



# **TEXTURE SYNTHESIS AND UNSUPERVISED RECOGNITION WITH A NONPARAMETRIC MULTISCALE MRF MODEL**

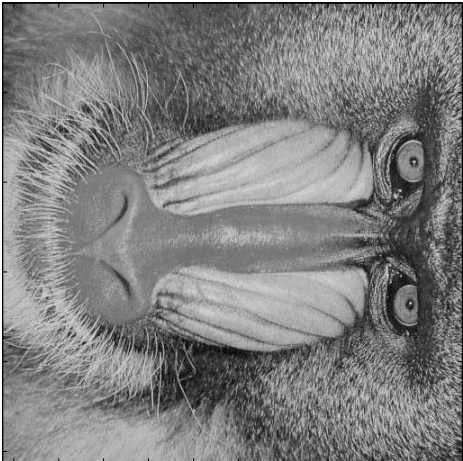
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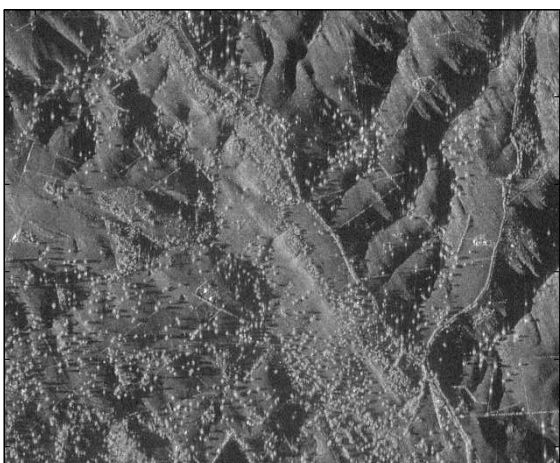
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# Texture in Images



Baboon face



Airborne SAR

**Texture** Is the visual characteristics within an area of an image which identifies that area as having a particular physical interpretation.

**Aim** To find a model that is capable of capturing the unique characteristics of a texture for segmentation and classification.

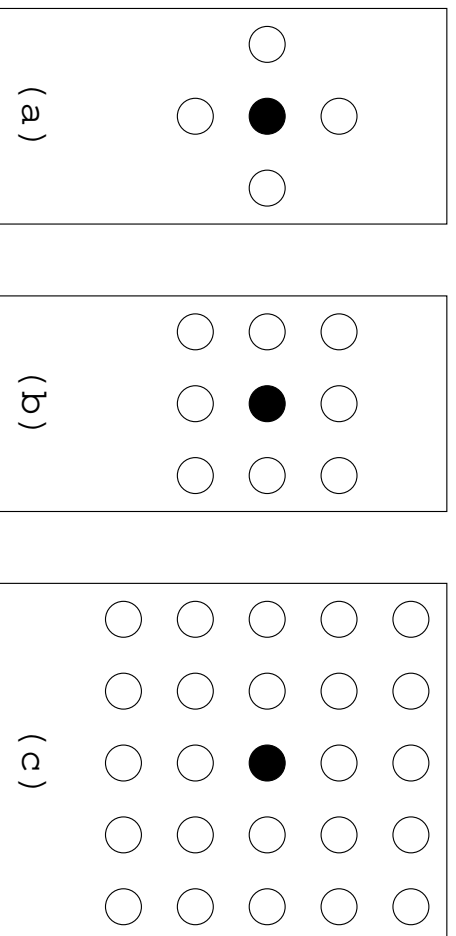
**Method** Use a nonparametric multiscale Markov random field texture model.

## Advantages

- Does not require parameter estimation.
- Only requires a small amount of sample data.
- Can model high dimensional statistics.

# Markov Random Field Model

For a texture to be modelled as a MRF, the value of each pixel in the texture must be dependent on a local set of neighbouring pixels. This dependence is then modelled by a **Local Conditional Probability Density Function (LCPDF)** which defines the probability of a pixel being a certain value given the values of its neighbouring pixels.



**Figure 1:** Neighbourhoods. (a) The first order or “nearest-neighbour” neighbourhood; (b) second order neighbourhood; (c) eighth order neighbourhood.

