Centre for Sensor Signal & Information Processing
Dept. Electrical & Computer Engineering
The University of Queensland, QLD 4072.

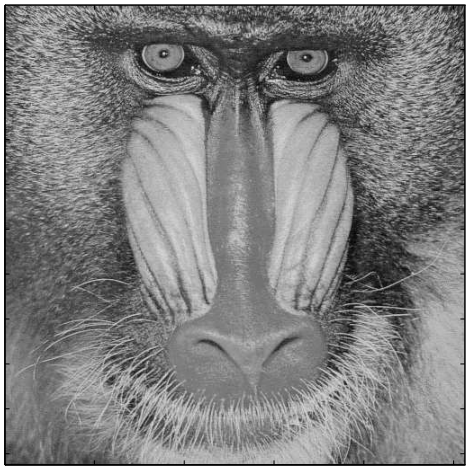
TEXTURE CLASSIFICATION USING A NONPARAMETRIC MARKOV RANDOM FIELD

Authors: R. Paget, I. D. Longstaff, and B. Lovell

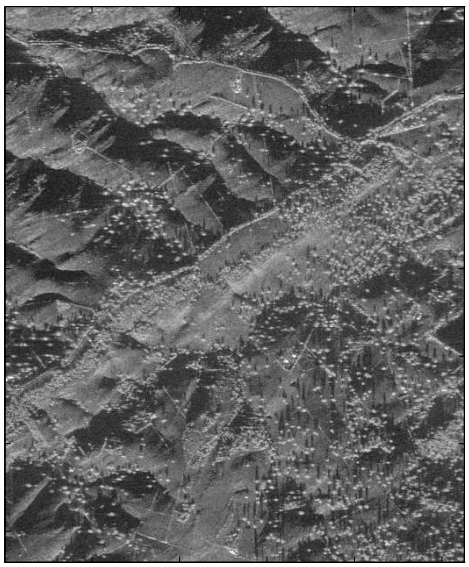
The authors are with the Department of Electrical and Computer Engineering, University of Queensland, QLD 4072 AUSTRALIA.
E-mail: {paget,idl,lovell}@elec.uq.edu.au

This work was supported by the Cooperative Research Centre for Sensor, Signal, and Information Processing.

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.

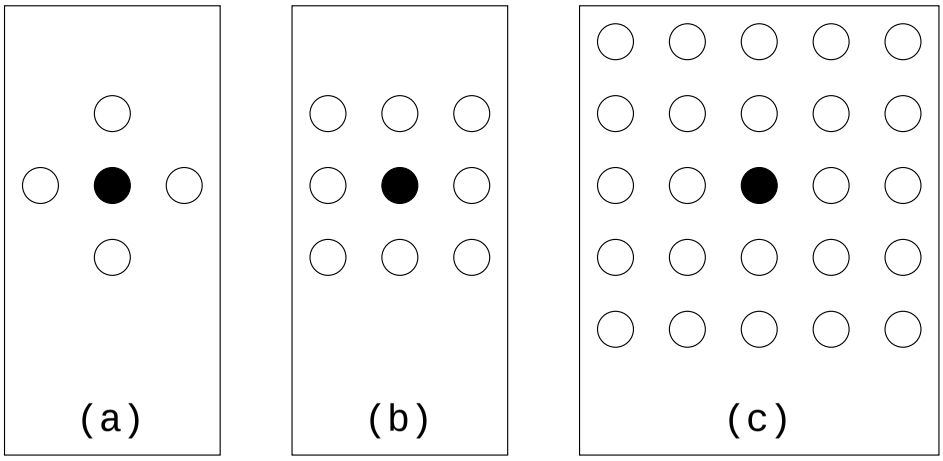


Figure 1: Neighbourhoods. (a) The first order or "nearest-neighbour" neighbourhood; (b) second order neighbourhood; (c) eighth order neighbourhood.

