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
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 robust edge 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
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, \([g_x, g_y] = \text{gradient}(B)\), **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**
## Comparison of Edge Responses

**Step Shape**

<table>
<thead>
<tr>
<th>$\sigma^2_{n,v}$ (%)</th>
<th>Original</th>
<th>Primal Model</th>
<th>Sketch</th>
<th>Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
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**Comparison of Edge Responses**

**Gaussian Shape**

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**Comparison of Edge Responses: Ramp Shape**

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<th>$\sigma^2_{nv}(%)$</th>
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Few Examples

Image is from Berkeley Segmentation Dataset
Few Examples

Original

SSGSM

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COMPARISON AGAINST EXISTING METHODS

(a) Sobel  (b) SIS  (c) Kirsch  (d) Prewitt  (e) Proposed
(f) Sobel  (g) SIS  (h) Kirsch  (i) Prewitt  (j) Proposed
Face Recognition Accuracies

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.
### Average Recognition Accuracy (%) for Different Classifiers

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

<table>
<thead>
<tr>
<th>Method</th>
<th>IBk</th>
<th>NNge</th>
<th>RandomForest</th>
<th>SMO</th>
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<tbody>
<tr>
<td>Proposed</td>
<td>76.1±6.4</td>
<td>67.0±9.2</td>
<td>41.4±9.3</td>
<td>80.9±6.1</td>
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<tr>
<td>Kirsch</td>
<td>46.8±8.5</td>
<td>41.6±9.7</td>
<td>32.2±8.4</td>
<td>62.02±8.9</td>
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<td>Prewitt</td>
<td>54.3±8.2</td>
<td>44.9±7.8</td>
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<td>61.6±8.1</td>
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<td>SIS</td>
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<td>25.6±7.2</td>
<td>20.1±8.9</td>
<td>39.5±8.8</td>
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<tr>
<td>Sobel</td>
<td>63.6±7.5</td>
<td>50.1±11.1</td>
<td>40.7±10.5</td>
<td>77.1±8.5</td>
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</table>
Performance Against 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 Shepard'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