**Problem 1** Determining the correct neighbourhood size.

**Problem 2** Estimation of the LCPDF.

# Nonparametric MRF

Estimation of nonparametric LCPDF.

**Step 1** Choose a neighbourhood size.

**Step 2** Build a multi-dimensional histogram with the neighbourhood from the texture. Example:

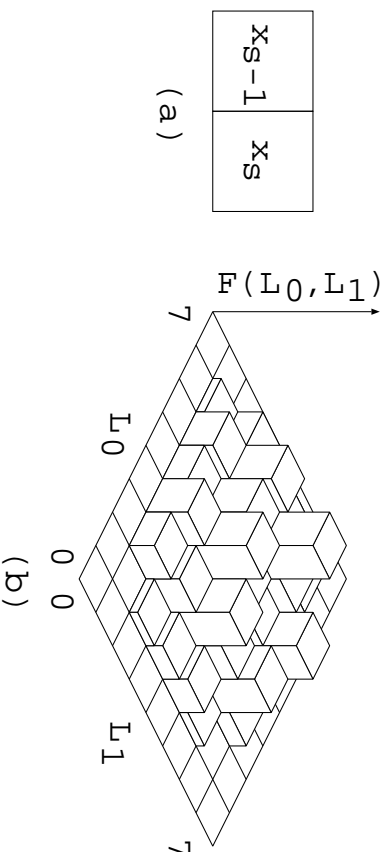


Figure 2: Neighbourhood and its 2-D histogram.

**Step 3** Smooth multi-dimensional histogram via nonparametric Parzen density estimation.

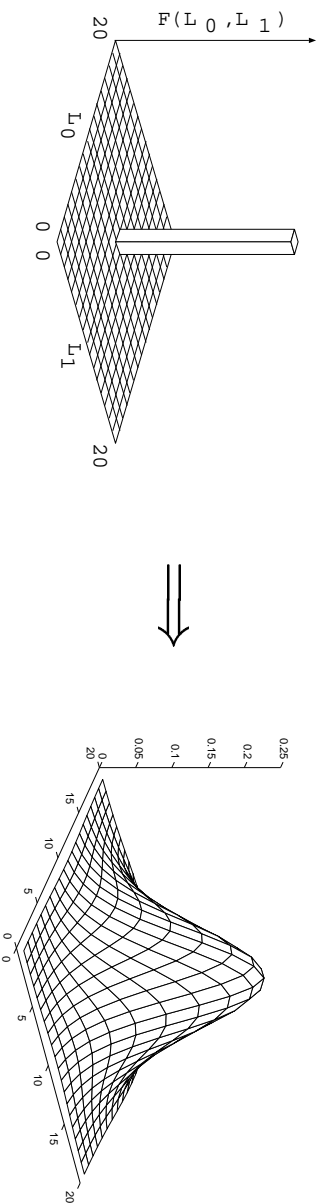


Figure 3: Histogram point is convolved with Gaussian kernel.

# Multiscale Texture Synthesis

To test whether a texture model has captured all the unique characteristics: use the model to synthesise textures so as to compare the visual similarity between the synthetic and the original textures.

