Ear Biometrics System

Why Ear Biometrics?

- Ears are rich in features
- **Stability:** Medical study[1] has shown that in ear variation over time is most noticeable during
  - the period from 4 months to 8 years old and
  - over 70 years old
- Features which makes ear biometrics a good choice
  - Uniqueness
  - Expression invariant (unlike face)
  - Ear's smaller size
  - Uniform color
- Passive Biometrics – does not need much user cooperation

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1. *A. Iannarelli, **Ear Identification**, Paramont Publishing, 1989*

Ear Recognition System

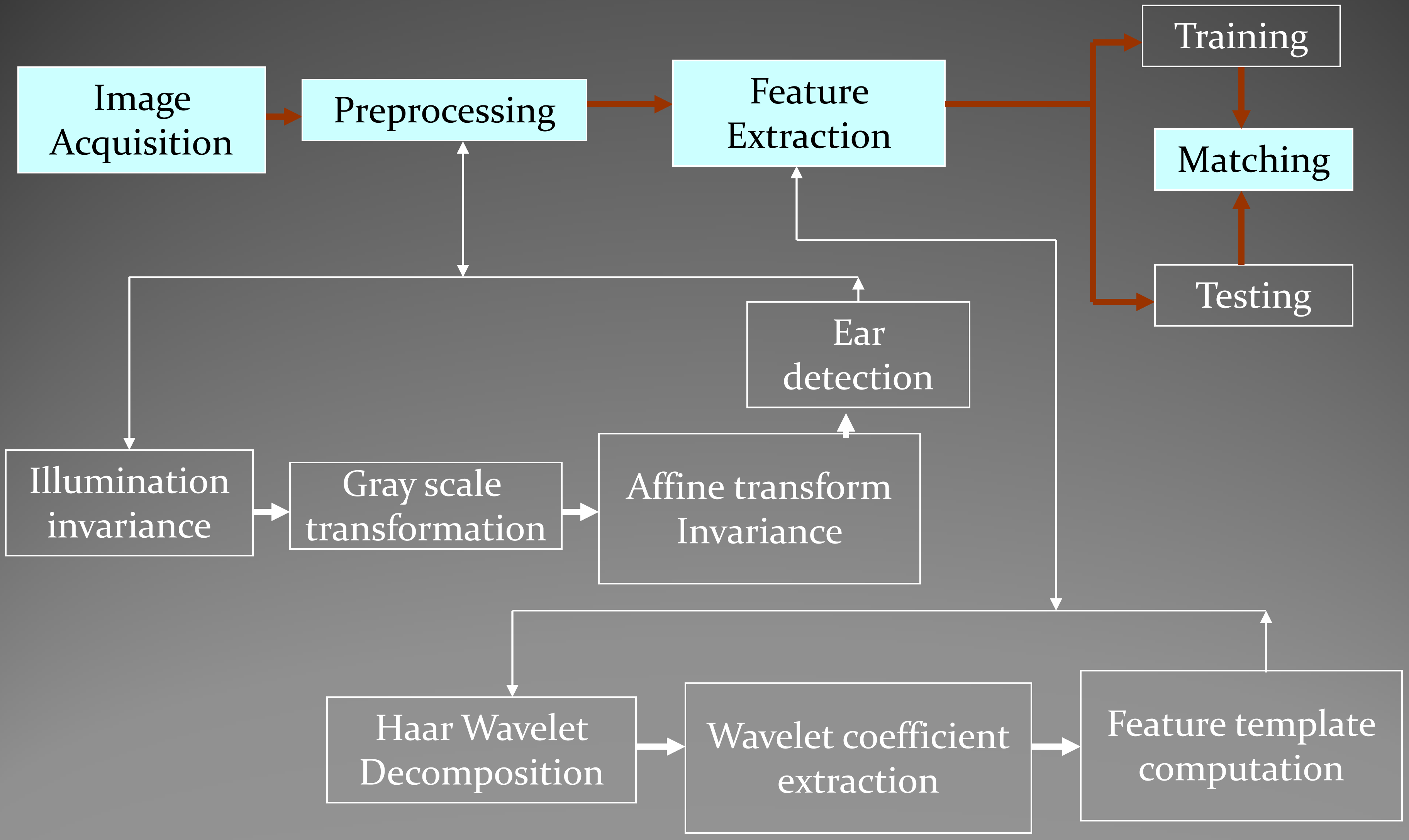


Image Acquisition

- The CCD camera is placed on a motorized stand.
- Halogen Light focused on the ear.
- Image captured on CCD camera.