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:

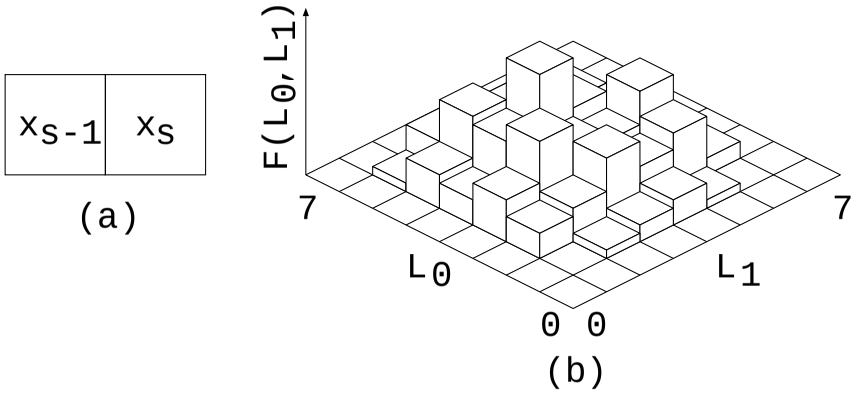


Figure 2: Neighbourhood and its 2-D histogram.

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

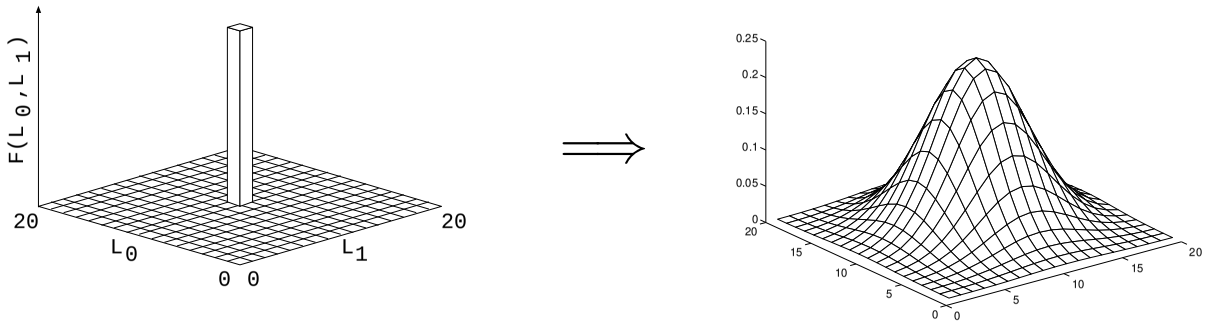


Figure 3: Histogram point is convolved with Gaussian kernel.

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.

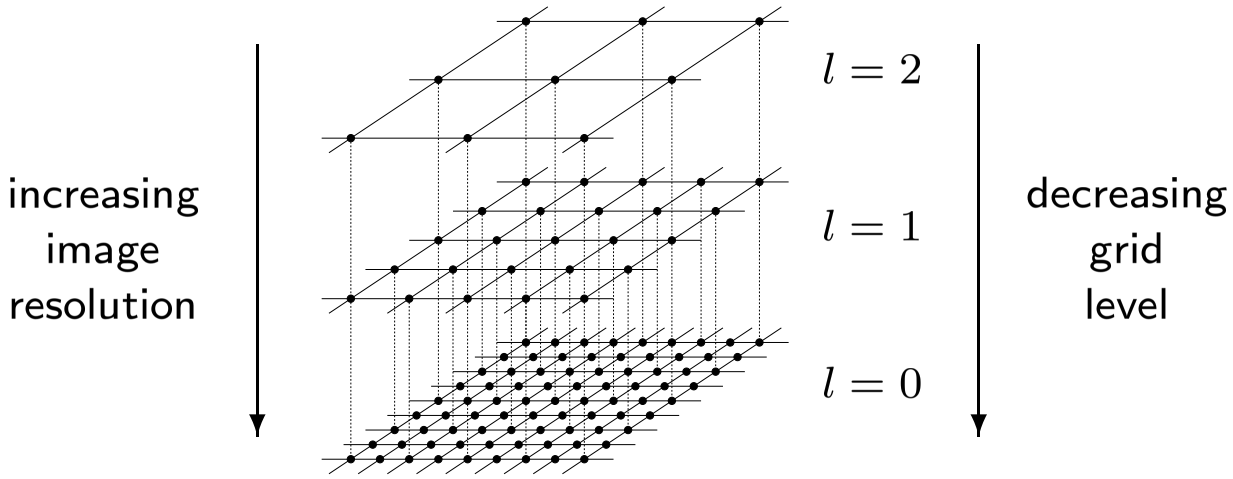


Figure 4: Grid organisation for multiscale modelling of a MRF.

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.

