Spatial Stimuli Gradient Sketch Model (SSGSM)

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Edge Detection

Basic Concept

- Detection of spatial transitions representing object boundaries and intensity-invariant structural details

Main challenge

- Maximum trade-off between true and false edges
- True edge results from inter-region transitions and false edges from intra-region transitions

Primary Criteria Of Any Edge Detection Technique

Ability to provide

- best response to edges
- good localization
- continuity of edges
- tolerance to image noise cum natural variance within the same regions

Primal Sketch Model

- A formal explanation on Edge Detection
- Inspired by the biological vision processing of human eye
- Describes an image using the image inherent structures
- Based on the response computed with respect to edge formations
- Uses optimal smoothing filters and detection of intensity changes

References
1. C.-e. Guo, S. C. Zhu, and Y. N. Wu, "Towards a mathematical theory of primal sketch and sketchability," in *Computer Vision, 2003. Proceedings. Ninth IEEE International Conference on. IEEE, 2003, pp. 1228–1235.*
2. D. Marr and E. Hildreth, "Theory of edge detection," *Proceedings of the Royal Society of London. Series B. Biological Sciences, vol. 207,* no. 1167, pp. 187–217, 1980.
3.E. C. Hildreth, "Implementation of a theory of edge detection," 1980.

Optimal Edge Detection

- Mathematical model of Primal Sketch Theory defines the quality of image based on
  - Sketchable and unsketchable edge responses.
- Sketchability
  - useable edges
- Unsketchability
  - false edges formed due the intra-region variability + image noise
- Ideal edge detection
  - primal structures retrieved comprising of all sketchable edges

Optimal Edge using Primal Sketch Model

Attempts to minimize

– trade-off between sketchable and unsketchable edges

Best efforts made

– applying smoothing as the first stage of edge detection

Drawback

– washing out of fine details due to smoothing operations

Paper is About

Hypothesis

- intra-region variability suppression can lead to more robustedge detection approaches.

Focus is on

- suppression of intensity variability other than edges
- minimization of unsketchable primitives

Proposing

An extension to image perception principles

- Mathematical implementation of Weber-Fechner law and Sheperd similarity law

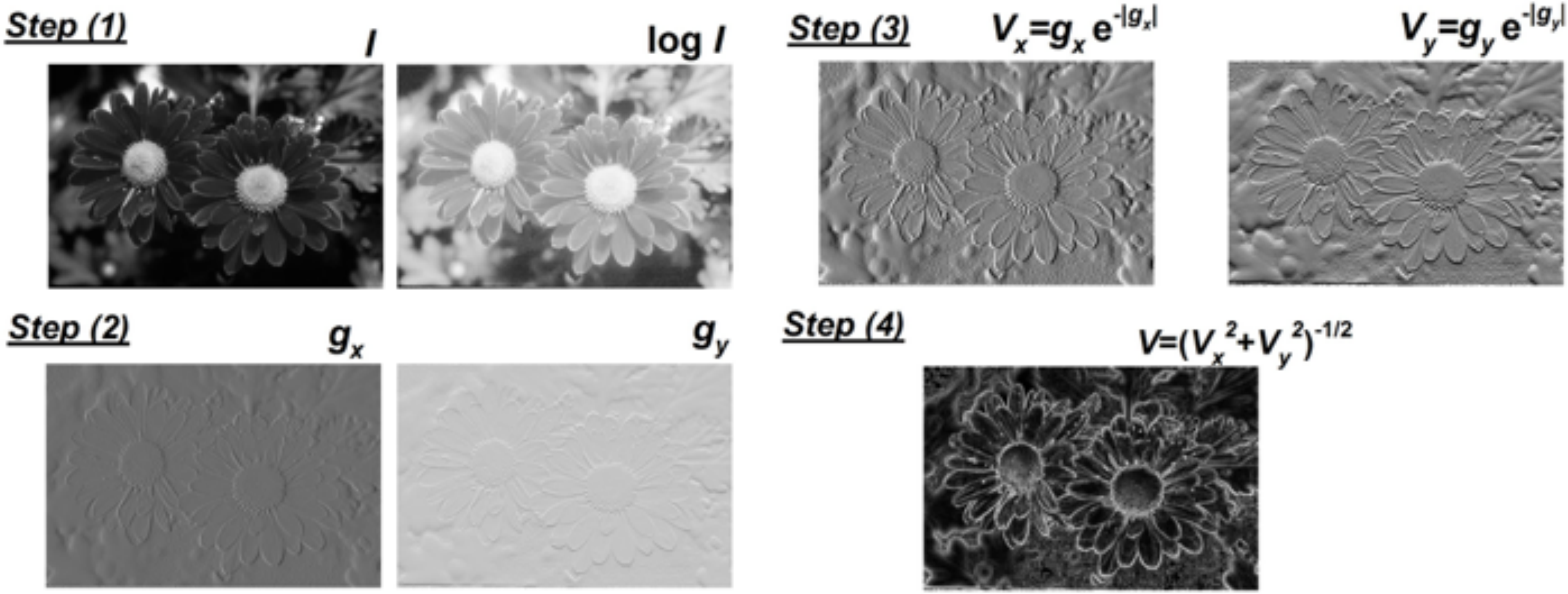
A new edge detection method and formulation use

