CHAPTER 4

EXTRACTION OF MODEL PARAMETERS AND CODING

This chapter introduces the centipede model. Extraction and coding of the model parameters are investigated. Compression results are also shown at the end of the chapter.

4.1 Introduction to the Centipede Model

There are many ways to describe the intensity variations of pixels in an image. In edge-based image coding, previous studies has modeled the intensity variations along edge normal (edge profile) with Gaussian edge model such as

$$Edge(x;V_e,\Delta V,\sigma_b,d)=V_e+\frac{\Delta V}{2}erf\left(\frac{x-d}{\sigma_b}\right) \tag{4.1}$$

where V_e is the mean, ΔV is the contrast, and σ_b is the blur parameter of the Gaussian. Such an edge profile model suffers from the following problems :

1) (4.1) does not work well for a non symmetric edge,

2) Edge profiles cannot be modeled by a Gaussian-like function due to the interactions of near edges in scale space ([21,33,38]).

When deciding on a description, it must be proved at least experimentally that the model represents the original image enough to reproduce within a small error distance. We present a model which gives a powerful description of the image. The centipede model is given by a tuple (I_L,C_L,C_R,W_L,W_R) with the edge map where I_L represents the intensity on the edge, C_L (C_R) represents left (right) contrast along the normal direction of the contour, and W_L (W_R) represents left (right) width. Width is defined as the distance at which difference in consecutive pixel is lower than a given threshold. Threshold is determined from the SNR_{dB} ratio for an image. Width is proportional to edge scale.

The image with the edge profile is obtained by minimizing the hybrid energy model. For 1D case, the model covers a vast range of edge profiles. Hybrid energy functional in 1D is given in (4.2).

$$E(f;\lambda,\tau)=\int[\beta(x)(f(x)-d(x))^2+\lambda(\tau f_x^2+(1-\tau)f_{xx}^2)]dx \tag{4.2}$$

Minimization of the energy functional is obtained by first discretization

$$E(f;\lambda,\tau)=\sum_{i\in I}\beta_i\,(f_i-d_i)^2+\lambda\,\tau\,(f_i-f_{i-1})^2+\lambda\,(1-\tau)(f_{i+1}+f_{i-1}-2f_i)^2 \tag{4.3}$$

followed by applying Successive Over Relaxation (SOR) [35] yields an iteration

$$f_i^{(n+1)}=f_i^{(n)}-\frac{w}{T}\frac{\partial E_i(f)}{\partial f_i} \tag{4.4}$$

$$\frac{1}{2}\frac{\partial E_i(f)}{\partial f_i} = -\beta_i d_i + (\beta_i + 2\lambda(3-2\tau)) f_i^{(n)} - \lambda(4-3\tau)(f_{i-1}^{(n+1)} + f_{i+1}^{(n)}) + \lambda(1-\tau)(f_{i-2}^{(n+1)} + f_{i+2}^{(n)}) \quad (4.5)$$

The curve denoted by C_{org} in Figure 4.1 represents a nonsymmetric edge profile. The curve $C_{centipede}$ is obtained by the centipede model (I_L=0,C_L=100,C_R=150,W_L=75,W_R=82). The reconstructed edge profile is denoted by C_{cons} and obtained by solving the iteration (4.5) with parameters (w=1.0, λ=0.8, τ=0.5, iteration number 2000). Shape of the reconstructed curve is controlled by the pair (λ,τ). λ controls the smoothness of the profile and τ controls the continuity of the profile. This is called λτ–space representation of functions.

We have also tested the model on different type of edge profiles (e.g. step-edge, linear edge), the centipede model performs well for all of them.