Issues on Image Acquisition

- **Rotation *along Vertical Axis***
  Image may be tilted in vertical direction.

- Caution must be taken to place the head parallel to focal plane.

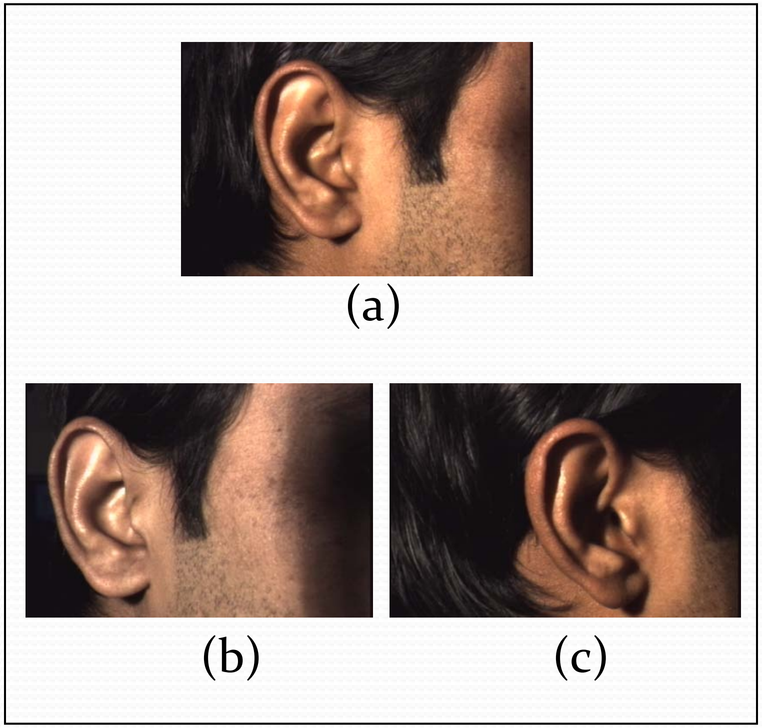


Fig. (a) image in right alignment

(b) (c) titled image

Contd....

- **Rotation *along Horizontal Axis***
- Image may be rotated along the horizontal axis of the image plane.
- This will be handled automatically.

(a)

(b)

Fig. (a) image with no rotation; (b) Rotated image.

Contd….

- **Image Occlusion:**
- Image may be occluded by hair.
- Hair should be removed from ear before acquisition or
- Occlusion should be removed automatically in preprocessing

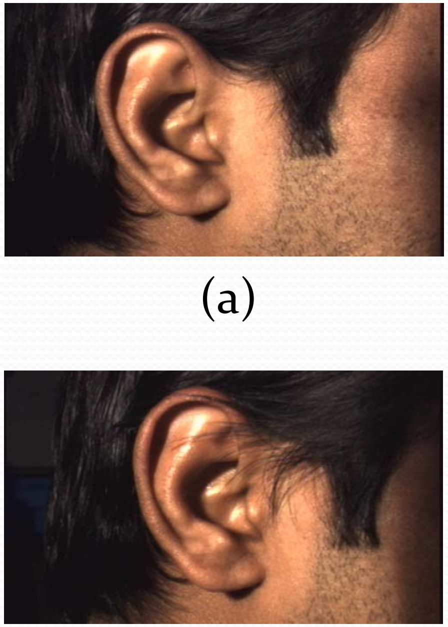


Fig. (a) Clear Image; (b) Occluded image.

Handling of Rotation and Occlusion

- At the time of image acquisition
  - Image should not be tilted in any direction.
  - Hair should be removed from ear of the person.