- perceived brightness
- neighbourhood similarity calculations
- edge is represented as local spatial stimuli

References

4. S. Hecht, “The visual discrimination of intensity and the weber-fechner law,” *The Journal of general physiology, vol. 7, no. 2, pp. 235–267,* 1924.
5. R. N. Shepard, “Toward a universal law of generalization for psychological science,” *Science, vol. 237, no. 4820, pp. 1317–1323, 1987.*

PROPOSED METHOD



A graphical illustration on the working of the proposed edge detection method

Proposed Method

Main steps involved

- Calculation of Perceived Brightness, B – according to Fechner law it is the logarithm of measured intensity, ie. for image *I*, *B=log(I)*, **STEP 1**
- Computation of local spatial stimuli, based on Weber Law it is the noticeable spatial change in perceived brightness. In proposed method it is implemented in three steps
  - Two dimensional change in B, which is realized using gradient operator, $[g_x, g_y] = gradient(B)$, **STEP 2**
  - Intra-region variance suppression using Shepard's similarity function, $V_x = g_x exp(|g_x|)$ and $V_y = g_y exp(|g_y|)$, **STEP 3**
  - Computing net change in B, ie. Local Spatial Stimuli Gradient Sketch Model, $V = sqrt(V_x^2 + V_y^2)$, **STEP 4**