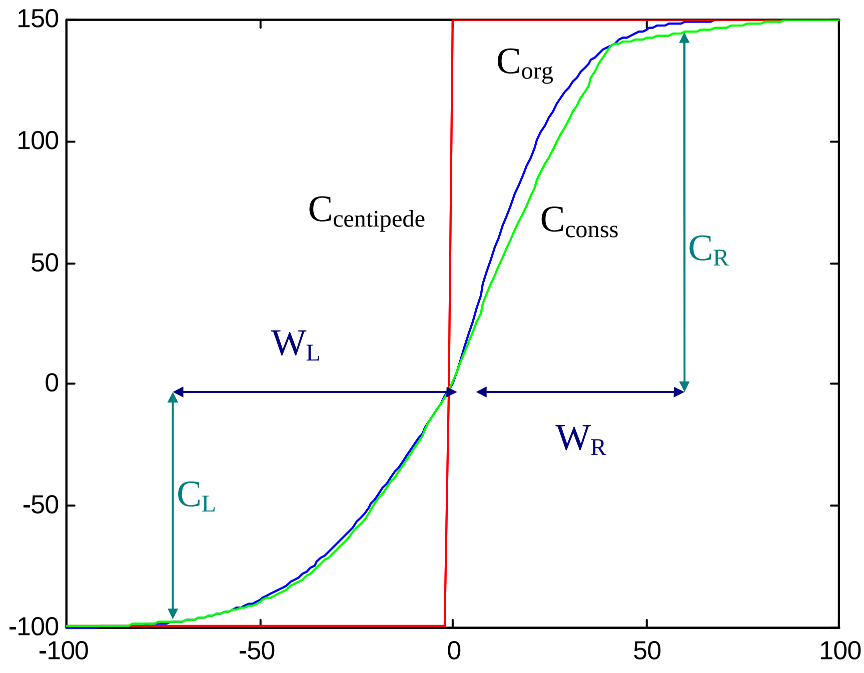

Figure 4.1 A non symmetric edge profile (C_{org}) and the reconstructed edge profile (C_{cons}) with the Centipede model ($C_{centipede}$).

4.2 Extraction of Model Parameters

In the previous section, the centipede model and its properties are explained. Performance of the model is dependent on how the parameters are extracted from given image and edge map obtained by GED. The problem is to extract numerical data for the Centipede Model. The extraction is done through the edge segments and along the normal direction to the contour for each edge element.

Let $P_n(c_i)$ be the edge profile along the direction perpendicular to the edge direction and $P_c(c_i)$ be the edge profile along the edge direction for the edge element $c_i = (x_i^{c_i}, y_i^{c_i})$. Since contours are obtained by following connected edge elements, $P_c(c_i)$ and consequently (I_L) is easily obtained. (C_L,C_R,W_L,W_R) is derived from the edge profile $P_n(c_i)$ captured by intensity along the normal direction at $(x_i^{c_i}, y_i^{c_i})$ (Figure 4.2).

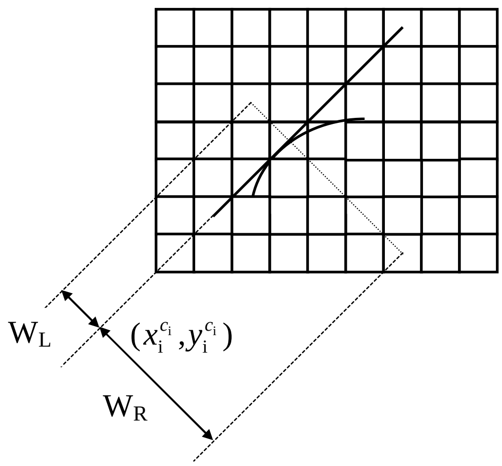

Figure 4.2 Edge profile extraction

Mathematical definitions for model parameters (C_L,C_R,W_L,W_R) are given in (4.6) and (4.7).

$$W_R = \text{Min}\{c_{W_R} \left| \left\| \frac{\partial P_n(n)}{\partial n} \right\|_{c_{W_R}} < T_R \right.\} - c_{\text{i}}$$

$$W_L = \text{Min}\{c_{W_L} \left| \left\| \frac{\partial P_n(n)}{\partial n} \right\|_{c_{W_L}} < T_L \right.\} - c_{\text{i}} \tag{4.6}$$

$$C_R = P_n(c_{W_R}) - P_{\text{c}}(c_{\text{i}}) \tag{4.7}$$

$$C_L = P_n(c_{W_L}) - P_{\text{c}}(c_{\text{i}})$$

where T_L and T_R represents the thresholds. Since difference operators are very sensitive to the noise, the definition of (W_L, W_R) is an ill-conditioned problem. The thresholds are used to make the extraction process robust to the noise. They are determined from the SNR_{dB} ratio for an image. As SNR_{dB} increases, T_L and T_R are lowered to zero.

