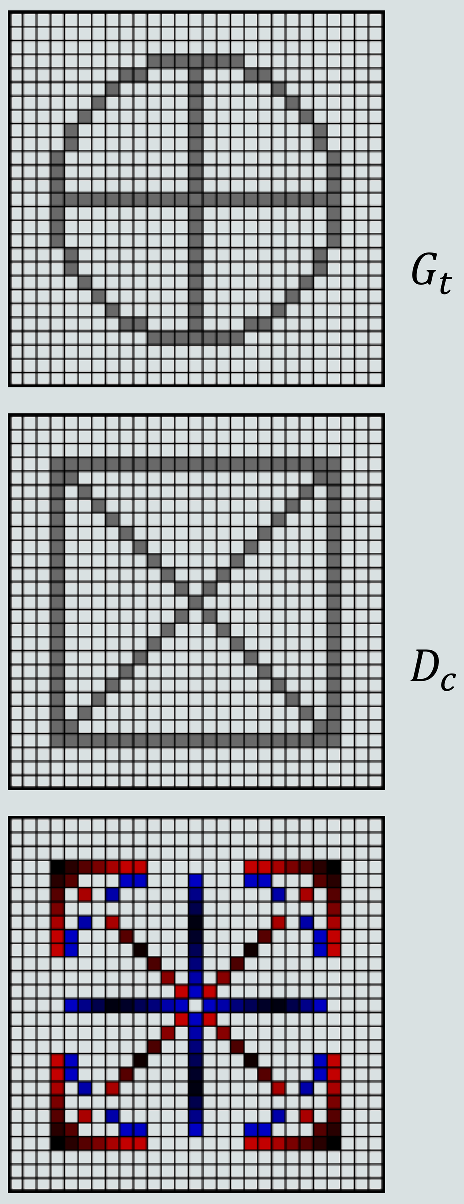
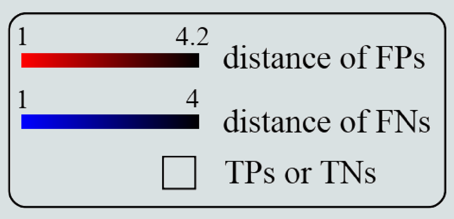
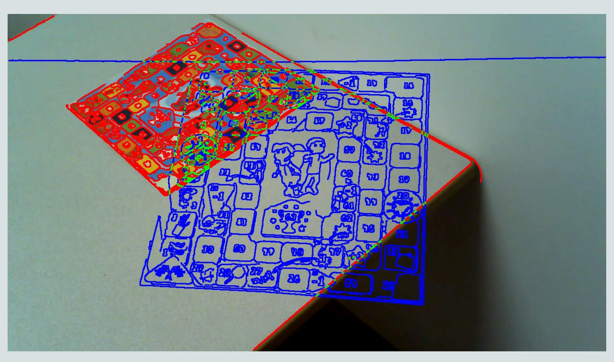


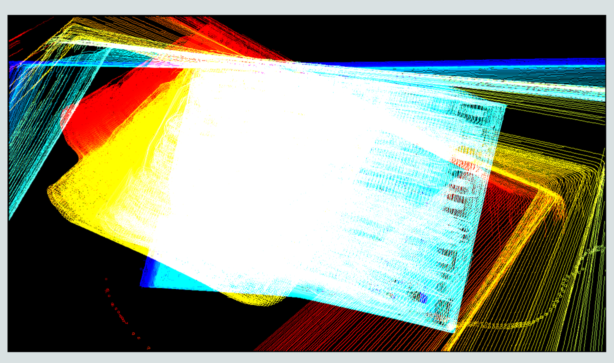
Illustration of d_{D_c} and d_{G_t}



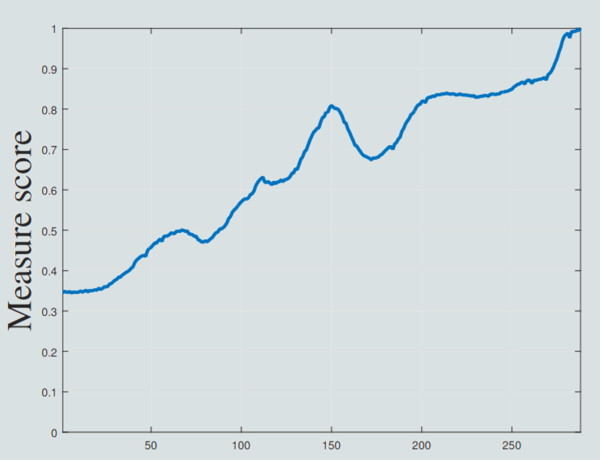
Future works:
Object localization



1st frame + edges



Accumulation of edges



Localization metric behavior

Existing Normalized Measures

The normalization remains valuable to compare a set of algorithms more easily. The most frequently normalized measures of dissimilarity are described here. Each measure computes a score of quality; **the closer to 1 the score of the evaluation is, the more the segmentation is qualified as suitable. On the contrary, a score close to 0 corresponds to a poor edge detection.**

