# CIS 663 Biometrics

Assignment #1

**This assignment is due by the week 4 live session. If you make any assumptions, clearly state them in your answer.**

1. Open the file, *s048r.txt*, provided with this assignment (tab delimited). This file contains a verification test result. It contains two columns, *test.subject* and *test.out*. *test.subject* is the true label, and *test.out* is the prediction result. You may use any tools or language you would like including excel. Answer the following questions based on the prediction result in this file. *Note that the positive class here is *s048*.

   a. Construct a confusion matrix. (10pt)

| n=404 | Pred S048 | NOT Pred S048 |
|---|---|---|
| Actual S048 | TP= 156 | FN= 48 |
| NOT Actual S048 | FP= 6 | TN= 194 |

   b. What is the *accuracy* of this model? Is this a useful measure to evaluate the model? (10pt)

$$\text{Accuracy} = \frac{TP+TN}{n} = \frac{156+194}{404} = \boxed{86.7\%}$$

This could definitely be useful, but might have very different thresholds for success based on the use case. ie sometimes even a 99% accuracy is not satisfactory.

   c. Compute *FMR*, *FNMR*, *Precision*, and *Recall*. (10pt)

$$FMR = \frac{FP}{n} = \frac{6}{404} = \boxed{1.5\%}$$

$$FNMR = \frac{FN}{n} = \frac{48}{404} = \boxed{11.9\%}$$

$$\text{Precision} = \frac{TP}{\text{Total S048 Pred}} = \frac{156}{156+6} = \frac{156}{162} = \boxed{96.2\%}$$

$$\text{Recall} = \frac{TP}{TP+FN} = \frac{156}{156+48} = \frac{156}{204} = \boxed{76.5\%}$$

2. Answer the following questions in your own words.

a. How are singularities used in fingerprint recognition? (10pt)

They are used for orientation of the fingerprint image, which assists with other recognition techniques. They can also be used on their own as recognition tools.

b. What is the thinning process in fingerprint feature extraction? And what benefit do they have? (10pt)

It is the process to take the input image and turn the ridges into single pixel lines. This has the benefit of making other techniques more effective and consistent.

c. Why do we need to find local ridge orientation and frequency earlier on in the processing of fingerprint image? (10pt)

We need that information early on because the orientation and frequency numbers are the inputs to algorithms that determine minutiae in the finger print, as well as singularities.

Once we extract these two value sets, we can functionally drop the actual input image altogether.

3. Perform a singularity detection in the following data. Use the definitions used in week 3 live session slides. Your answer should include all missing values in the table and the type of singularity detected. (20pt)

| $k$ | $\theta$ | $\delta$ | $\Delta$ |
|---|---|---|---|
| 0 | 80 | 10 | 10 |
| 1 | 90 | 170 | -10 |
| 2 | 260 | -210 | -30 |
| 3 | 50 | 60 | 60 |
| 4 | 110 | 160 | -20 |
| 5 | 270 | -140 | 40 |
| 6 | 130 | 50 | 50 |
| 7 | 180 | -100 | 80 |

Use the following two equations to fill in the column titled $\delta$ and the column titled $\Delta$.

$$\delta(k) = \theta((k+1) \bmod N) - \theta(k)$$

$$\Delta(k) = \begin{cases} \delta(k) & \text{if } |\delta(k)| < \frac{\pi}{2} \\ \delta(k) + \pi & \text{if } \delta(k) \leq -\frac{\pi}{2} \\ \delta(k) - \pi & \text{if } \delta(k) \geq \frac{\pi}{2} \end{cases}$$

Once you have filled in the table give the type of singularity you believe is being represented based on:

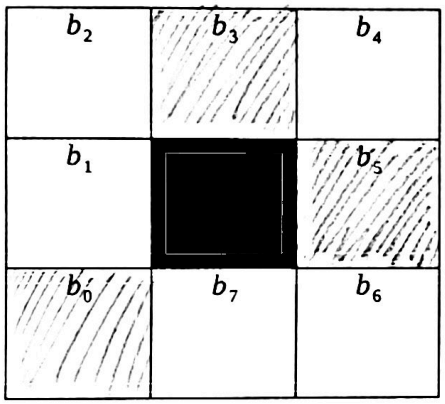
$$\sum_{k \in (0 \ldots 7)} \Delta(k) = \begin{cases} 360, & \text{then whorl} \\ 180, & \text{then loop} \\ -180, & \text{then delta} \\ 0, & \text{then singularity} \end{cases}$$