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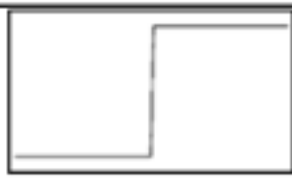
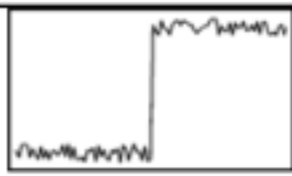
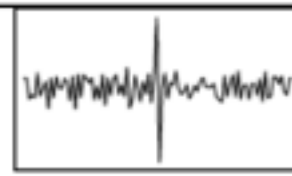
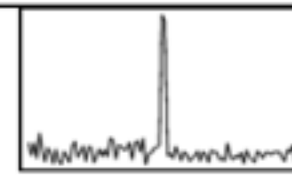
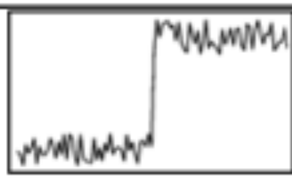
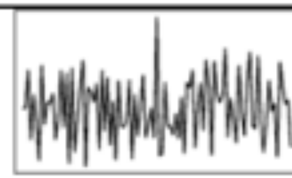
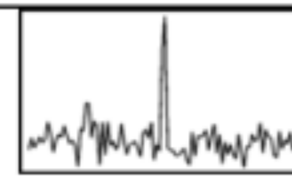
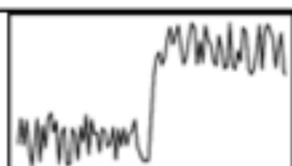
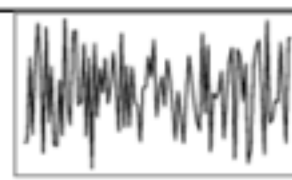
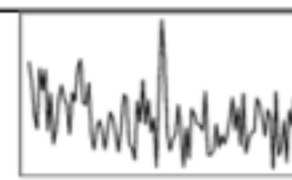
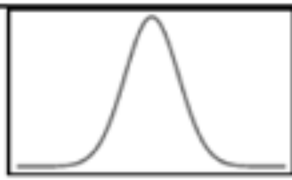
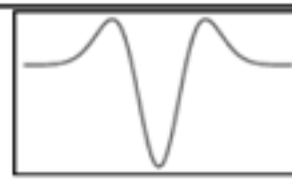
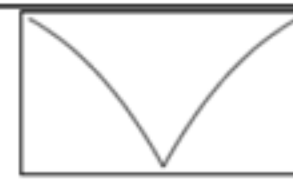
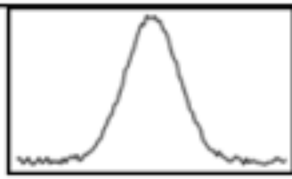
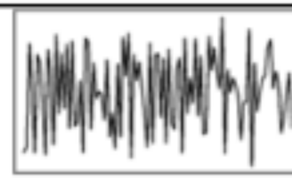
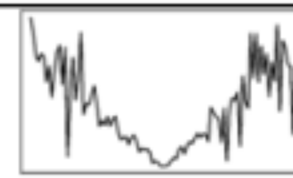
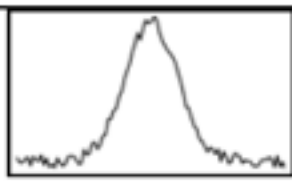
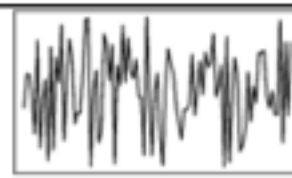
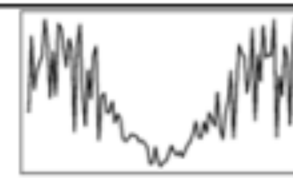
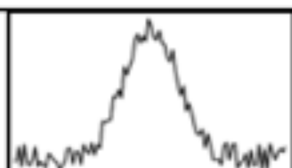
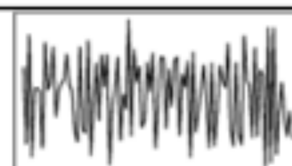
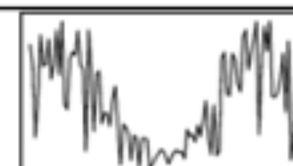
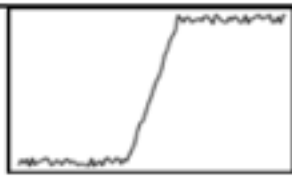
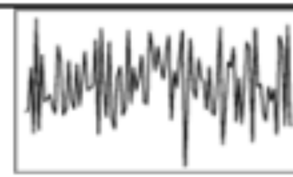
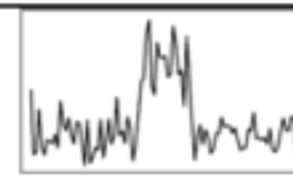
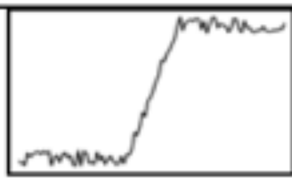
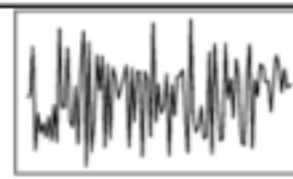
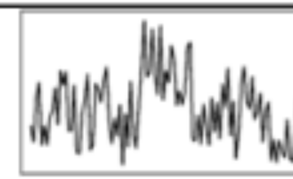
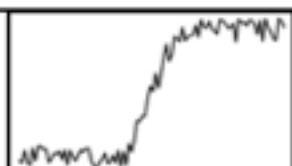
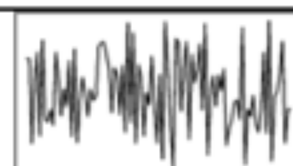
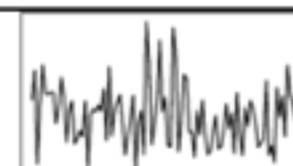
Comparison Of Edge Responses
Step Shape