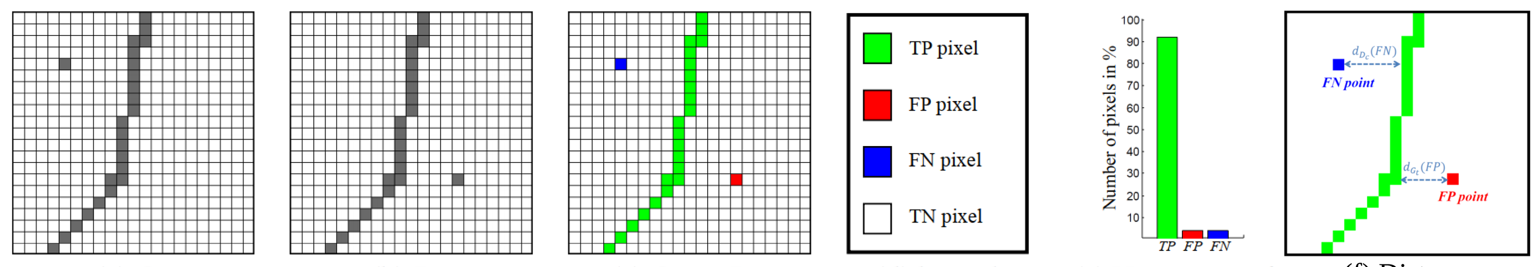
Let G_t be the reference contour map corresponding to ground truth and D_c the detected contour map of an original image I. Comparing pixel per pixel G_t and D_c, a basic evaluation is composed of statistics:

- True Positive points (TPs), common points of G_t and D_c: $TP = |G_t \cap D_c|$,
- False Positive points (FPs), spurious detected edges of D_c: $FP = |\neg G_t \cap D_c|$,
- False Negative points (FNs), missing points of D_c: $FN = |G_t \cap \neg D_c|$,
- True Negative points (TNs), common non-edge points: $TN = |\neg G_t \cap \neg D_c|$.

The *Performance measure* P_m simultaneously considers the three entities TP, FP and FN [5, 6] and is currently used in segmentation:

$$P_m(G_t, D_c) = \frac{TP}{|G_t \cup D_c|} = \frac{TP}{TP + FP + FN}$$

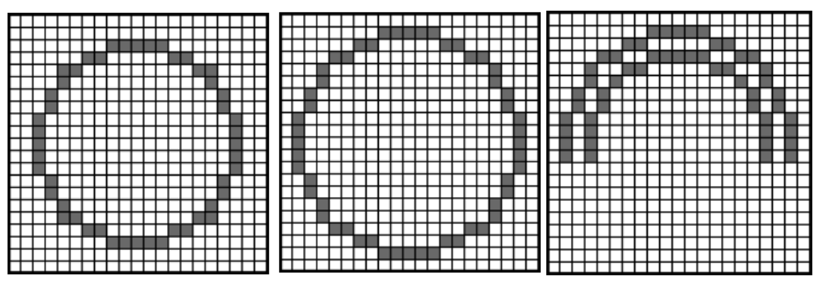
A reference-based edge map quality measure requires that a displaced edge should be penalized in function of FPs and/or FNs and of the distance from the position where it should be located [7]. Thus, for a pixel p belonging to D_c, $d_{G_t}(p)$ represents the minimal Euclidian distance between p and G_t. Also, if p belongs to G_t, $d_{D_c}(p)$ corresponds to the minimal distance between p and D_c.



(a) G_t, 21×21 (b) D_c, 21×21 (c) G_t vs. D_c, 21×21 (d) legend of (c) (e) Histogram of TPs, FPs and FNs (f) Distances of FPs and FNs

List of normalized dissimilarity measures involving distances, usually: $\kappa = 0.1$ or $1/9$.