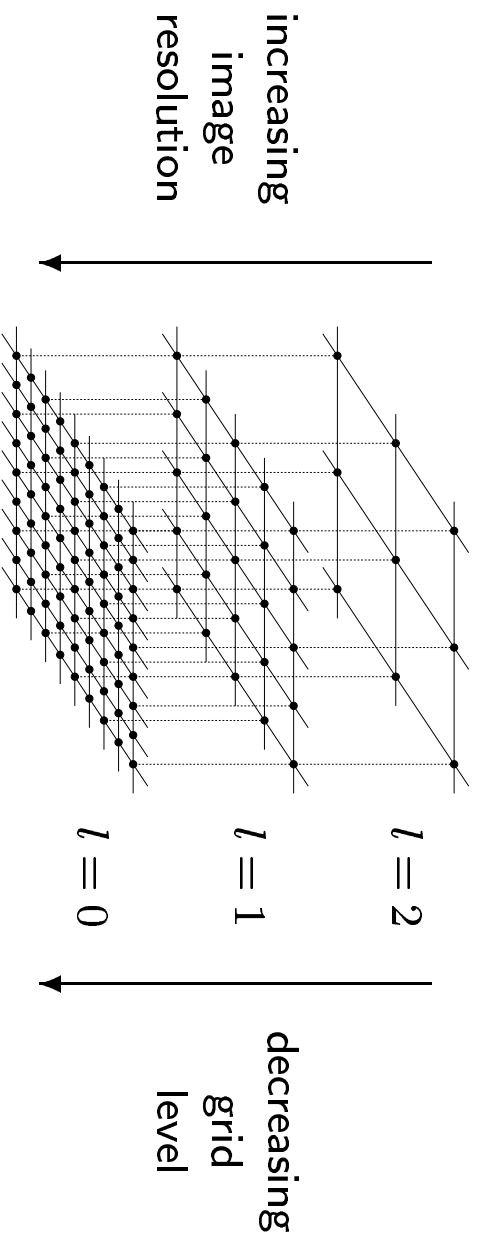


Figure 4: Grid organisation for multiscale modelling of a MRF.

The multiscale synthesis algorithm starts from the top and works its way down performing the following at each resolution:

- Estimation of the LCPDF from original texture at same resolution.
- Applies stochastic relaxation (SR) (*i.e.*, ICM or Gibbs sampler).
- While constraining the SR with respect to the above image.

# Pixel Temperature

The pixel temperature helps constrain the SR process while implementing local annealing.

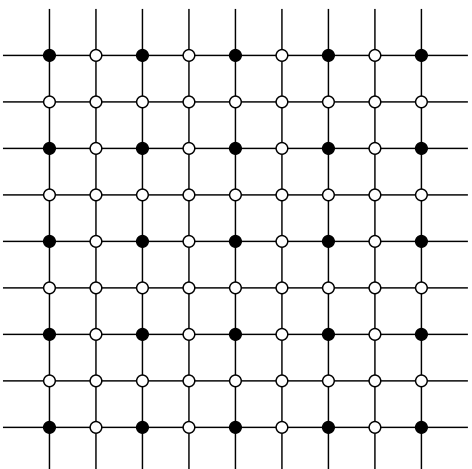


Figure 5: The sites “●” are from the above level.

**Step 1** Initialise pixel temperature  $t_s$ ,

$$t_s = \begin{cases} 1 & \text{if sites} = \circ \Rightarrow \text{low confidence} \\ 0 & \text{if sites} = \bullet \Rightarrow \text{high confidence} \end{cases}$$

**Step 2** Modify the estimate of the LCPDF to be more dependent on pixels with low temperature (*i.e.*, high confidence).