$\sigma_{nv}^2(\%)$	Original	Primal Sketch Model	Proposed
0			
5			
10			
20			

Comparison Of Edge Responses
Gaussian Shape

σ^2_{nv}(%)	Original	Primal Sketch Model	Proposed
0			
5			
10			
20			

Comparison Of Edge Responses
Ramp Shape

$\sigma_{nv}^2(\%)$	Original	Primal Sketch Model	Proposed
0			
5			
10			
20			

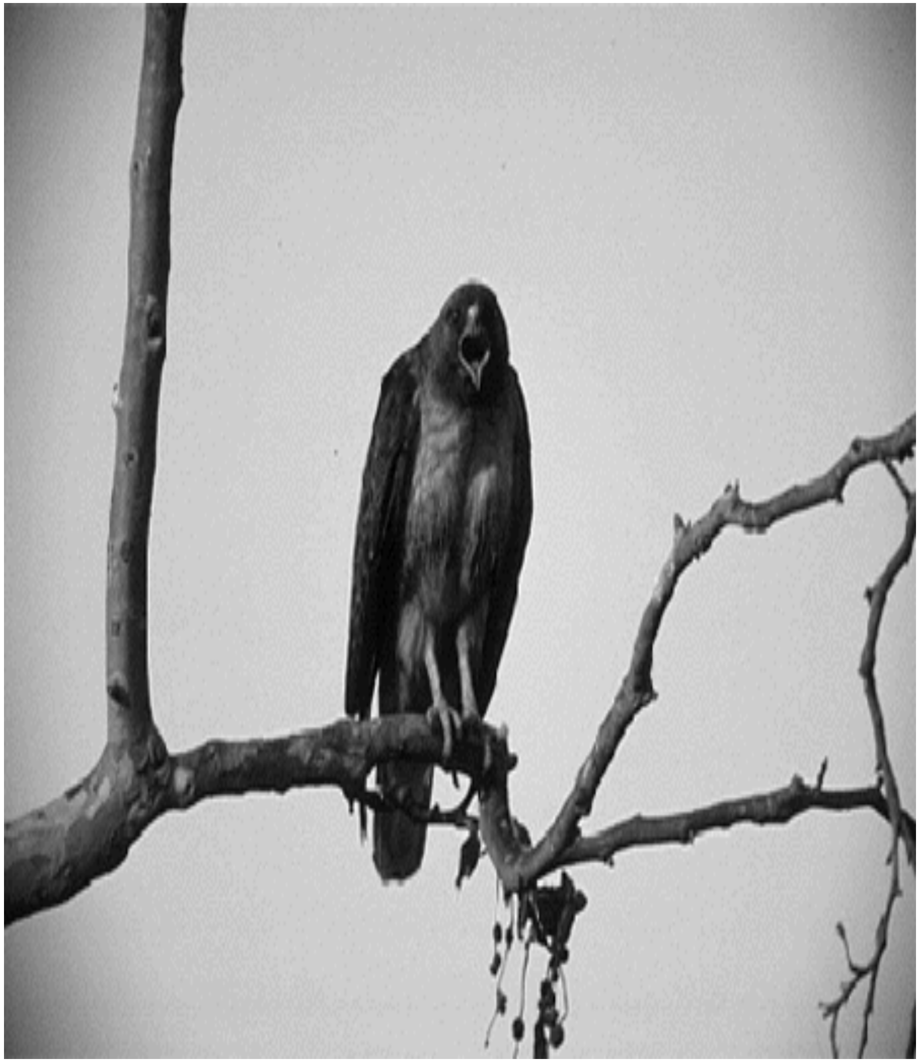