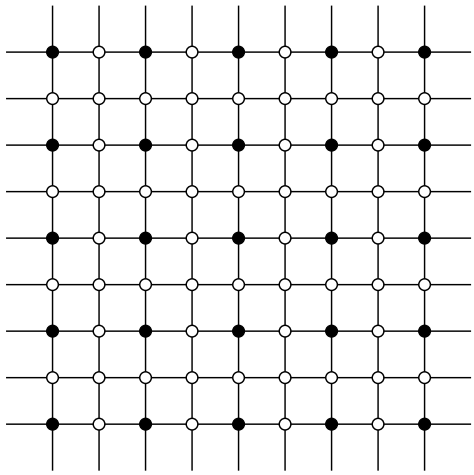


Figure 5: The sites "•" are from the above level.

Step 1 Initialise pixel temperature t_s,

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

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

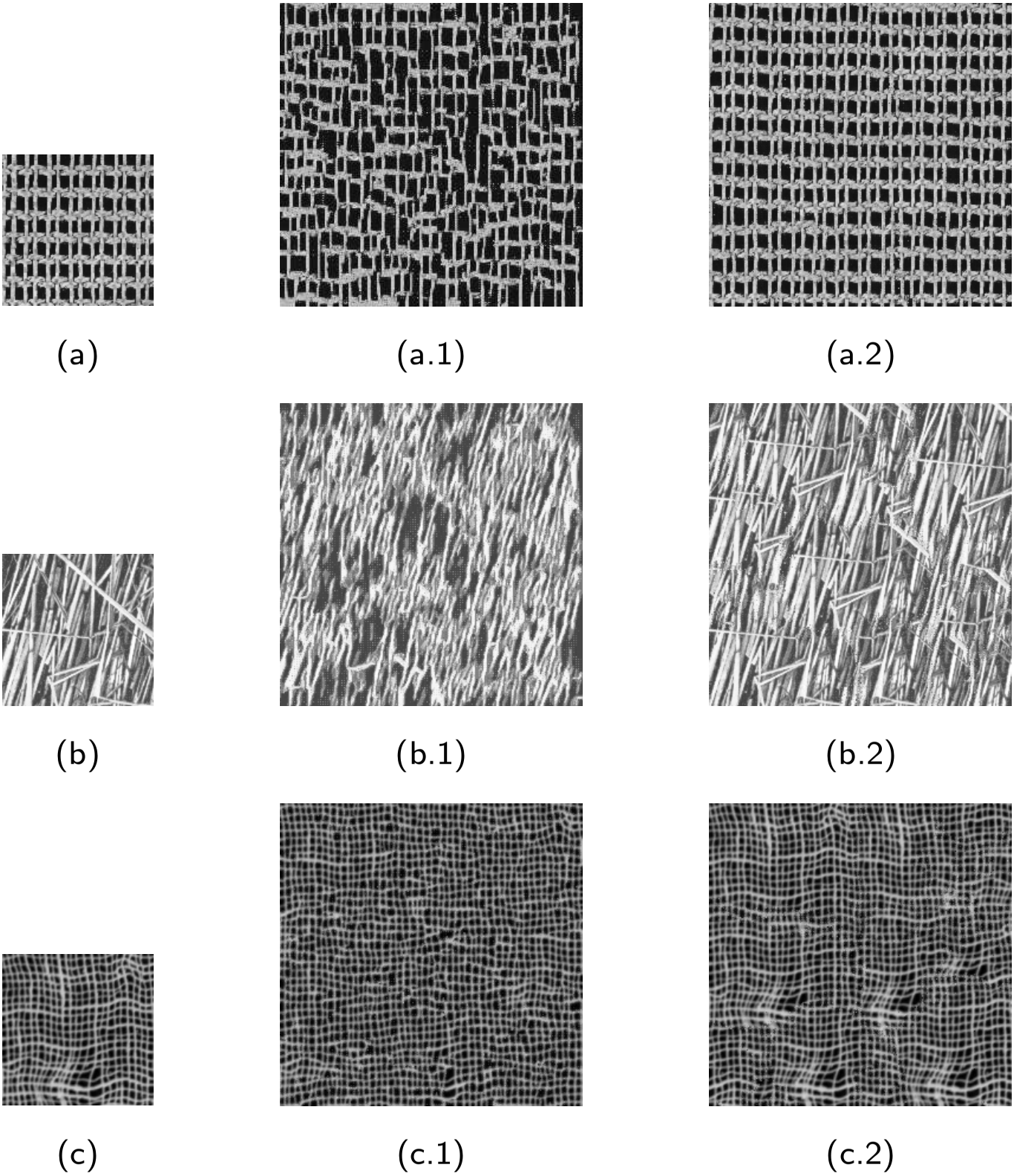


Figure 6: Brodatz textures: (a) D20 - magnified French canvas; (b) D15 - straw; (c) D103 - loose burlap; (?.1) textures synthesised with small neighbourhood; (?.2) textures synthesised with large neighbourhood.