Preprocessing

Noise Removal using Median Filter

- Here we are using Median filter.
- The idea of Median filtering is simply to replace each pixel value in an image with the median value of its neighbors.
- The median is calculated by first sorting all the neighbourhood pixel values into numerical order and then replacing the pixel with the middle pixel value.

Preprocessing

Illumination invariance

- RGB channel are adjusted to make the image illumination smoothened all over the ear.
- If *I(R,G,B)* be the detected RGB ear image then adjusted image I' (r, g, b) be as

$$I(R, :, :) \rightarrow I'(r, :, :)$$

$$I(:, G, :) \rightarrow I'(:, g, :)$$

$$I(:, :, B) \rightarrow I'(:, :, b)$$

Preprocessing

Illumination Invariance ....*contd*

- Then make the contrast of the image smoothened over the image.
- Here mean (M) & variance (V) of illumination of the image are utilised to normalise the image.

$$N(i,j) = \begin{cases} M_0 + \sqrt{\frac{V_0(I(i,j)-M)^2}{V}} & \text{if } I(i,j) > M, \\ M_0 - \sqrt{\frac{V_0(I(i,j)-M)^2}{V}} & \text{otherwise,} \end{cases}$$

where, M and V are the estimated mean and variance of *I(i, j)*, respectively, and M_0 and V_0 are the desired mean and variance values, respectively.

Preprocessing

Gray Scale Transformation

- Monochrome luminance is calculated by combining the RGB values according to the NTSC standard, which applies coefficients related to the eye's sensitivity to RGB colors.
- Gray scale image (I gray) is obtained from RGB image (I rgb) using the following equation.

$$I\,gray = 0.2989 * I\,rgb\,(:,:,R) + 0.5870 * I\,rgb\,(:,:,G) + 0.1140 * I\,rgb\,(:,:,B)$$

- I gray is an intensity image with integer values ranging from a 0 - 255

Preprocessing

Affine Transformation Invariant

- The image may come in different size.
- Image may be rotated in any direction.
  - These should be handled as a way that after transformation of the image it preserves well all its information.
  - It becomes scale and rotational invariant.

Scale Invariance

- The image which is given as input to the system is resized into constant size.
- Scale normalization is the important step for feature extraction that would give same size feature template.

$$I\left(x', y'\right) \xrightarrow{\textit{resizing}} I\left(x, y\right)$$

$$I\left(x'', y''\right) \xrightarrow{\textit{resizing}} I\left(x, y\right)$$

Rotational Invariance

- Here the feature extraction technique is very sensitive on orientation of the image.
- All the images should be rotated to a unique direction
- Taking moment of inertia of the image about centroid axis all images of same person are oriented in that direction.

Ear Detection

- **Template Matching:**
  - Ear detection is implemented using template matching technique.
- **Template Creation:**
  - A set of images are manually cropped to get the different sizes of ear images and are decomposed into level 2 using Haar wavelet.
  - These decomposed images are trained as templates

Contd..

Detection using Template

- Input raw image is also decomposed into level 2 using same technique.
- Each template is retrieved from the trained set and matched with the same sized overlapping block of the decomposed input image.
- Thus for each trained template the best matched block in input image is traced.
- Among them the best matched block is chosen and the corresponding region from the original image is extracted

Contd..

