



Human Visual Perception Model for Measuring Fingerprint Image Quality

For
NIST Biometric Quality Workshop

Department of Defense
Biometrics Management Office
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Agenda

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- ▶ **Background**
- ▶ **Existing Measurement Tools**
- ▶ **Fingerprint Image Quality Measurement (FIQM) – A New Approach**
- ▶ **Discussion**



Background



- ▶ Fingerprint Image Quality Measurement – an important function for monitoring and controlling of image entry and transmission processes
 - Matching Algorithms depend on quality of features (for example: minutiae) that can be extracted from digitized fingerprint images
 - Poor quality images can negatively impact the matching performance of automatic fingerprint recognition systems
 - Sub-par quality images can occupy a large part of databases and increase search time



Summary of Approaches



Approaches	Algorithms	Outputs of Quality Measurement
Human Visual Perception Model for Measuring Fingerprint Image Quality	Calculation of orientation information from Region of Interest	0 (poor) – 100 (excellent), can be configured to return quality level based on thresholds
NIST Fingerprint Image Quality (NISTIR 7151) – NFIQ	Feature vector and Artificial neural network training process	1 (excellent) – 5 (poor)
Quality Check – Aware	Proprietary	0 (poor) – 100 (excellent)
Others	A) Gabor filter based B) Minutiae based C) Discrete Cosine Transformation based	Recoverable and non-recoverable; Good, poor, smudged, dry; Good, medium, poor, background



Proposed Algorithm – Concepts



- ▶ The human visual perception has a remarkable ability to detect the edges (high frequency signals) in a processed visual image and encoded edge orientations.
- ▶ The orientation of ridges can be calculated using the gradient values of the connected pixels.
 - Gradient is a measurement of how rapidly pixel values are changing with distance in the horizontal and vertical directions.
- ▶ Clear orientation information of ridges within a local area is interpreted (“perceived”) as high quality level of this area



Examples

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Excellent



Good/Fair



Poor



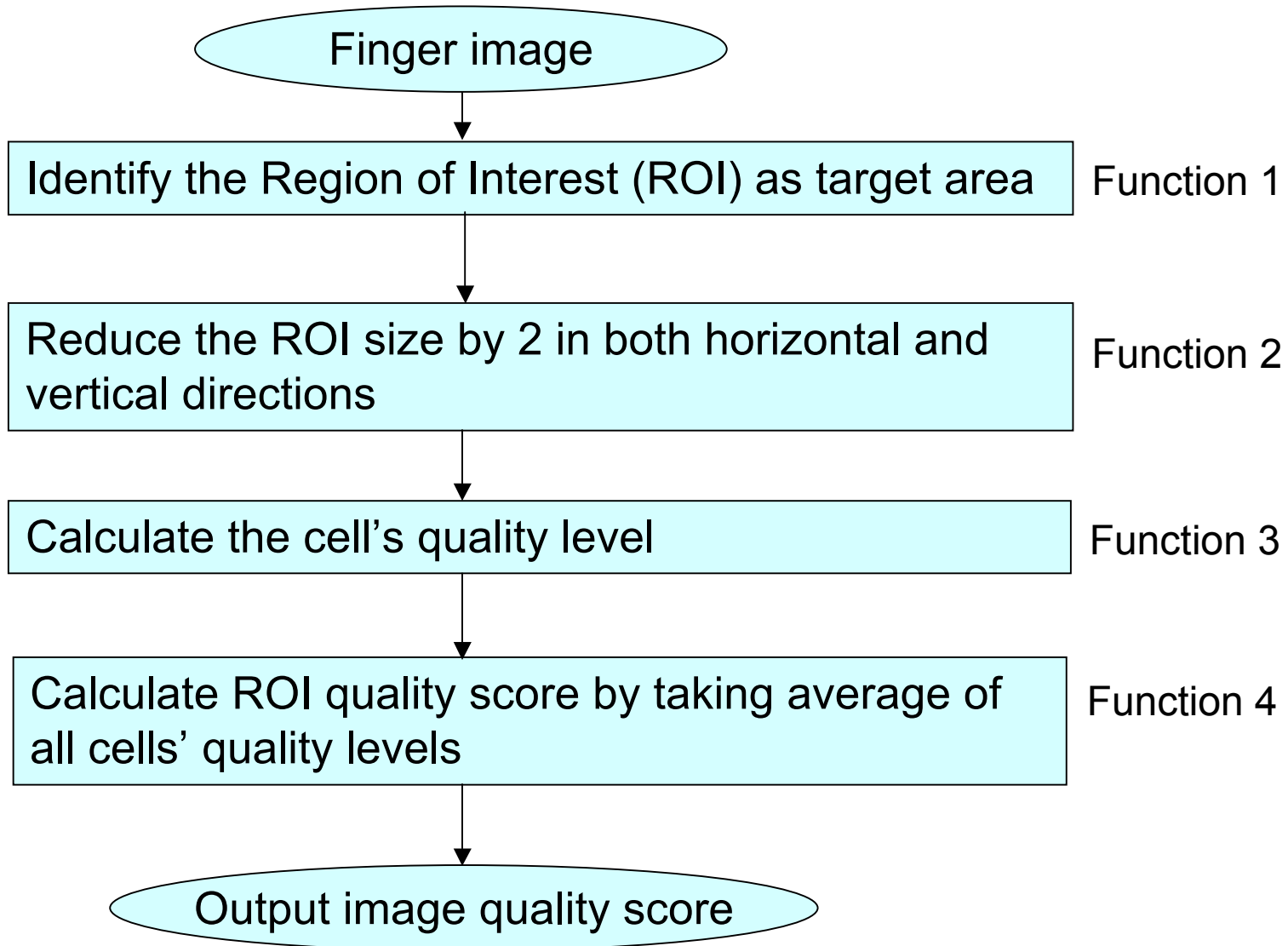
Measuring Fingerprint Image Quality – Concepts