**Step 3** After a pixel has been relaxed  $\Rightarrow$  decrease pixel temperature (*i.e.*, increase confidence).

# Synthetic Textures

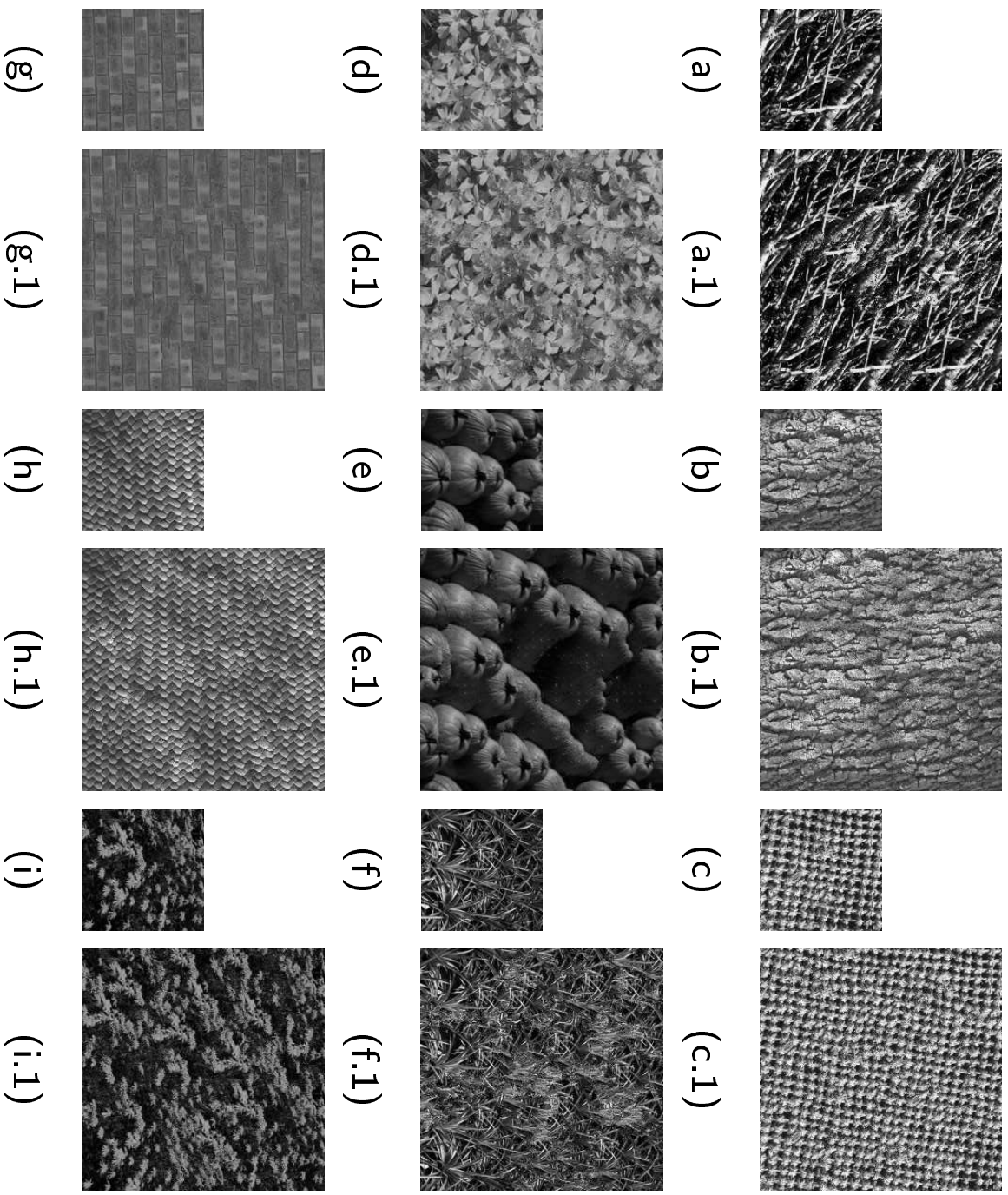


Figure 6: VisTex textures: (a) Bark.0003; (b) Bark.0009; (c) Fabric.0010; (d) Flowers.0003; (e) Food.0010; (f) Leaves.0016; (g) Brick.0000; (h) Fabric.0002; (i) Flower-s.0000; (? .1) Textures were synthesised from a nonparametric MRF model with a  $7 \times 7$  neighbourhood.

# Strong Nonparametric MRF

Estimation of strong nonparametric LCPDF.

**Step 1** Choose a neighbourhood  $\mathcal{N}_s$ .

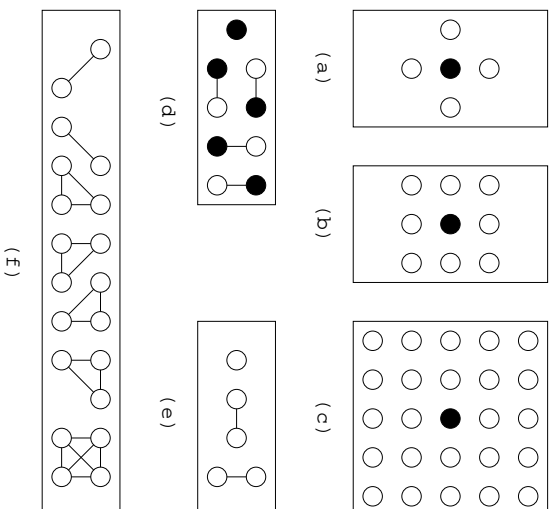


Figure 7: Neighbourhoods and their cliques.