Classification

Probability Measurement

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

Edges

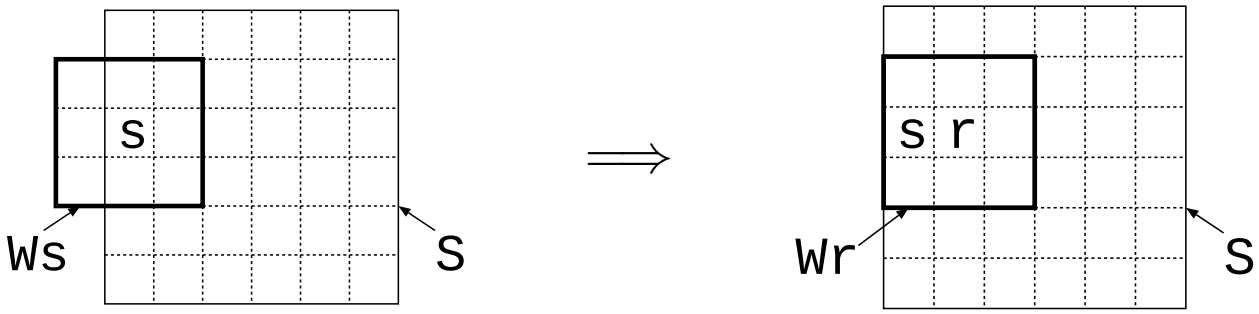


Figure 7: Move the window position for an edge pixel

Boundaries

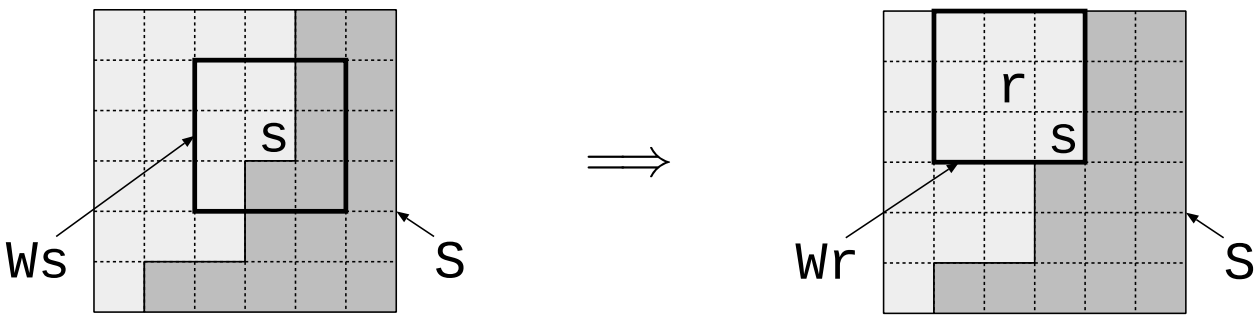


Figure 8: Move the window position for a boundary pixel

Segmented and Classified Textures

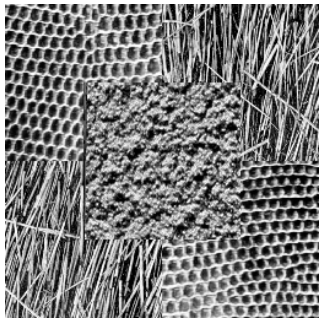


Fig. 1

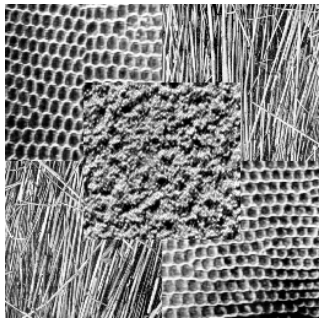
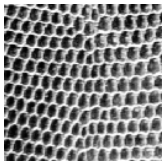


Fig. 2



(a)