- ▶ Quality measurement is based on the Region of Interest (ROI) orientation information, which is calculated by the quality levels of all cells.
- ▶ Each cell (9 x 9 pixels) quality level is collected from the majority pixels' orientations within the cell.
 - “Good” cells would have very uniform orientation information that would give a high majority orientation information.
 - “Blurred” cells would have very random orientation information that would give a low majority orientation information.
 - Total black cell or equal gray scale value cell would not provide orientation information.
- ▶ Averaging of all quality levels from ROI will represent the whole image quality score



Quality Measurement Process

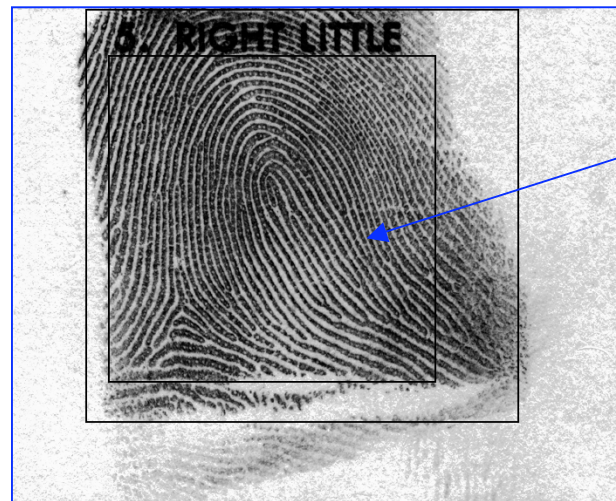




Function 1: Identifying ROI

Purposes:

- ▶ Identify most important area as quality measurement target area.
- ▶ Background area should be excluded in quality measurement processing.



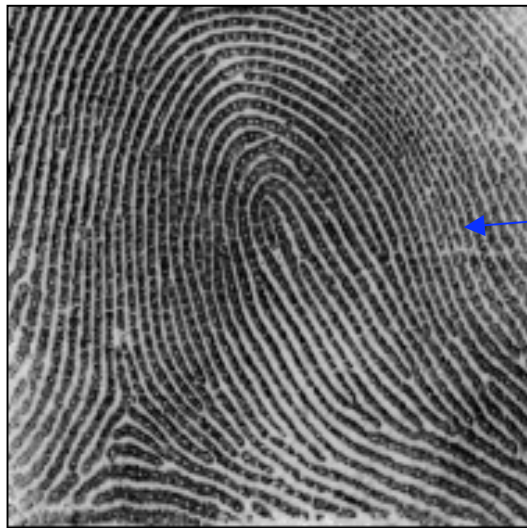
Region of Interest (ROI)



Function 2: Reduce ROI Size

Purposes:

- ▶ Remove redundancy and noise pixels
- ▶ Increase performance speed



- Low-pass filtering to convolve 5X5 Gaussian Weighting matrix to each 5X5 block pixels
- Sub-sampling process to reduce the resolutions of horizontal and vertical directions by 2
- $\frac{1}{4}$ size of original ROI