**Step 2** Choose a set of major cliques  $\{C \subset \mathcal{N}_s\}$ , cliques that are not subsets of other cliques.

**Step 3** For each major clique, estimate the marginal distribution  $\text{LCPDF}_C$ .

**Step 4** The simple estimate of the strong LCPDF is,

$$\text{LCPDF} = \prod_{C \subset \mathcal{N}_s, C \not\subset C' \subset \mathcal{N}_s} \text{LCPDF}_C.$$

# Synthetic Textures for Strong MRF

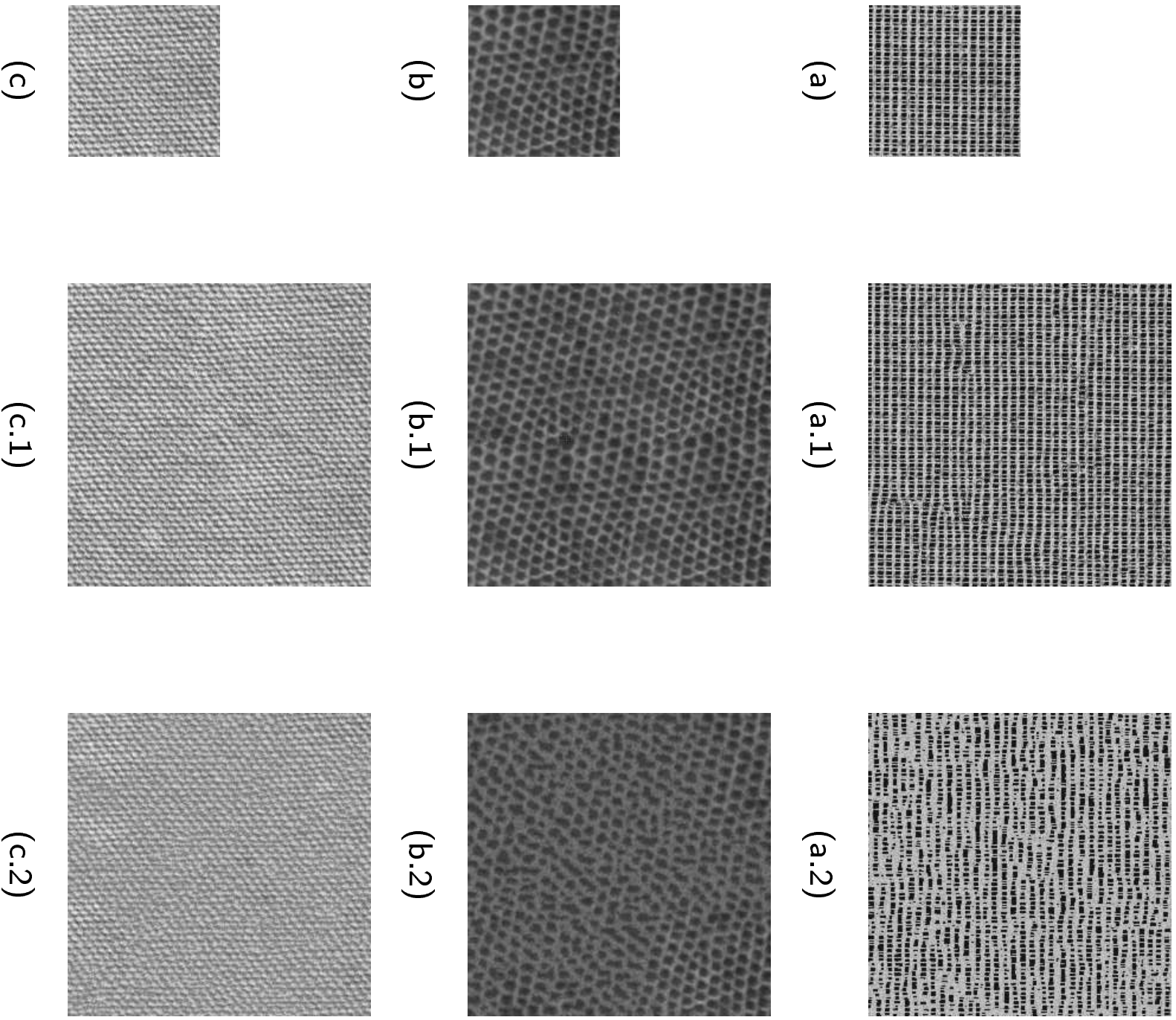


Figure 8: Brodatz textures: (a) D21 - French canvas; (b) D22 - Reptile skin; (c) D77 - Cotton canvas; (? .1) textures synthesised with MRF Model; (? .2) textures synthesised with Strong MRF Model.