Few Examples

Original

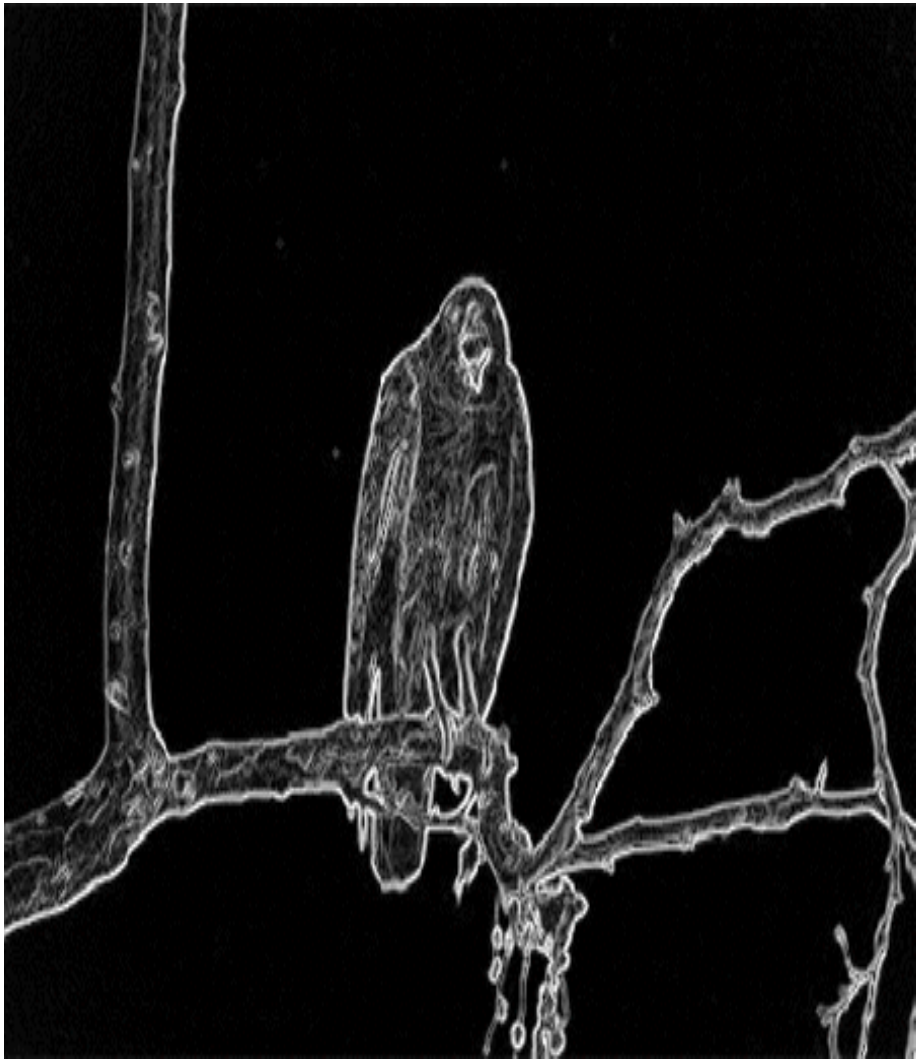
SSGSM

Image is from Berkeley Segmentation Dataset

Few Examples



Original



SSGSM

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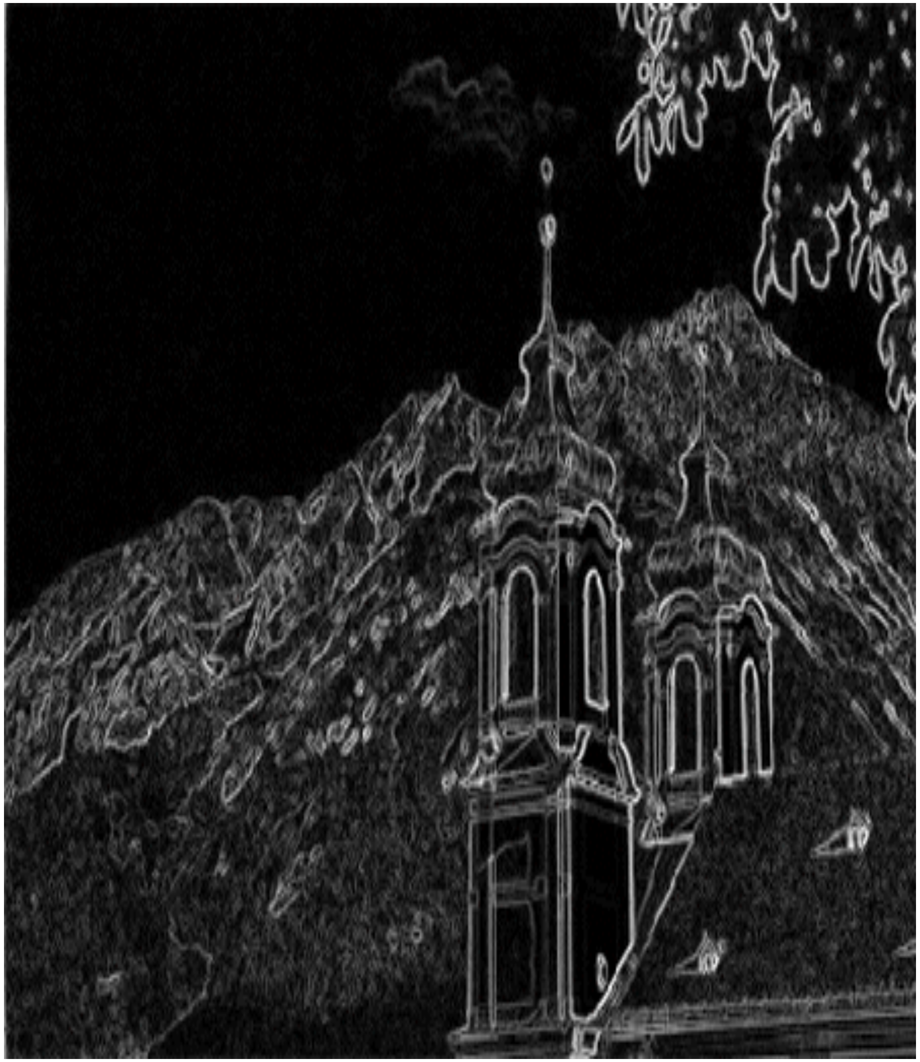
Few Examples

Original



SSGSM

Image is from Berkeley Segmentation Dataset