Original house image and edge map obtained by GED with parameters (λ=2.0, τ=0.5) are given in Figure 4.3 (a)-(b). Extracted centipede model images are given in Figure 4.3 (c)-(d) for T_L =8 and T_R =12. These parameters are experimentally chosen. In Figure 4.3 (e), some of the lines whose length is left and right widths (W_L, W_R) normal to the edge direction are drawn. The centipede model being overlaid on the original image is shown in Figure 4.3 (e). Also, Figure 4.3 (e) explains why the model is called "centipede". Results for two different types of images (brain and Lenna) are given in Figure (4.4) and (4.5).

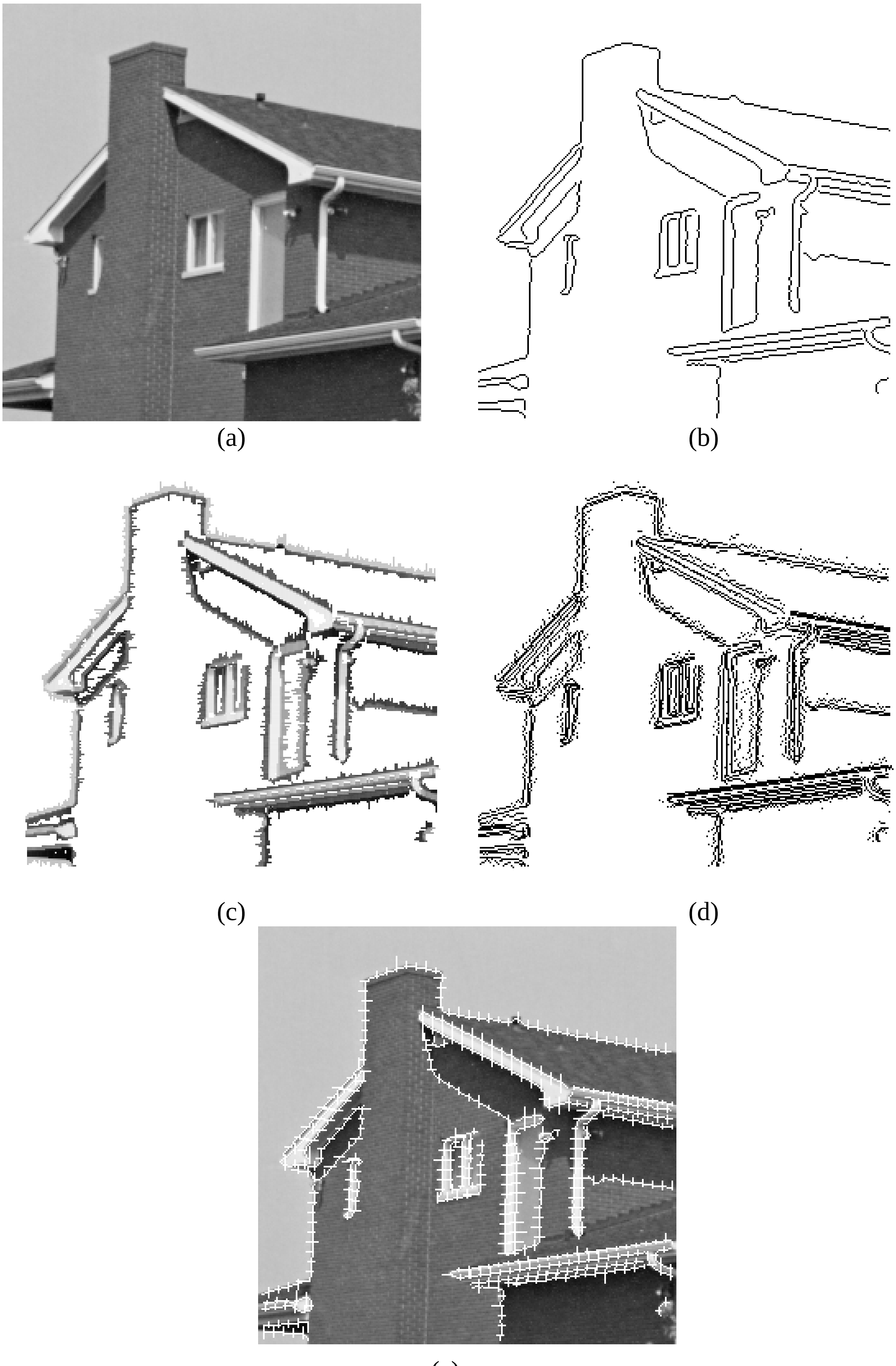

Figure 4.3 Extracted Centipede Model For House Image

(a) Original House Image
(b) Edges detected by GED for (λ=2.0,τ=0.5,Case II)
(c) Intensities at (d)
(d) Edge and Width Map
(e) The centipede model overlied on the original House image