## Probability Measurement

1. Get an **unbiased** set of local probabilities from sample texture  $y$ :  $\{LPDF_s\}$
2. Get a set of local probabilities from a segment window in image  $x$ :  $\{LPDF_r\}$
3. Make comparison between the two sets via the Wilcoxon test.

## Edges

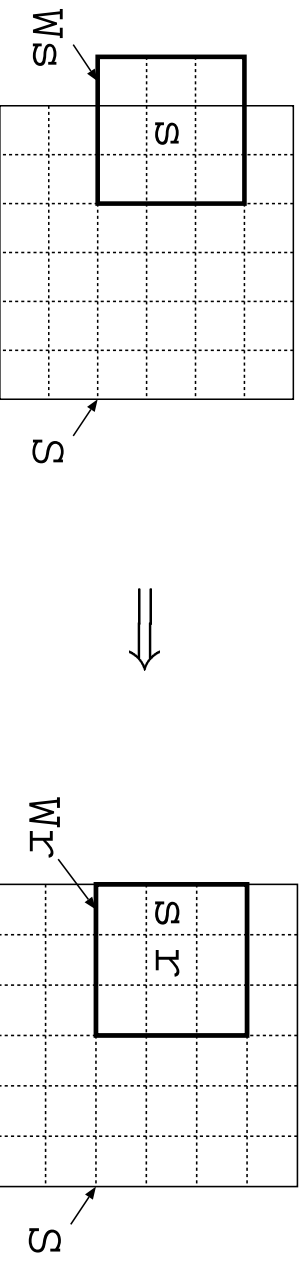


Figure 9: Move the window position for an edge pixel

## Boundaries

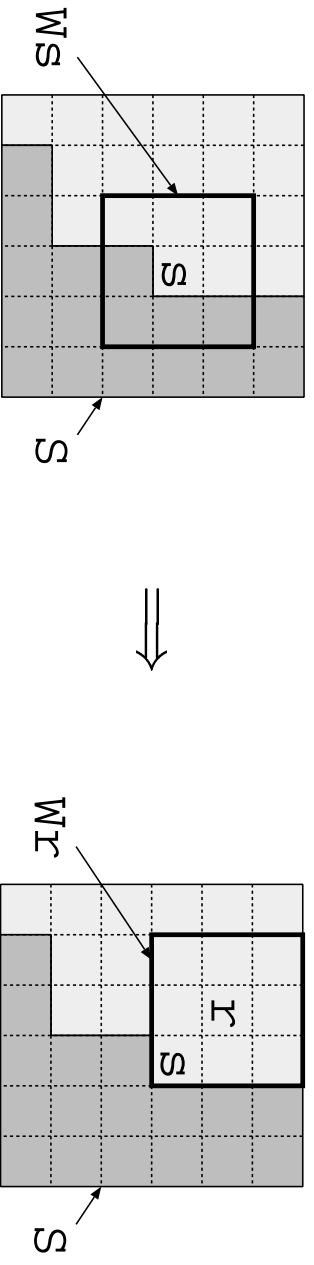


Figure 10: Move the window position for a boundary pixel

# Segmented and Classified Textures

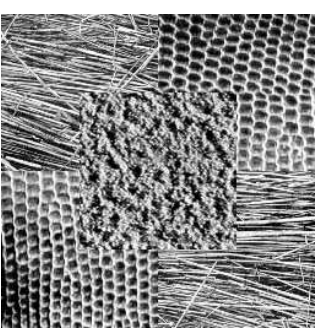
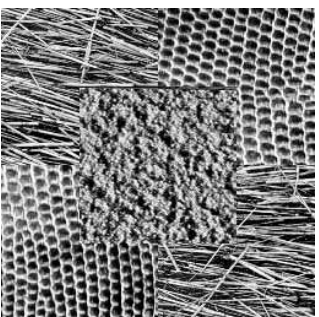
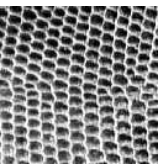


