

## Pattern recognition of Images

**Input:** Images as standard computer keyboard character or integers. Hand written Images with characters or images

**Output:** Geometrical features extracted from the each image and classification of the image to its character or integer.

### Pattern Recognition process:

1. **Image acquisition:** Read the input image using ImageIO java library.
2. **Image digitizing:** Digitizing the input character image.
3. **Image binarization:** Converts an image of up to 256 gray levels into a two-tone image represented by 0 and 1
4. **Size Normalization:** Normalize the binary image to the size of 30 pixels height and 25 pixels of width(**Size Normalization**)
5. **Image Skeletonization:** Apply **Zhang-Suen Skeletonization** to skeletonize the binary image
6. **Feature extraction:** Feature extraction and selection can be defined as extracting the most representative information from the raw data, which minimizes the within class pattern variability while enhancing the between class pattern variability  
Extract features from the skeletonized binary image

#### Features extracted (Geometrical features)

1. Start/ end pixels
  2. Intersection points
  3. Horizontal lines
  4. Vertical lines
  5. Number of Holes
  6. Left diagonals
  7. Right Diagonal
7. **Image classification:** Classify the image to its respective character or integer according to the extracted features.

1. Image 4 (Standard Computer Image )

(i) Input: Image 4

4

```

Problems @ Javadoc Declaration Search Console
<terminated> ImageProcessing [Java Application] C:\Program Files\Java\jre8\l
[Console output redirected to file:G:\Console.txt]
IMAGE INPUT DETAILS
Input image height: 128
Input image width: 128

```

(ii) Size Normalization: Output: Image after converting to binary and size normalization

```

_____BINARY IMAGE AFTER SIZE NORMALIZATION ( 30H x 25W ) _____
Alpha : 0.234375
Beta : 0.1953125
Length and width after size normalization
Binary Image length: 30
Binary Image width : 25

11111
11111
111111
111111
1111111
1111111
111 1111
1111 1111
1111 1111
111 1111
111 1111
1111 1111
111 1111
111 1111
1111111111111111
1111111111111111
1111111111111111
1111111111111111
1111111111111111
1111111111111111
1111
1111
1111
1111
1111

```

(iii) **Skeletonization:** Image after Zhang-Suen Skeletonization

```
_____
                BINARY IMAGE AFTER ZHANG-SUEN THINNING
_____
Binary Image length:    30
Binary Image width :    25

      1
      1
     111
    111 1
   1  1
  1  1
 11  1
 1  1
 1  1
 1  1
 1  1
 1  1
 1  1
 1111111111
      1
      1
      1
      1
      1
```

(iv) **Feature Extraction and classification:** Features extracted from Skeletonized image and Image Classification

```
Problems  @ Javadoc  Declaration  Search  Console
<terminated> ImageProcessing [Java Application] C:\Program Files\Ja

_____EXTRACTED FEATURES_____

Starter Pixel Count      : 3
Intersection Count       : 2
Horizontal Line Count    : 1
Vertical Line Count      : 2
Character's Hole Count   : 1
Left Diagonal Line Count : 1
Right Diagonal Line Count: 0

_____IMAGE CLASSIFICATION_____

Image is recognized as   : 4
```

## 2. Image ( Hand written 4 )

(i) Input: Hand written Image 4



```
<terminated> ImageProcessing [Java Application] C:\Program Files\Java\jre8\bin\javaw.exe (I
[Console output redirected to file:G:\Console.txt]
IMAGE INPUT DETAILS
Input image height:      900
Input image width:       900
```

(ii) Size Normalization: Output: Image after converting to binary and size normalization

```
Problems @ Javadoc Declaration Search Console History D
<terminated> ImageProcessing [Java Application] C:\Program Files\Java\jre8\bin\javaw.exe (I
[Console output redirected to file:G:\Console.txt]
IMAGE INPUT DETAILS
Input image height:      900
Input image width:       900

BINARY IMAGE AFTER SIZE NORMALIZATION ( 30H x 25W )

Alpha :      0.03333333507180214
Beta  :      0.02777777798473835

Length and width after size normalization
Binary Image length:    30
Binary Image width :    25

      1
     111
    111
   1111
  11111
 11 11
11 11
11 11
111111111111
111111111111
      1
     11
     11
     11
```

(iii) **Skeletonization:** Image after **Zhang-Suen Skeletonization**

```
_____
      BINARY IMAGE AFTER ZHANG-SUEN THINNING
_____
```

```
Binary Image length: 30
Binary Image width : 25
```

```

      1
      1
    111
    1 1
  11 1
  1 1
11111111
    1
    1
    1
    1
```

(iv) **Feature Extraction and classification:** Features extracted from Skeletonized image and image Classification

```
Problems @ Javadoc Declaration Search Console
<terminated> ImageProcessing [Java Application] C:\Program Files\J
```

```
_____
      EXTRACTED FEATURES
_____
```

```
Starter Pixel Count      : 3
Intersection Count       : 2
Horizontal Line Count    : 1
Vertical Line Count      : 1
Character's Hole Count   : 1
Left Diagonal Line Count : 1
Right Diagonal Line Count: 0
```

```
_____
      IMAGE CLASSIFICATION
_____
```

```
Image is recognized as : 4
```

### 3. Image ( Hand written 4 )

(i) Input: Hand written Image 4



```

Problems @ Javadoc Declaration Search Console
<terminated> ImageProcessing [Java Application] C:\Program Files\Jav
[Console output redirected to file:G:\Console.txt]
IMAGE INPUT DETAILS
Input image height: 900
Input image width: 900

