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A Novel Biometric Fingerprint Pressure Deformation Algorithm

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Abstract: - Biometrics is the automated use of physiological or behavioral characteristics to determine or verify identity. Finger-scan, facial-scan, iris-scan, hand-scan, and retina-scan are considered physiological biometrics, based on direct measurements of a part of the human body. Each biometric method has its strengths and weaknesses. The skin-dependant biometric method (finger-scan, and hand-scan) have their weakness on the factor of skin elasticity and deformation. This paper examines the effects of pressure on skin and simultaneously the accuracy of finger matching. The model accounts for the various levels of dynamic non-linearity that exist during the capture of the data for fingerprints

Keywords: - Biometric, elasticity, pressure, minutiae, deformation

1 Introduction

One of the most important tasks considering an automatic fingerprint biometric recognition system is the minutia biometric pattern extraction from the captured image of the desired hand part. Due to imperfections of the acquired image, in some cases certain minutia can be missed by the extraction algorithm, and in others spurious minutia can be inserted. Image imperfections can also generate errors in determining the coordinates of each true minutia and its relative orientation of the image. All these facts make remarkable decrease of the recognition system reliability.

Pubols [1], Gulati and Srinivasan [2], investigated the dynamic force response of a fingerpad and the deformation profile. Westling et al [3], and Lee et al [4] examined the growing area, the net peak force and pressure centroid on a fingerpad during grasping. However none of these studies have considered the pressure distribution. Several distributed, linear, mechanical models have been proposed to relate mechanical stimuli on the surface of the skin to the tactile sensory response [5-9]. None of these models agree with the nonlinear variation of pressure that is expected to come out from this proposed research.

2 Properties of skin

The skin has two main layers: the epidermis and the dermis. The epidermis is the outside layer of cells that serve as a protective shield for the body. It consists of thin layer of closely packed cells approximately 0.12mm thick. It is considerably thicker in areas subjected to constant pressure or friction such as the soles of the feet or the palms of the hand. The cells of the epidermis only live for about one month, therefore the epidermis is constantly regenerating itself. The epidermis consists of five layers as follows:

- Stratum Corneum(outermost layer)
- Stratum Lucidum(second layer)
- Stratum Granulosum(third layer)
- Stratum Spinosum(fourth layer)
- Stratum Basale(Bottom layer)

The dermis is positioned just under the stratum basale and is the second main area of the skin. The thickness varies at different locations, but averages approximately 2mm thick. It is well supplied with blood vessels, lymph vessels, and nerves. It also contains specialized glands and sense organs. It has two distinct layers, as follows:

- Papillary Layer(top layer)

- Reticular Layer(bottom layer).

3 Methodology

Our investigations have taken into account us the non linear relationship between the contact force, contact area and compliance of the object. Different pressure values are applied, showing the deformation and the direction of the deformation of the finger tissue. The novel algorithm is shown below in figure 1.

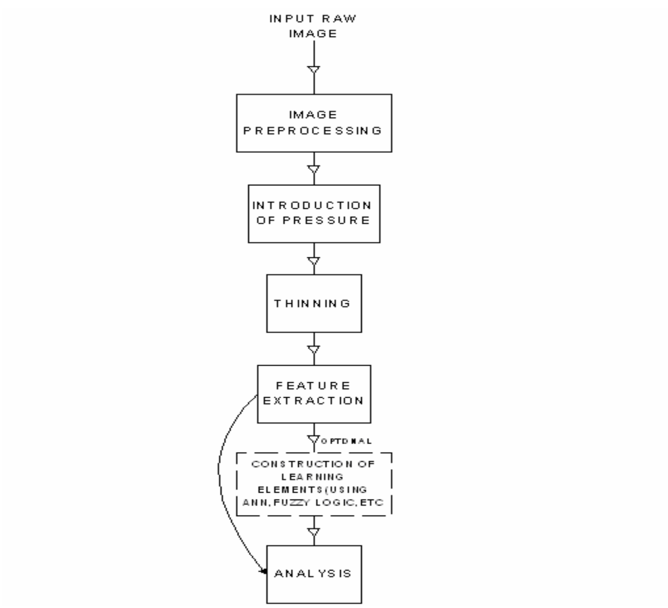

Fig. 1: The proposed algorithm.

3.1 Hardware

To measure the surface deformation of the fingerpad due to various pressure values, a mechanical rig is designed and manufactured. This rig comprises the following: Firstly the stand, holds the subject's outstretched palm, to prevent minor movements that would result in false measurements. A motorized pressure pad system is placed, with controlled displacements on the vertical axes. This applies different pressure values on the subject's fingerpad. The various pressure values will dependent on the speed of the motorized pressure pad which in turn is controlled by a mechanical control circuit. The mechanical control circuit interfaces to a software program. A number of cameras and sensors are placed on the stand in order to capture the deformation of the skin and send it in digital form to the software for further processing and classification.

3.2 Image preprocessing

The quality of the images is of great importance to biometric methodologies. As images are noisy, minutia may be broken or linked, and these result in spurious minutia. The methods of general image enhancement are not suitable for fingerprint image preprocessing. Our algorithm is based on the method of contextual filters based enhancement and restoration. In this approach, each pixel in a fingerprint image, the local ridge direction is calculated and a contextual filter is selected according to the direction. This filter is used for convolution in the local region. The basic filter consists of linear combination of two filters, one for averaging in the horizontal direction (ridge direction) and another for separating the cluttered parallel ridges along the vertical directions. In practice, most ridge breaks and links are getting eliminated by this contextual filtering. An enhanced image is then converted to a binary image.