Sum = 180 → Loop

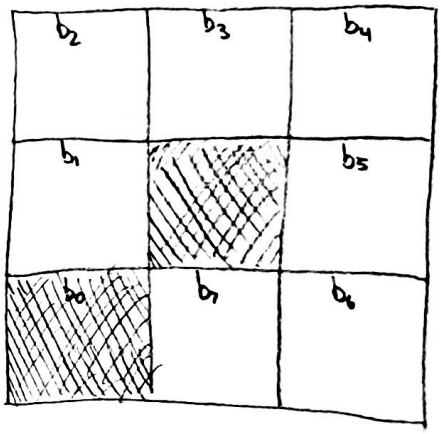
4. Determine the 3x3 binary pixel grid for:
   a) A bifurcation point;
   b) A non-minutiae point
   (In live session we displayed and discussed the grid for the termination case).

   For each specify:
   - The values of $b_0,\ldots,b_7$ for each case.
   - What are their crossing numbers?

A (bifurcation)




B (termination)




going off this equation vs the version w/ ½ in the slides.

$$\text{Crossing Number} = \sum_{i\in(1\ldots7)} |b_i - b_{(i+1)\bmod 8}|$$

A) $|1-0| + |0-0| + |0-1| + |1-0| + |0-1| + |1-0| + |0-0| + |0-1|$

$= 1+0+1+1+1+1+0+1 = \boxed{6}$ or 3 using ½ calculation

$b_0 = 1$ $b_4 = 0$
$b_1 = 0$ $b_5 = 1$
$b_2 = 0$ $b_6 = 0$
$b_3 = 1$ $b_7 = 0$

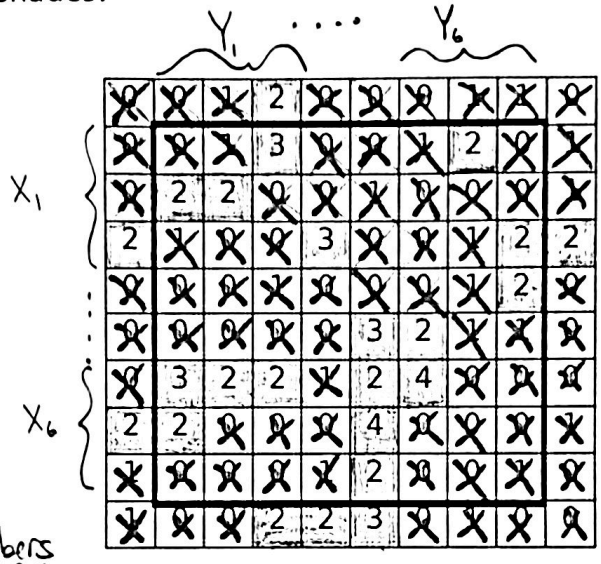
B) $|1-0| + |0-0| + |0-0| + |0-0| + |0-0| + |0-0| + |0-0| + |0-1|$

$= 1+0+0+0+0+0+0+1 = \boxed{2}$ or 1 using ½ calculation

$b_0 = 1$ $b_4 = 0$
$b_1 = 0$ $b_5 = 0$
$b_2 = 0$ $b_6 = 0$
$b_3 = 0$ $b_7 = 0$

5. The following image shows the values in grayscale. Perform the necessary steps to detect minutiae points. You don't need to detect any minutiae centered at the edge. Show your steps. Your result will include the coordinate of detected minutiae points and their types. (20pt)

   Note: 0 represents the darkest shade, higher numbers represent brighter shades.




Binary Filter: $f(x) = \begin{cases} x \le 1 : y = 0 \\ x > 1 : y = 1 \end{cases}$

Calculate Crossing Numbers

| X↓ Y→ | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 2 | 1 | 1 | 2 |
| 2 | 1 | 2 | 0 | 1 | 0 | 1 |
| 3 | 0 | 1 | 2 | 2 | 1 | 2 |
| 4 | 1 | 1 | 2 | 1 | 1 | 2 |
| 5 | 2 | 1 | 2 | 2 | 1 | 1 |
| 6 | 1 | 1 | 2 | 2 | 1 | 1 |

using coordinates as labelled on grid

Termination Points:
(1,4), (1,5), (2,1), (2,4), (2,6), (3,2), (3,5), (4,1), (4,2), (4,4), (4,5), (5,2), (5,5), (5,6), (6,1), (6,2), (6,5), (6,6)

Bifurcation Points:
(1,2)