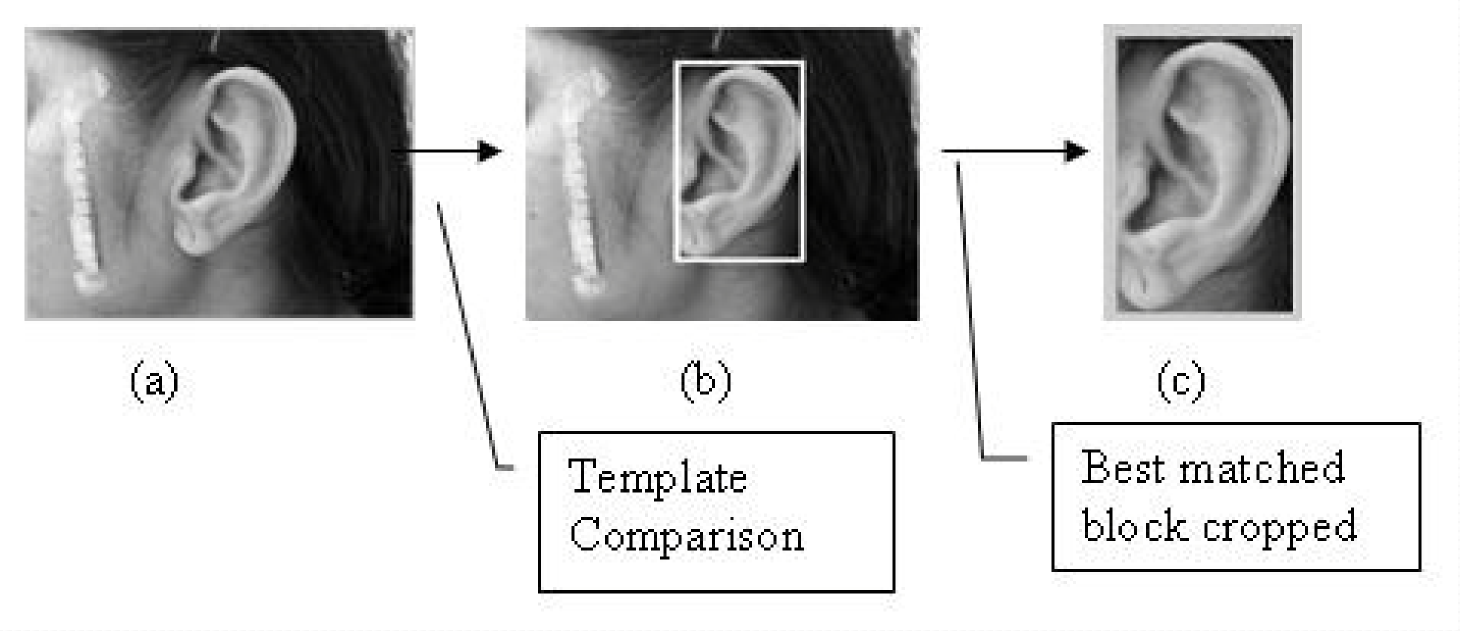


Fig (a) Raw image, (c) Cropped image

Feature Extraction

- Detected preprocessed gray scale image is given to the feature extraction module.

- Feature Extraction using Haar wavelet:

  - This module based on Haar wavelet transformation.
  - Extracted wavelet coefficients are the feature of ear.
  - Coefficient matrix is represented as binary matrix.

Matching

- In the training session database have to be created and trained binary template are stored in that database using unique index .
- Testing binary template (S) matched with the query template (T) of the database using Hamming distance.

Matching (using Hamming Distance)

$$HD = \frac{1}{n \times m} \sum_{\substack{i=1 \\ j=1}}^{\substack{n \\ m}} T_{i,j} \otimes S_{i,j}$$

- The T and S are XOR-ed element wise to calculate the matching bits between them.
- The computed HD is the matching score between training and testing template.

Thank you

Wavelets

- Wavelets belong to the same family of Fourier analysis.
- Wavelets can keep track of time and frequency information. They can be used to “zoom in” on the short bursts, or to “zoom out” to detect long, slow oscillations.
- High-frequency noise are eliminated and not distribute the rest of the signal.

Haar Wavelets

- Wavelet functions
  - Scaling function Φ (father wavelet)
  - Wavelet Ψ (mother wavelet)
  - These two functions generate a family of functions that can be used to break up or reconstruct a signal
- The Haar Scaling Function
  - Translation
  - Dilation
- Disadvantages

  Discontinuous and does not approximate continuous signals very well.