Fig. 1

Fig. 2



(a)

Fig. 1(a)

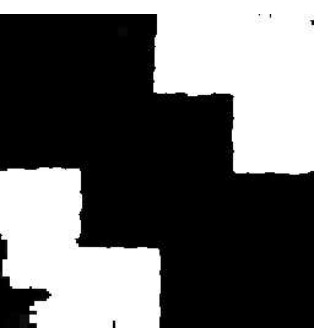


Fig. 2(a)

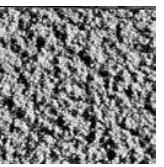


(b)

Fig. 1(b)



Fig. 2(b)



(c)

Fig. 1(c)



Fig. 2(c)

Probability scale

0



1

# Practical Application

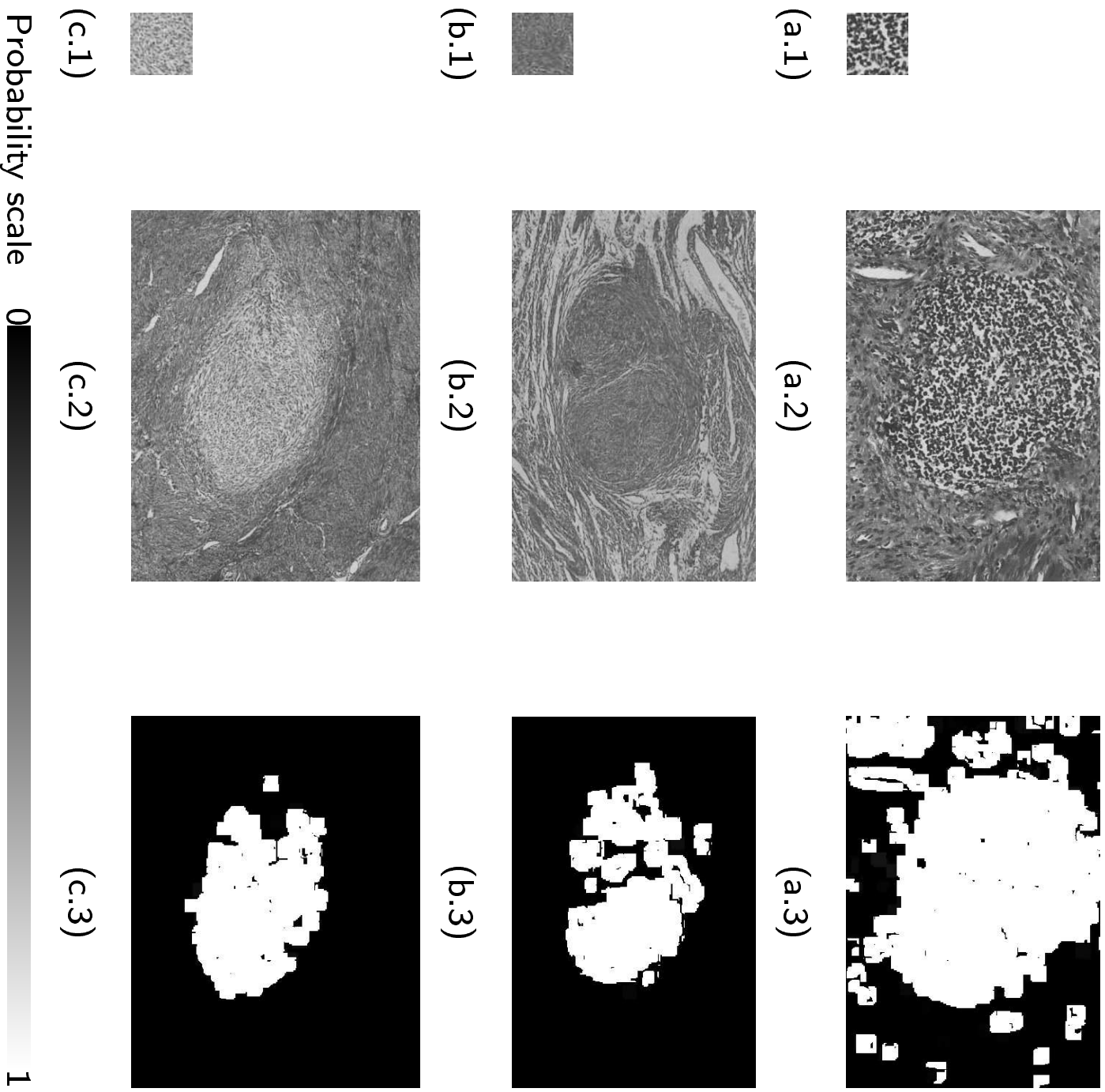


Figure 11: Probability maps of medical images: (a) lymphoid follicle in the cervix; (b) small