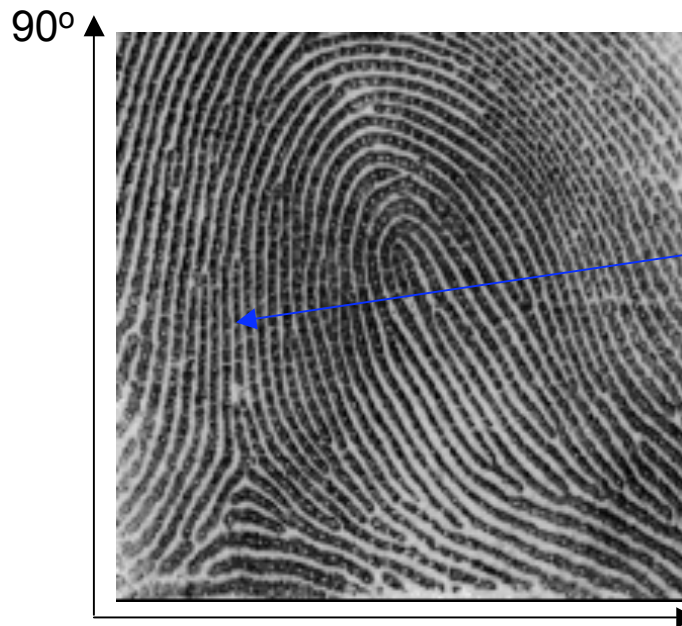


Function 3: Calculate Cell's Quality Level (1/3)



Purposes:

- ▶ Calculate each individual pixel's gradient information and convert to orientation information.
- ▶ Calculate each cell's quality level based on the majority pixels' orientations inside the cell.



5	5	5	5	5	5	5	6	6
5	5	5	5	5	5	5	5	6
5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5

9 x 9

Cell quality level: $78/81 \times 100 = 96.3$

0° 1-8: Pixel orientation index – 1: 0° ... 5: 90° 6: 112.5° ...

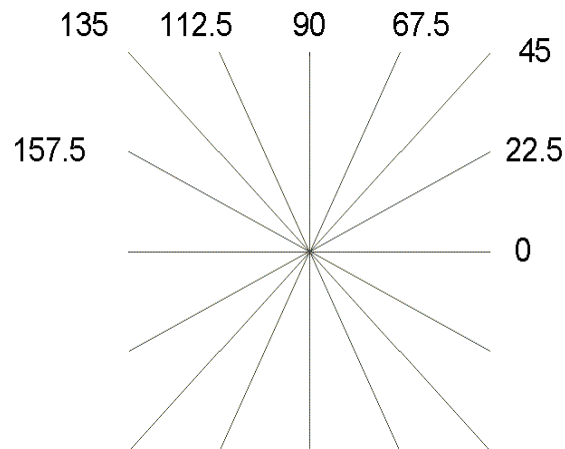


Function 3: Calculate Cell's Quality Level (2/3)

- ▶ To calculate gradient value (“*Grad*”) from a 3X3, the nearest neighbor pixels are used to determine the center pixel’s (*e*) orientation index, DI_e .
- ▶ The pixel *e*’s DI_e equals 0 if the difference of maximum gray scale value and minimum gray scale value from 3X3 pixels is less than a pre-defined threshold, δ .

a	b	c
d	e	f
g	h	i

3 x 3 pixel block



$$\begin{aligned} \text{Grad}_1 &= |(a+2d+g) - (c+2f+i)| && \text{for } 0^\circ \\ \text{Grad}_2 &= |2(c+f) - 2(d+g)| && \text{for } 22.5^\circ \\ \text{Grad}_3 &= |(b+2c+f) - (d+2g+h)| && \text{for } 45^\circ \\ \text{Grad}_4 &= |2(b+c) - 2(g+h)| && \text{for } 67.5^\circ \\ \text{Grad}_5 &= |(a+2b+c) - (g+2h+i)| && \text{for } 90^\circ \\ \text{Grad}_6 &= |2(a+b) - 2(h+i)| && \text{for } 112.5^\circ \\ \text{Grad}_7 &= |(b+2a+d) - (f+2i+h)| && \text{for } 135^\circ \\ \text{Grad}_8 &= |2(a+d) - 2(f+i)| && \text{for } 157.5^\circ \end{aligned}$$

$$DI_e = \text{Index of Minimum Grad}_i \quad i = 1, 2, \dots, 8$$

$$DI_e = 0 \text{ if } (\text{MAX}(a, b, \dots, i) - \text{MIN}(a, b, \dots, i)) < \delta$$



Function 3: Calculate Cell's Quality Level (3/3)



- ▶ The majority pixels' orientation information from each cell is equivalent to the randomness (entropy) measurement of orientation indices from the cell.
 - High majority orientation information ~ low randomness
 - Low majority orientation information ~ high randomness
- ▶ The randomness, $R(DI)$, of orientation indices in a cell is defined by

$$R(DI) = - \sum_{i=1to8} p_i \log \frac{1}{p_i} \quad \text{where } p_i \text{ is the probability of orientation } i$$

For example: The $R(DI)$ value from the previous example is **0.1237** with $p_5 = 78/81 = 0.963$ and $p_6 = 3/81 = 0.03704$, respectively.