Approximation by Haar Wavelet

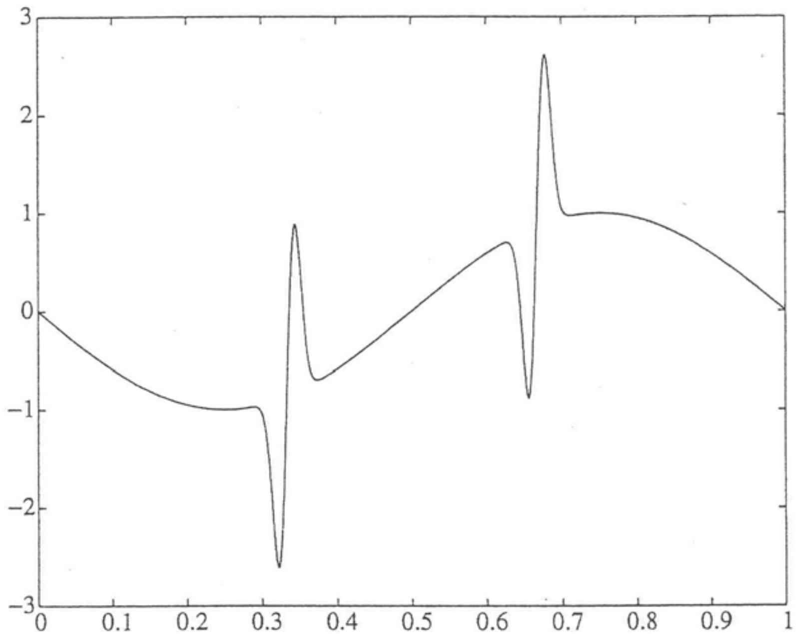


Figure 2 Voltage from a faulty meter

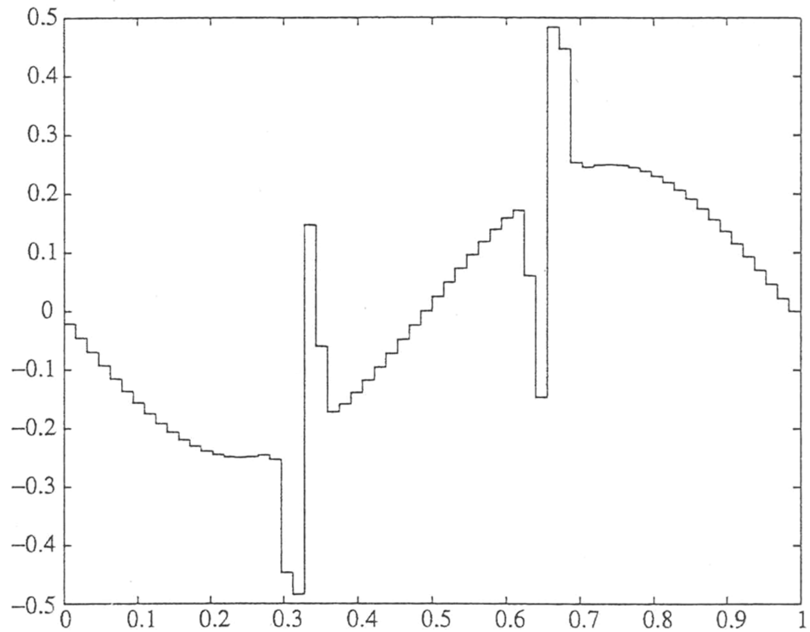
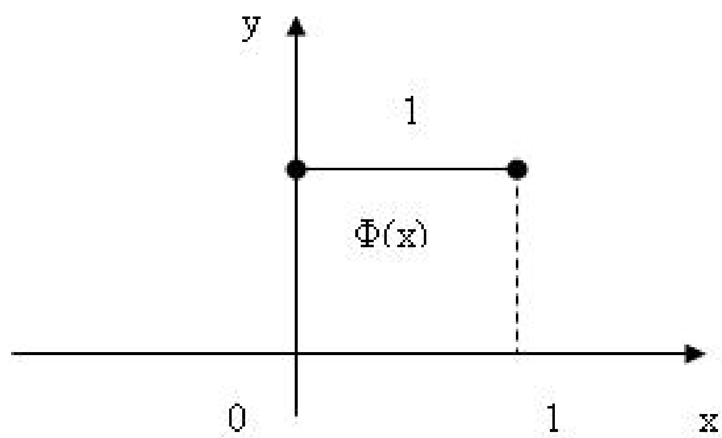