myoma; (c) focus of stromal differentiation in the myometrium.

# Practical Application

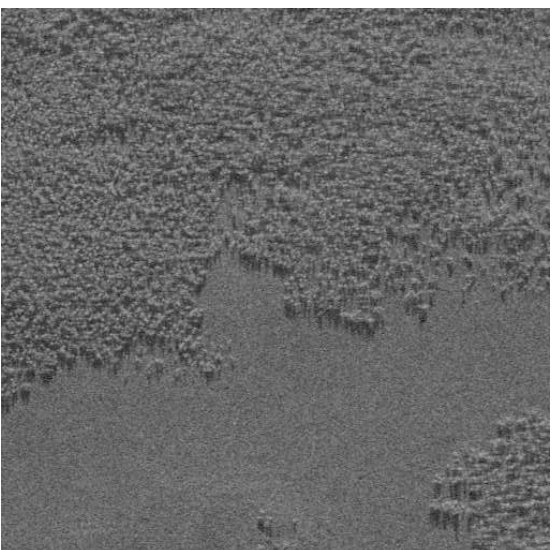
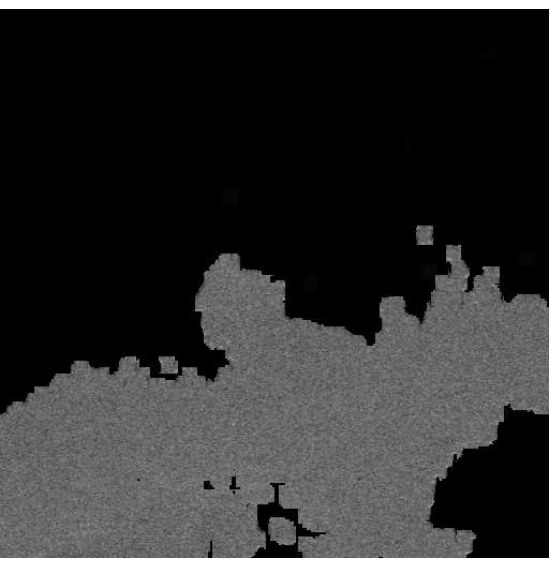
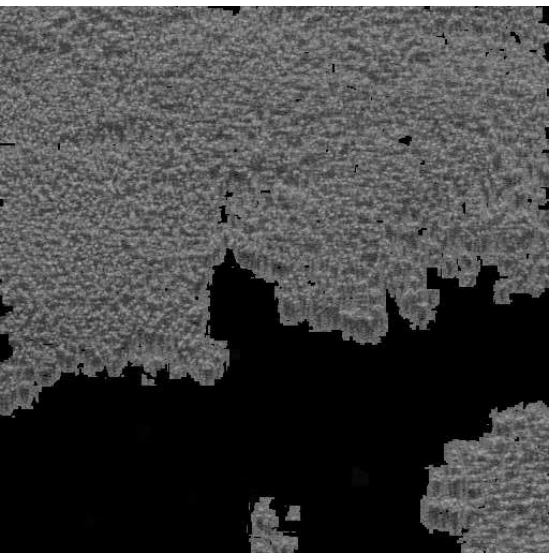


Figure 12: Airborne SAR image of Cultana.



Probability scale 0  1

Figure 13: Probability maps of the trees and grass superimposed on to Cultana image.