Few Examples

Original

SSGSM

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Image is from Berkeley Segmentation Dataset

Few Examples

Original

SSGSM

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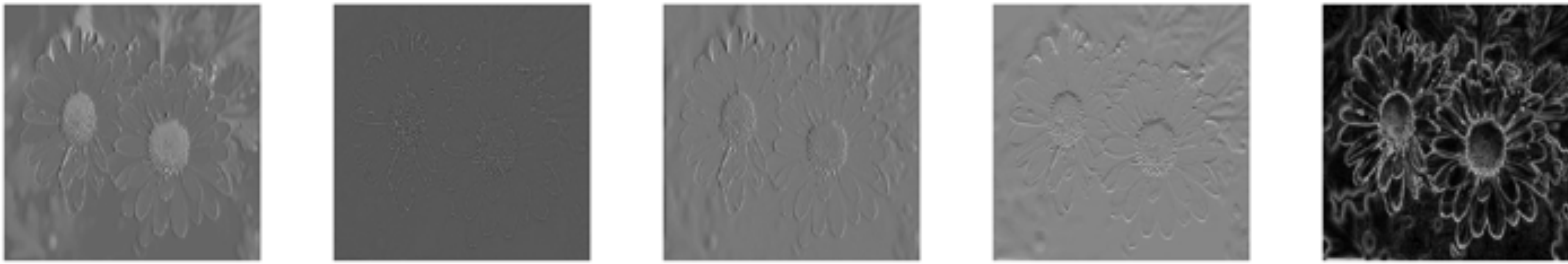
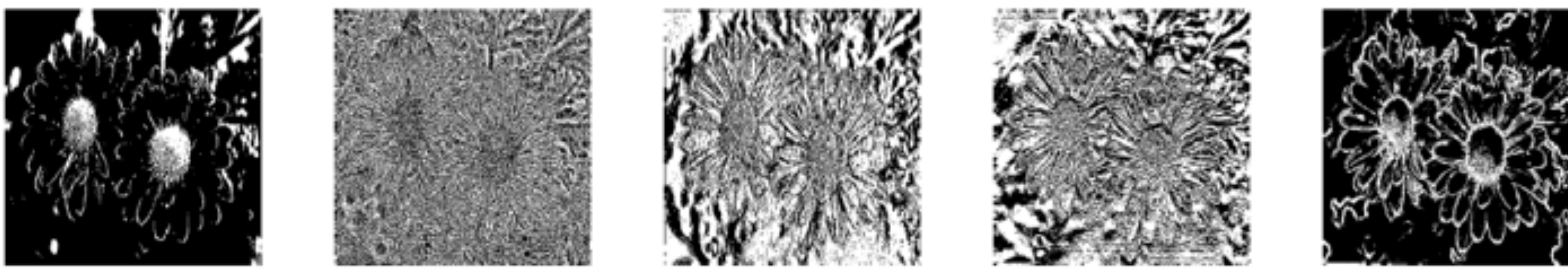
Image is from Berkeley Segmentation Dataset