Figure 3 Approximation of voltage signal by Haar functions

Haar Wavelet transform & Coefficient matrix extraction

- The Haar Scaling function is defined as

$$\phi(x) = \begin{cases} 1, if\ 0 \le x \le 1 \\ 0, elsewhere \end{cases}$$

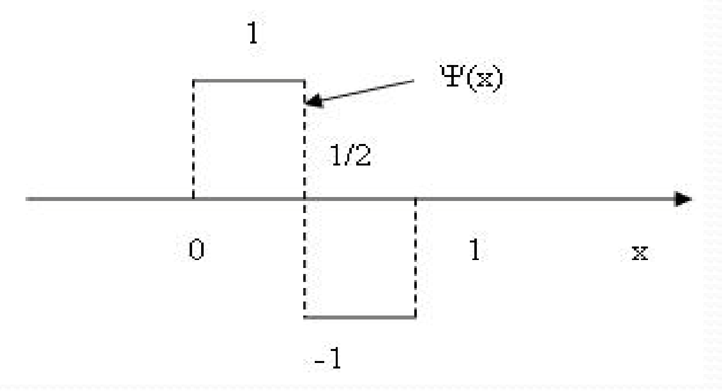


Graph of Haar scaling function Φ(x)

Contd..

- Haar wavelet function Ψ: R->R defined by

$$\varphi(x) = \begin{cases} 1 \forall x \in [0,1/2) \\ -1 \forall x \in [1/2,1) \\ 0 \forall \notin [0,1) \end{cases}$$

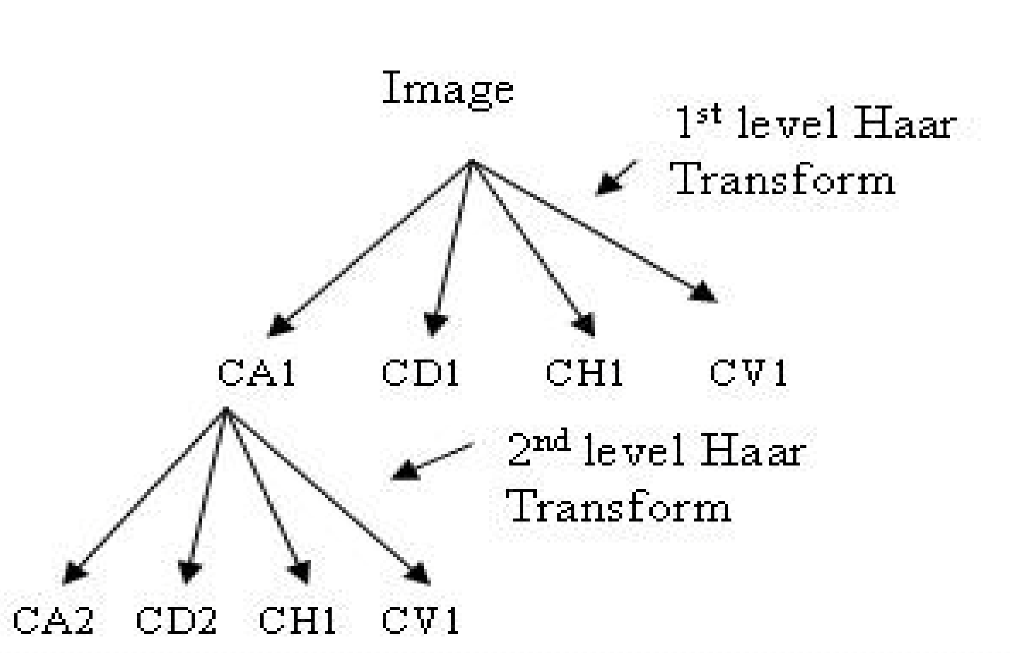


The Haar Wavelet Ψ(x)

Wavelet decomposition

- A standard decomposition of a image is done by first performing a one dimensional transformation on each row followed by one dimensional transformation of each column.
- Here 4 level decompositions is used to compressed the image in desired size and coefficient are extracted.

Wavelet decomposition….



Wavelet decomposition level

Feature Template

- To get binary template of the input image the usual technique is: the negative element of the coefficient matrix set to 0 and positive in 1.

- Now this template is binary template. This template is used as feature matrix of the image. Ear images are decomposed in 4 level that compressed the image and extract wavelet coefficients that are clustered in one 2D matrix