Shadow free segmentation in still images using local density measure

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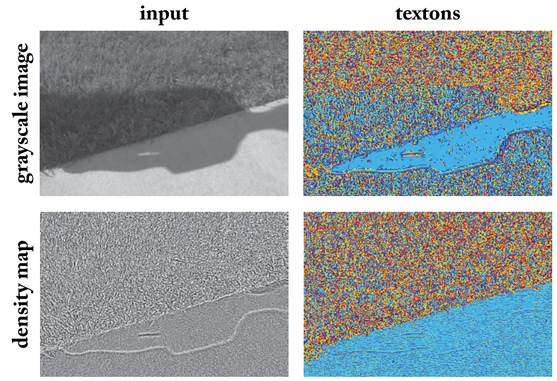
Image Density Map

Problem: classical filterbank based texture descriptors are not robust to shadows

Solution: preprocess images using local density measure



Formulation

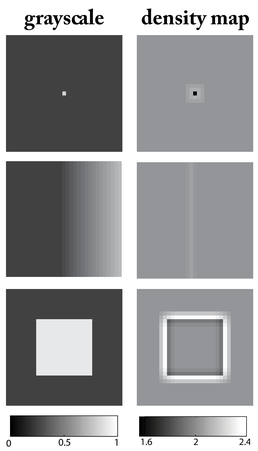
- Define a measure function on the image over radius r

$$\mu(\mathbf{x}, r) = \sum_{\|\mathbf{y}-\mathbf{x}\| \le r} I(\mathbf{y})$$

- Hypothesize that it varies as an exponential of r

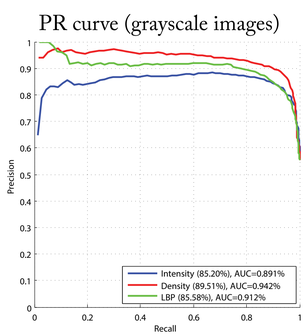
$$\mu(\mathbf{x}, r) = k r^{d(\mathbf{x})}$$
$$\log(\mu(\mathbf{x}, r)) = \log k + d(\mathbf{x}) \log r$$
$$d(\mathbf{x}) = \lim_{r \to 0} \frac{\log(\mu(\mathbf{x}, r))}{\log r}$$

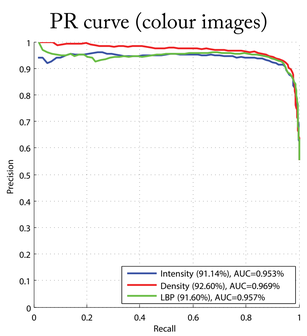
- d(x) is the local density function of image I(x) at pt. x
- Intuitively measures the degree of regularity of intensity variation in a local neighbourhood around x
- Important properties:
  - Preserves texture details
  - Invariant to multiplicative illumination changes



Application to shadow boundary detection

- Goal: detect shadow boundaries in images
- For each edge pixel compare appearance features on both sides of the edge
- Features:
  - intensity ratios
  - RGB colour channel ratios
  - textons on intensity | textons on density | Local Binary Patterns
- Evaluate on shadow image dataset by Zhu et al
- Two experimetns
  - Grayscale images (intensity and texture features only)
  - Colour images (intensity, texture and colour features)





Shadow free segmentation

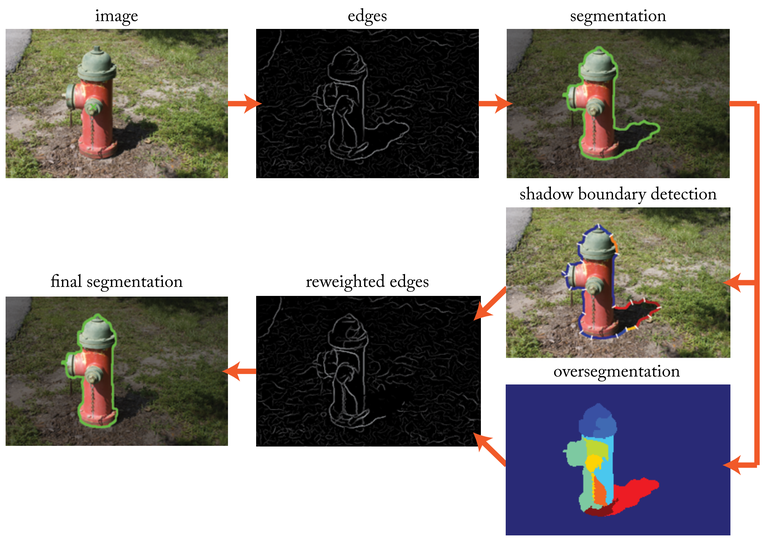
- Graph cut image segmentation formulation

$$E(f) = \sum_{p \in \mathcal{P}} D_p(f_p) + \lambda \sum_{\{p,q\} \in \mathcal{N}} V_{p,q} \cdot \delta(f_p \neq f_q)$$

- Shadows change the colour model of the shadowed region
  - use an illumination invariant colourspace (L*a*b*)
- Shadows affect the binary weights by
  - introducing string gradients at the boundary of shadow region
  - reducing gradients in shadowed regions
- Two most common segmentation mistakes
  - undersegmentation
  - oversegmentation

Our approach

- Observation: wrong segmentation boundary always goes along shadow boundaries
- Our approach:
  1. segment
  2. modify binary weights
     - attenuate shadow boundary edges
     - reinforce internal edges
  3. resegment



Evaluation

- Dataset of 52 outdoor images
- Manually labelled figure ground segmentations
- Baseline: segmentation without shadow removal
- Test our method with three different shadow detectors
  - intensity textons
  - density textons
  - Local Binary Patterns

Algorithm	F-measure
Baseline	0.77±0.033
Intensity textons	0.80±0.052
Density Textons	0.84±0.045
LBP	0.81±0.055

Results