Function 4: Calculate ROI Quality Score



Purpose:

- ▶ Averaged ROI quality score, Q_{ROI} , will represent the whole image quality.

$$Q_{ROI} = \frac{1}{N} \sum_{n=1}^N q_n$$

where N is the total number of cells within ROI and q_n is the quality level of n^{th} cell.

- ▶ The output quality score is from 0 to 100; the best score is 100.
- ▶ The output quality score could be mapped to other scoring systems.





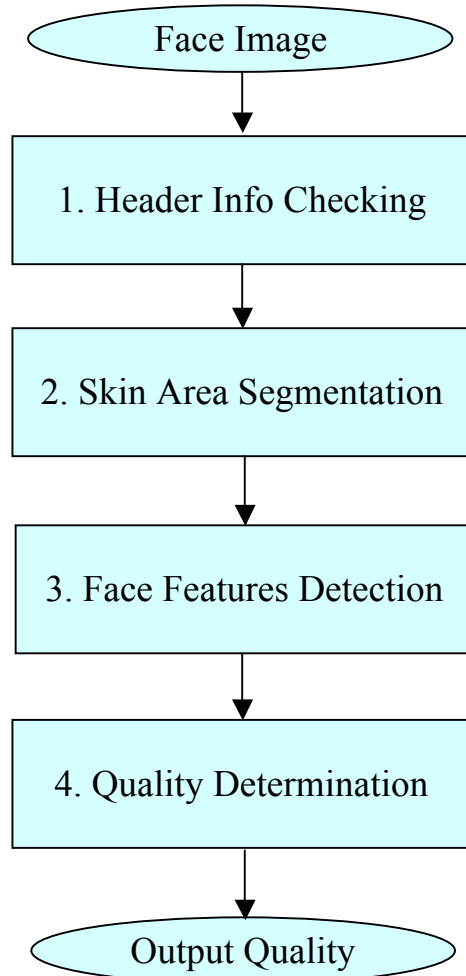
Related Activities



- ▶ Completed initial test to evaluate correlation between FIQM quality scores and DoD ABIS internal metrics using 20,000 fingerprint images
- ▶ Plan to work with NIST to study the correlation with NFIQ quality scores
- ▶ Other quality measurement tool is under development – Face Image Quality Measurement (FaceQM) Tool



Face Image Quality Measurement Flow



1. Image Header Information Checking Module

- The image header information consistency checking

2. Skin Area Segmentation Module

- Segment skin area by using Skin Color Decision Tree
- Generate skin area mask

3. Face Features Detection Module

- Locate eyes, mouth, and ears
- Estimate face area
- Measure and calculate face features

4. Quality Determination Module

- Verify values of face features with constrains
- Determine and output quality



Face Features Detection



- ▶ Face features can be detected by color feature components that are constructed by combinations of Y, Cr, Cb, Hue, and Saturation:
 - Sight Features
 - Near/Far
 - Centered Image
 - High/Low
 - Orientation Features
 - Roll Angle
 - Yaw Angle
 - Lighting Features
 - Contrast (Sharpness)
 - Vertical/Horizontal Saturation Ratios
 - Luminance Dynamic Range
 - Eyes, Mouth, and Ears Detection
 - Locations of eyes
 - Location of mouth
 - Locations of ears



References



Resources for Fingerprint Image Quality Measurement information

- ▶ “Electronic Fingerprint Transmission Specification, Appendix F,” CJIS-RS-0010 (v7), Criminal Justice Information Services Division
- ▶ “Fingerprint Image Quality,” NISTIR 7151, National Institute of Standards and Technology (NIST)
- ▶ “QualityCheck,” Aware Company, www.aware.com
- ▶ “Revision 4 of Biometric Sample Quality Draft Standard,” M1/06-0003
- ▶ “Text of 1st Working Draft 29794-1, Biometric Sample Quality Standard – Part 1: Framework,” SC 37 N1477
- ▶ “Interim Editor’s Proposed Base Document Toward a Working Draft for Biometric Sample Quality Standard – Part 4: Fingerprint Sample Quality,” SC 37 N1391
- ▶ “Korea National Body Response on SC 37 N1221, Call for National Body Contributions on Quality metrics/standards,” SC 37 N1338



Discussion



Contact Information



Robert Yen
Department of Defense
Biometrics Management Office
Booz Allen Hamilton

Phone: (703) 984-0434
Email: yen_robert@bah.com

www.biometrics.dod.mil