Error measure name	Formulation	Parameters
Pratt's FoM [0]	$FoM(G_t, D_c) = \frac{1}{\max(\lvert G_t\rvert, \lvert D_c\rvert)} \cdot \sum_{p \in D_c} \frac{1}{1 + \kappa \cdot d^2_{G_t}(p)}$	$\kappa \in]0;1]$
Over-segmentation FoM [1]	$FoM_e(G_t, D_c) = \frac{1}{\max(e^{FP}, FP)} \cdot \sum_{p \in FP} \frac{1}{1 + \kappa \cdot d^2_{D_c}(p)}$	$\kappa \in]0;1]$
FoM revisited [2]	$F(G_t, D_c) = \frac{1}{\lvert G_t\rvert + \beta \cdot FP} \cdot \sum_{p \in G_t} \frac{1}{1 + \kappa \cdot d^2_{D_c}(p)}$	$\kappa \in]0;1]$ and $\beta \in \mathbb{R}^+$
Combination of *FoM* and statistics [3]	$d_4(G_t, D_c) = 1 - \frac{1}{2} \cdot \sqrt{\frac{(TP - \max(\lvert G_t\rvert, \lvert D_c\rvert))^2 + FN^2 + FP^2}{(\max(\lvert G_t\rvert, \lvert D_c\rvert))^2} + (1 - FoM(G_t, D_c))^2}$	$\kappa \in]0;1]$
Edge map quality measure [4]	$D_p(G_t, D_c) = 1 - \frac{1/2}{\lvert I\rvert - \lvert G_t\rvert} \sum_{p \in FP}\left(1 - \frac{1}{1 + \kappa \cdot d^2_{G_t}(p)}\right) - \frac{1/2}{\lvert G_t\rvert} \sum_{p \in FN}\left(1 - \frac{1}{1 + \kappa \cdot d^2_{TP}(p)}\right)$	$\kappa \in]0;1]$



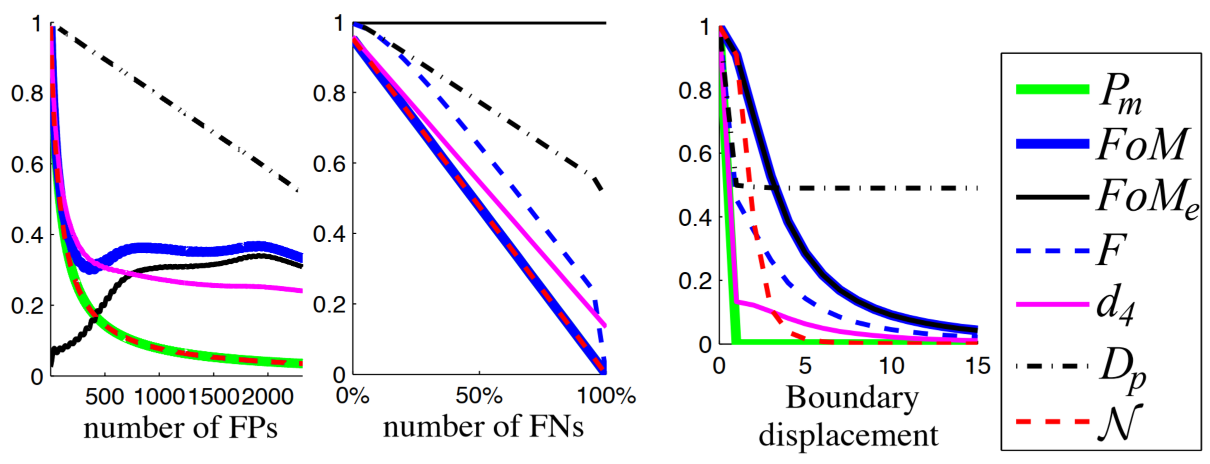
(a) G_t, $|G_t| = 48$ (b) C_1, $TP = 0$ (c) C_2, $TP = 0$