Finally this binary image is segmented and skeletonised in order to extract the minutia points. In the skeletonised images, each ridge line is of one pixel width. By using the connectivity number (CN) we extract the minutia points using the table below.

CN for a pixel of value "1" defined for 8-connectedness is:

$$CN = \sum_{k \in S} \bar{f}(P_k) - \bar{f}(P_k)\,\bar{f}(P_{k+1})\,\bar{f}(P_{k+2})) \qquad (1)$$

Where S is a set of 4-neighbors and $\bar{f}(P_k)$ means 1- $\bar{f}(P_k)$. The values of CN characterize the property of a pixel as follows.

CN	Property
0	Isolated element
1	Edge element
2	Connecting element
3	Branching element
4	Crossing element

Table 1: Properties of Connectivity numbers

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4 Results

It is found that the quasi-static pressure response of the fingerpad can be successfully approximated be Hertzian [10] contact modified to allow for a non-linear variation of the modulus of elasticity. The contact pressure distribution p(r, x) can be described by:

$$p(r,x) = \left[\frac{2E^*_{f(x)}}{\prod R_f}\right] * \sqrt{[\alpha(x)^2 - r^2]} \qquad (2)$$

where r = radial distance from the center of contact.
x = maximum fingerpad deformation (i.e., at r=0)
E^*_f = radius of curvature of the fingerpad
$\alpha(x)$ = radius of contact area.

From the Hertz model, the deformation of the fingerpad, referenced to its undeformed shape F(r), is:

$$u_z(r) = \frac{1}{E_f^{\;*}}\left[\frac{3PE_y}{32a^3R^2}\right]^{\frac{1}{3}} * 2a^2 - r^2 \qquad (3)$$

Where x = $u_z(0)$

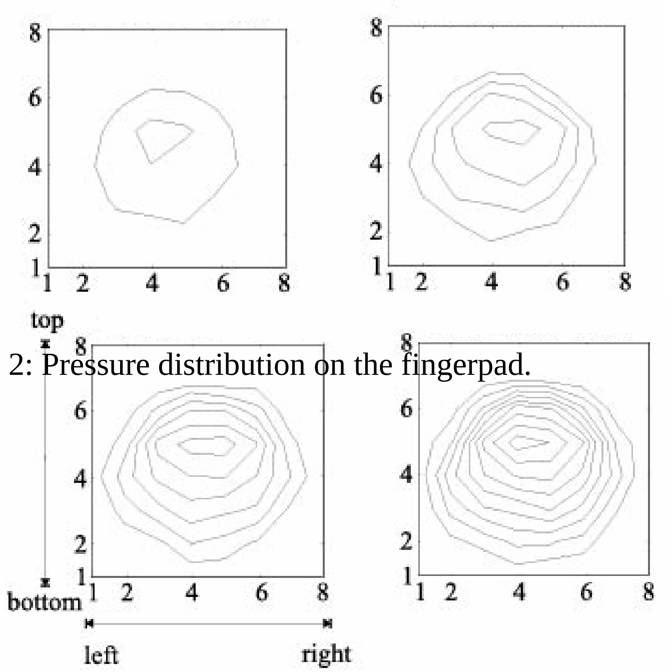

Fig. 2: Pressure distribution on the fingerpad.

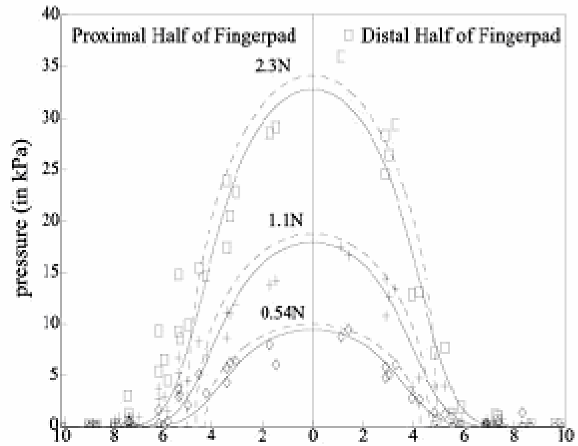

Fig. 3: Radial displacement from center (mm).

Fig. 2 shows the deformation results for various pressure values. It can be seen that the fingerpad is expanding non-linearly. The pressure point is as the center of the fingerpad. Fig. 3 has the radial displacement from center (mm). Measured pressures are indicated by symbols, the width and height of which indicate the standard deviation of the measurement error. The data points on the left-hand side of the graph show the pressure measurements.

The deformation and matching process takes a total of 23 seconds to complete on a Pentium 4 3.2 GHz. It successfully finds the ridge bifurcations and endings in a fingerprint image.

5 Conclusions

This paper has presented a novel algorithm to model the effects of fingerprint pressure deformation. The model accounts for the various levels of dynamic non-linearity that exist during the capture of the data for fingerprints. Furthermore a computationally efficient matching algorithm has been accurately used to match fingerprints.

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