Comparison Agaist Existing Methods



(a) Sobel (b) SIS (c) Kirsch (d) Prewitt (e) Proposed



(f) Sobel (g) SIS (h) Kirsch (i) Prewitt (j) Proposed

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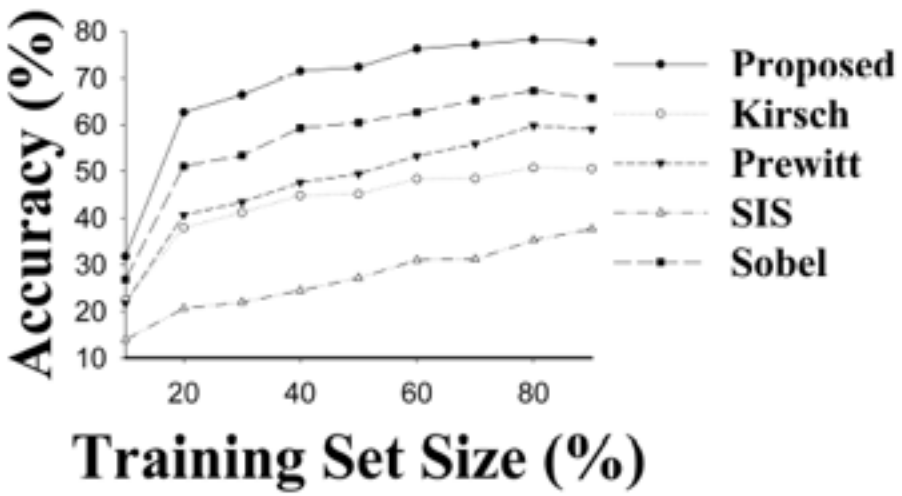
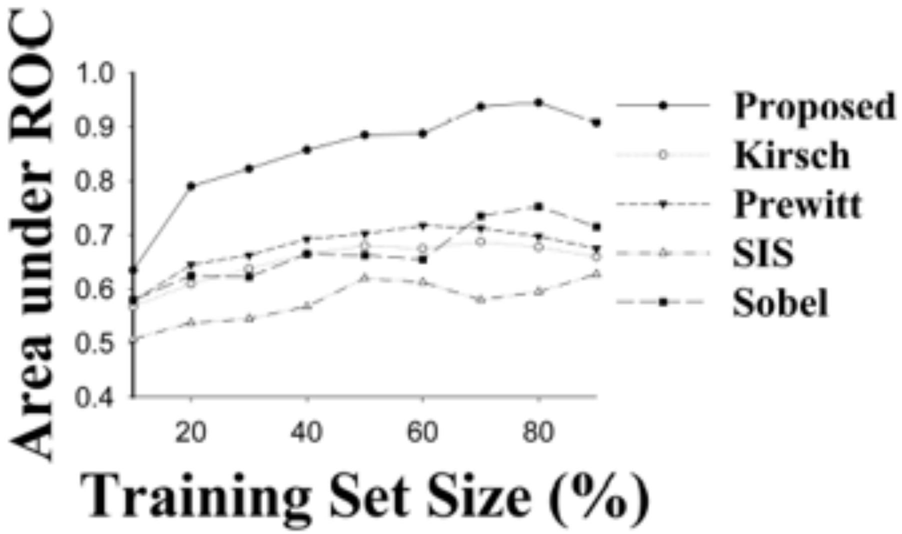
Face Recognition Accuracies