$P_m(G_t, C_1) = 0$	$P_m(G_t, C_2) = 0$
$FoM(G_t, C_1) = 0.8$	$FoM(G_t, C_2) = 0.8$
$FoM_e(G_t, C_1) = 0.2$	$FoM_e(G_t, C_2) = 0.2$
$F(G_t, C_1)$=0.38	$F(G_t, C_2) = 0.26$
$d_4(G_t, C_1)$= 0.15	$d_4(G_t, C_2) = 0.15$
$D_p((G_t, C_1)$= 0.48	$D_p(G_t, C_2) = 0.46$
$\mathcal{N}^{\kappa_{FP}=0.1}_{\kappa_{FN}=0.4}(G_t, C_1) = 0.81$	$\mathcal{N}^{\kappa_{FP}=0.1}_{\kappa_{FN}=0.4}(G_t, C_2) = 0.64$
$\mathcal{N}^{\kappa_{FP}=0.1}_{\kappa_{FN}=0.2}(G_t, C_1) = 0.87$	$\mathcal{N}^{\kappa_{FP}=0.1}_{\kappa_{FN}=0.2}(G_t, C_2) = 0.70$

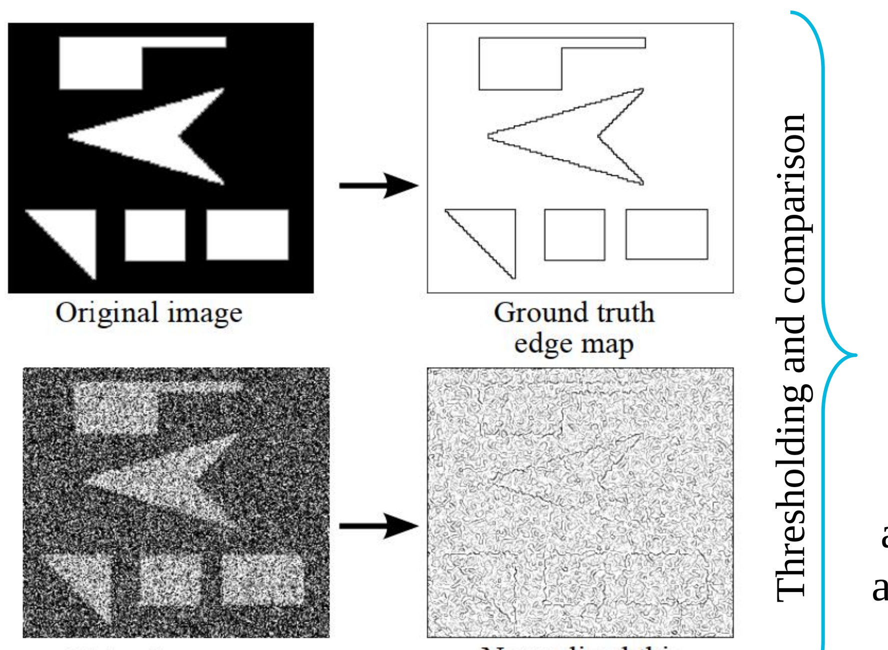
A New Normalized Measure

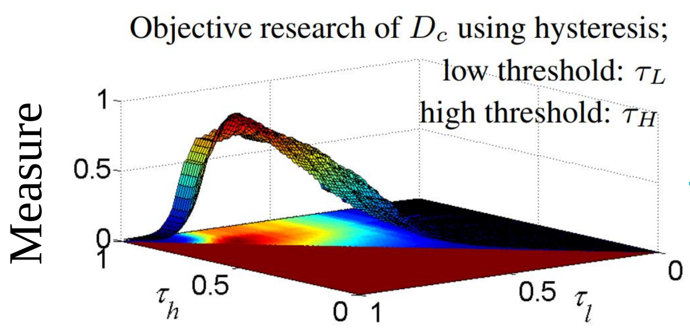
$$\mathcal{N}(G_t, D_c) = \frac{1}{FP + FN} \cdot \left[\frac{FP}{|D_c|} \cdot \sum_{p \in D_c} \frac{1}{1 + \kappa_{FP} \cdot d^2_{G_t}(p)} + \frac{FN}{|G_t|} \cdot \sum_{p \in G_t} \frac{1}{1 + \kappa_{FN} \cdot d^2_{D_c}(p)} \right],$$

where $(\kappa_{FP}, \kappa_{FN}) \in]0, 1]^2$ represent two scale parameters and the coefficient $\frac{1}{FP+FN}$ normalizes the $\mathcal{N}$ function. If FP=FN=0, then $\mathcal{N}$=1.