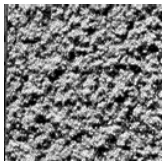
Fig. 1(a)

Fig. 2(a)

(b)

Fig. 1(b)

Fig. 2(b)



(c)

Fig. 1(c)

Fig. 2(c)

Probability scale 0 1

Practical Application

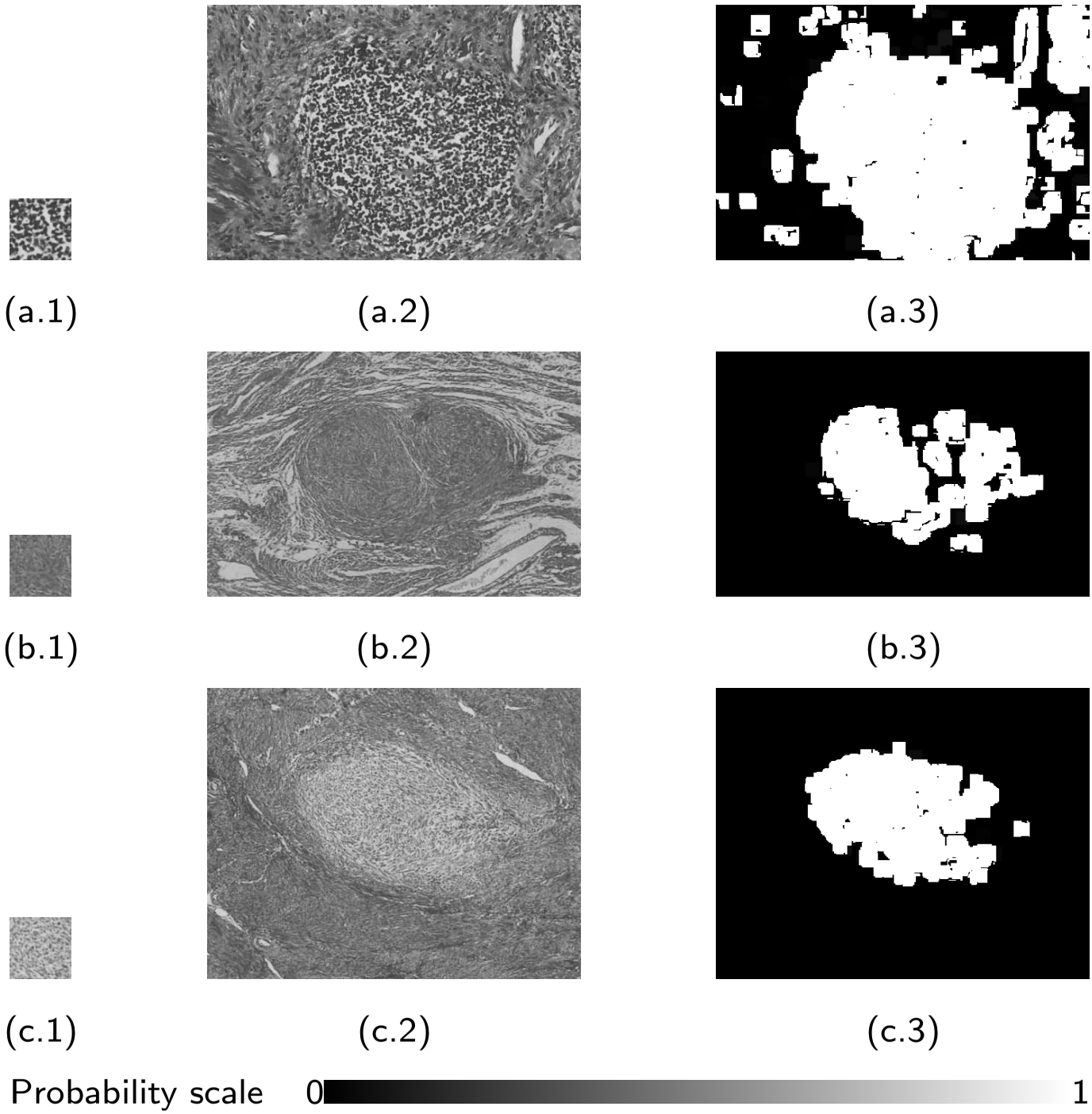


Figure 9: Probability maps of medical images: (a) lymphoid follicle in the cervix; (b) small myoma; (c) focus of stromal differentiation in the myometrium.