(a)



(b)

Average variation in accuracy (%) (a), and area under ROC (b) for varying sizes of training set (%) computed for ORL, AR, Georgia Tech, and JAFFE face databases calculated using a lazy classifier

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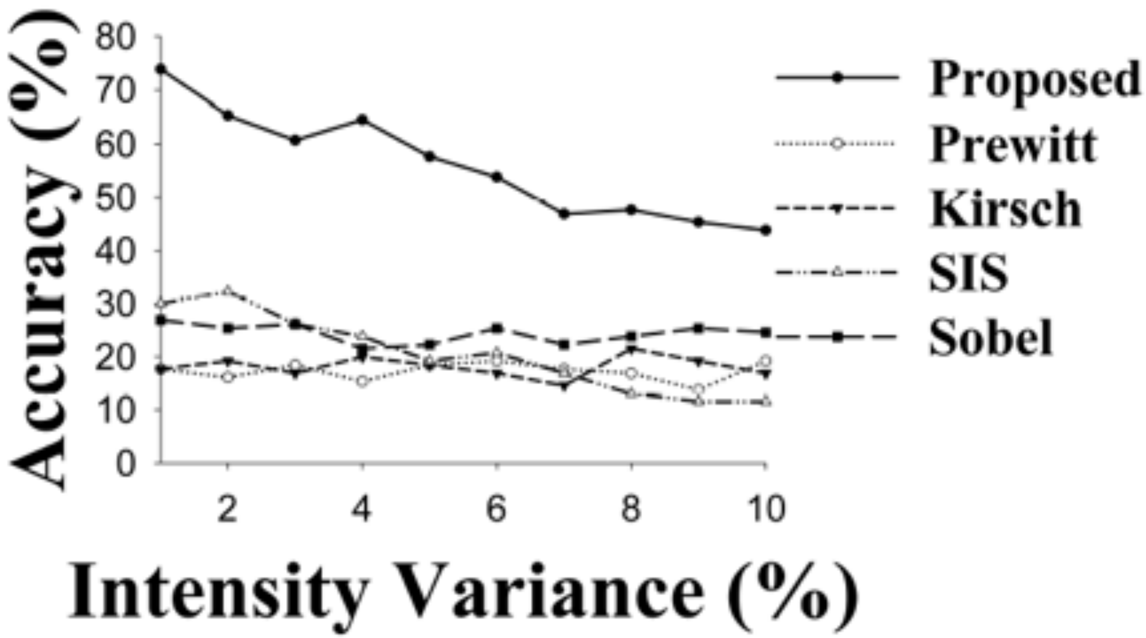
AVERAGE RECOGNITION ACCURACY (%) FOR DIFFERENT CLASSIFIERS

Face databases used ORL, AR, GEORGIA TECH, AND JAFFE

Method	Database			
	IBk	NNge	RandomForest	SMO
Proposed	**76.1±6.4**	**67.0±9.2**	**41.4±9.3**	**80.9±6.1**
Kirsch	46.8±8.5	41.6±9.7	32.2±8.4	62.02±8.9
Prewitt	54.3±8.2	44.9±7.8	34.4±7.2	61.6±8.1
SIS	31.2±8.2	25.6±7.2	20.1±8.9	39.5±8.8
Sobel	63.6±7.5	50.1±11.1	40.7±10.5	77.1±8.5

Performance Agianst Percentage Intensity Variability



Face database used AR

Conclusion

- Idea of spatial stimuli gradient sketch model is proposed
- Relationships between the image intensity and psychological measurement space is demonstrated
- Mathematical implementation of Fechner’s and Weber’s law, along with Sheperd's similarity measure are used
- Robust response to noise in pixels intensity along the edges of different nature
- Higher level of tolerance to pixel noise levels
- Overcome the limitations of edges based on primal sketch models
- Face recognition accuracies displayed statistically significant improvement over the benchmark edge detection methods and datasets