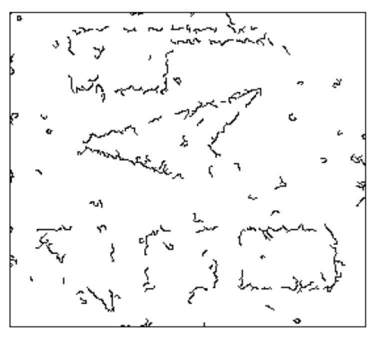


Experimental Results: Objective Evaluation

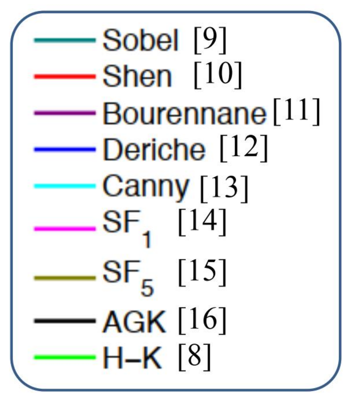


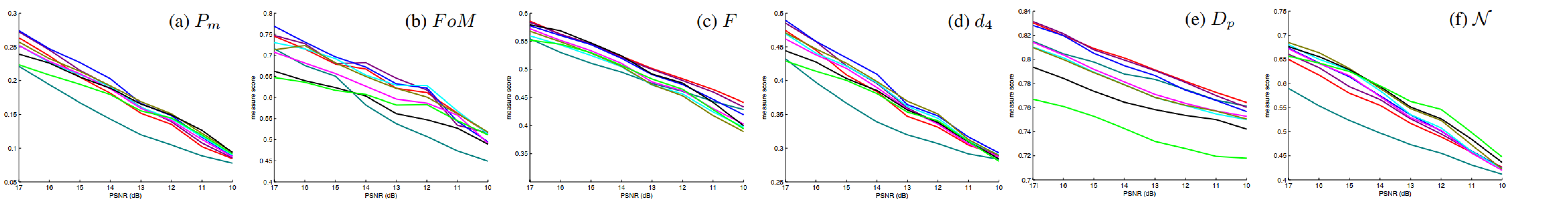


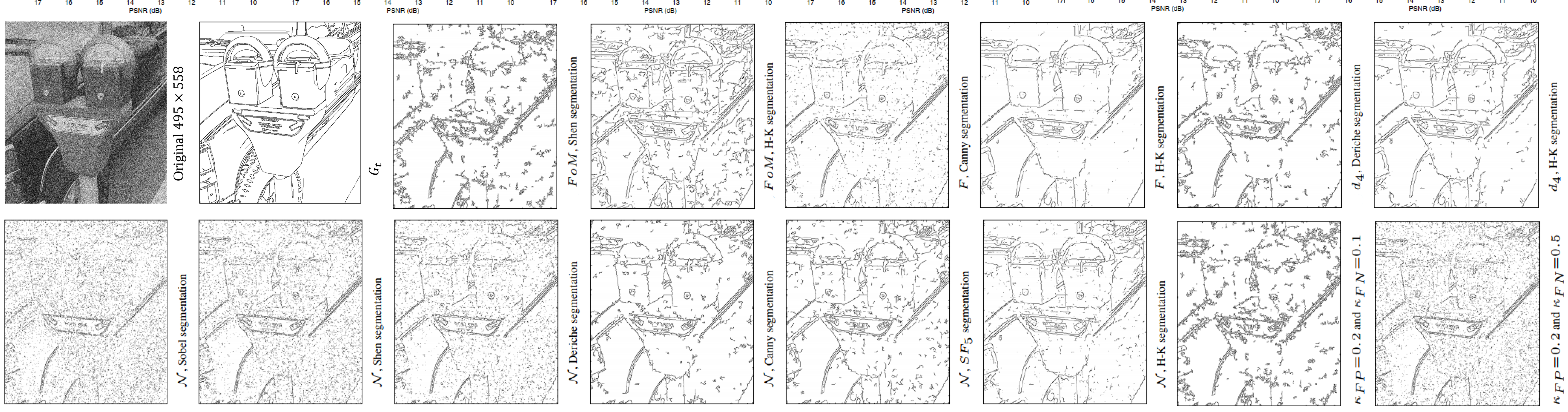
Objective research of the ideal edge map for a measure corresponding to the segmentation at which the evaluation obtains the **maximum** score using hysteresis thresholds.



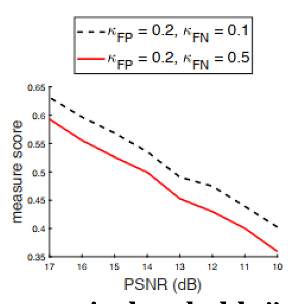
Best edge map for the tied to the edge map quality measure.







Shen [10], PSNR = 14dB Shen [10], PSNR = 14dB



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