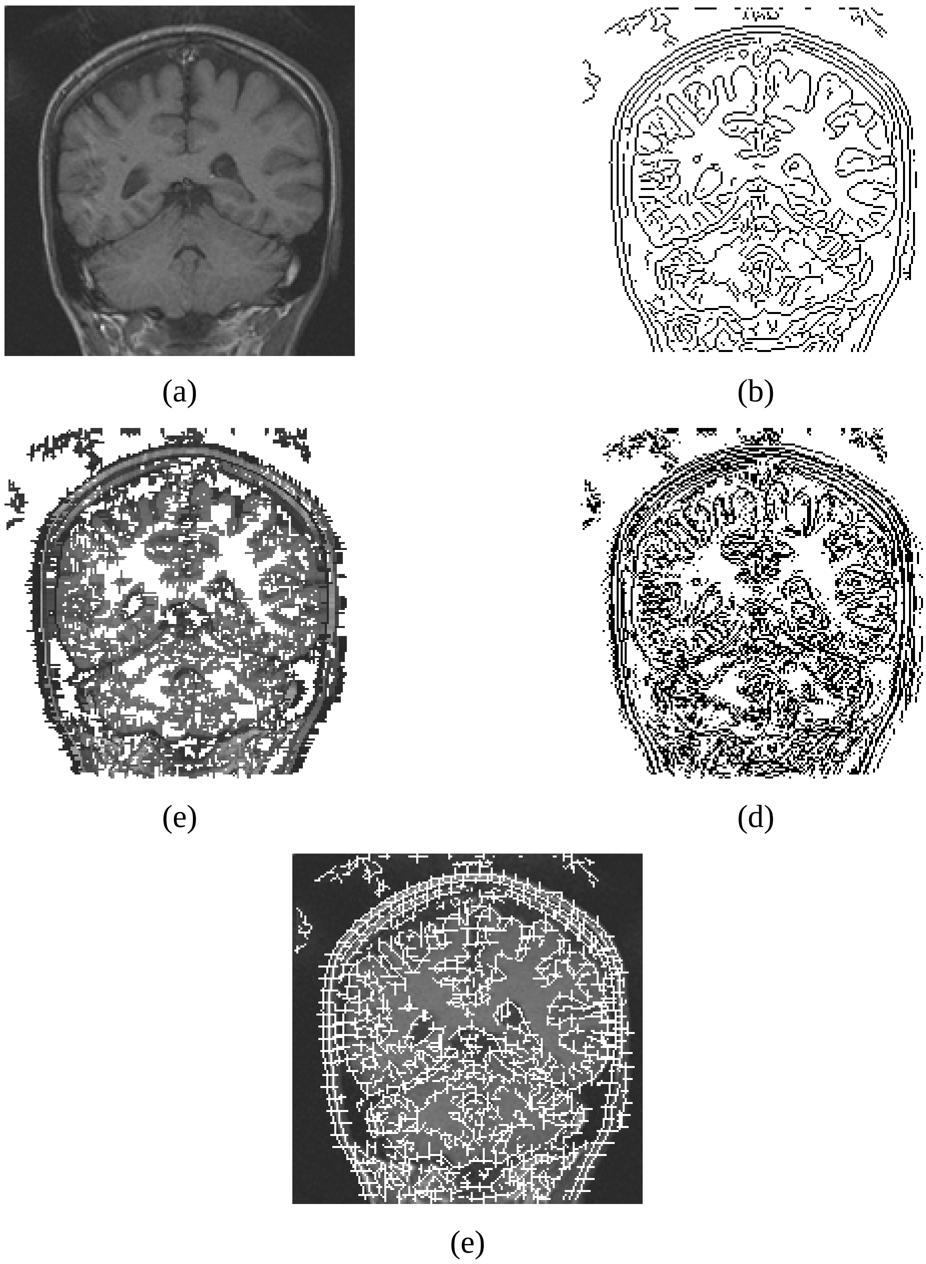

Figure 4.4 Extracted Centipede Model For Brain Image

(a) Original Brain Image
(b) Edges detected by GED for (λ=0.5,τ=0.5,Case II)
(c) Intensities at (d)
(d) Edge and Width Map
(e) The centipede model overlied on the original Brain image

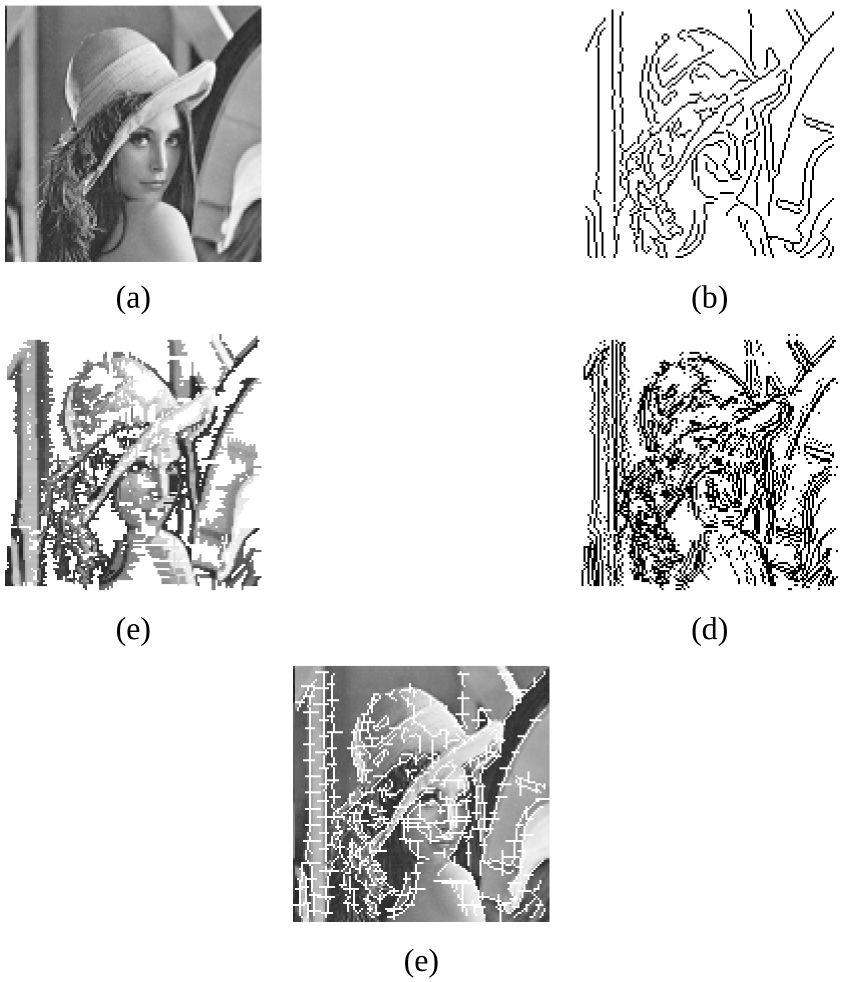

Figure 4.5 Extracted Centipede Model For lenna Image

(a) Original Lenna Image
(b) Edges detected by GED for (λ=0.5,τ=0.5,Case II)
(c) Intensities at (d)
(d) Edge and Width Map
(e) The centipede model overlied on the original Lenna image