```

(ii) Size Normalization: Output: Image after converting to binary and size normalization

```

_____BINARY IMAGE AFTER SIZE NORMALIZATION ( 30H x 25W ) _____

Alpha : 0.03333333507180214
Beta : 0.02777777798473835

Length and width after size normalization
Binary Image length: 30
Binary Image width : 25

1
11
11
111
111 11
11 111
11 111
11 1111
11111111
11111111
1111111
11
11
11
11
111
11
1

```

(iii) **Skeletonization:** Image after Zhang-Suen Skeletonization

```
_____  
      BINARY IMAGE AFTER ZHANG-SUEN THINNING  
_____  
Binary Image length:  30  
Binary Image width :  25
```

```

1
1
1
1
1
1
1  1
1  1
1  11
11111
  1
  1
  1
  1
  1
  1
  1
  1
```

(iv) **Feature Extraction and classification:** Features extracted from Skeletonized image and image Classification

```
_____  
      EXTRACTED FEATURES  
_____
```

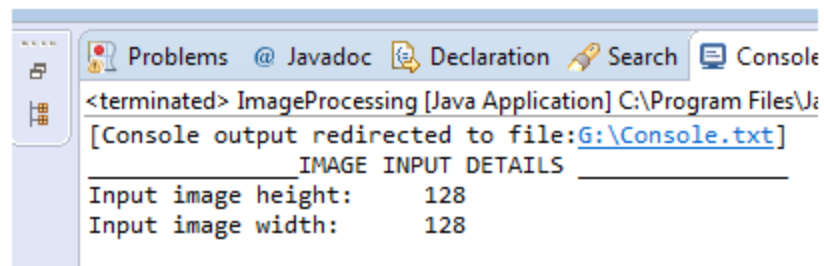
```
Starter Pixel Count      : 3  
Intersection Count      : 1  
Horizontal Line Count   : 1  
Vertical Line Count     : 2  
Character's Hole Count  : 0  
Left Diagonal Line Count : 0  
Right Diagonal Line Count: 0
```

```
_____  
      IMAGE CLASSIFICATION  
_____
```

```
Image is recognized as : 4
```

4. Image (Standard Computer Image 8 )

(i) Input: Image 8



(ii) **Size Normalization:** Output: Image after converting to binary and size normalization

```

_____BINARY IMAGE AFTER SIZE NORMALIZATION ( 30H x 25W ) _____
Alpha :      0.234375
Beta  :      0.1953125

Length and width after size normalization
Binary Image length:  30
Binary Image width :  25

    1111111
   111111111
  11111111111
 111111111111
11111  11111
11111  11111
11111  11111
11111  11111
 11111 11111
 11111111111
  111111111
  111111111
 111111111
111111 111111
11111  11111
11111  11111
11111  11111
11111  11111
11111  11111
11111  11111
1111111111111
 11111111111
  111111111
  11111111

```



(iii) **Skeletonization:** Image after Zhang-Suen Skeletonization

---

BINARY IMAGE AFTER ZHANG-SUEN THINNING

---

Binary Image length: 30

Binary Image width : 25

```
      111
     11  111
      1    1
     1    1
     1    1
     1    1
     1    1
     1    1
     1    1
     1    1
    111111
     1    1
     1    1
     1    1
     1    1
     1    1
     1    1
     1    1
     1    1
    111111
```

(iv) **Feature Extraction and classification:** Features extracted from Skeletonized image and image Classification

---

EXTRACTED FEATURES

---

Starter Pixel Count : 0  
Intersection Count : 2  
Horizontal Line Count : 2  
Vertical Line Count : 3  
Character's Hole Count : 2  
Left Diagonal Line Count : 0  
Right Diagonal Line Count: 1

---

IMAGE CLASSIFICATION

---

Image is recognized as : 8

5. Image ( Hand written Image 8 )

(i) Input: Image 8



```
<terminated> ImageProcessing [Java Application] C:\Program Files\Jav
[Console output redirected to file:G:\Console.txt]
IMAGE INPUT DETAILS
Input image height:      800
Input image width:       800
```

(ii) **Size Normalization:** Output: Image after converting to binary and size normalization

```
_____BINARY IMAGE AFTER SIZE NORMALIZATION ( 30H x 25W ) _____
Alpha :      0.03750000149011612
Beta  :      0.03125

Length and width after size normalization
Binary Image length:   30
Binary Image width :   25

      11
      11
    11 11
  11111111
1111111111
111  11
11  111
111  11
111111
1111
1111
111111
11  111
111  111
111  11
11  11
11  111
11  111
111 1111
11111111
11111
```

(iii) **Skeletonization:** Image after **Zhang-Suen Skeletonization**

```

      _____
      BINARY IMAGE AFTER ZHANG-SUEN THINNING
      _____
Binary Image length:  30
Binary Image width :  25

      1
      1
    111111
    11  1
    1   1
    1   1
    1   1
    11  1
      11
      111
      1  1
      1   1
      1   1
      1   1
      1   1
      1   1
      1   1
      1  11
    11111

```

(iv) **Feature Extraction and classification:** Features extracted from Skeletonized image and image Classification

```

      _____
      EXTRACTED FEATURES
      _____
Starter Pixel Count      : 1
Intersection Count      : 3
Horizontal Line Count    : 2
Vertical Line Count      : 0
Character's Hole Count   : 2
Left Diagonal Line Count : 0
Right Diagonal Line Count: 1

```

```

      _____
      IMAGE CLASSIFICATION
      _____

```

Image is recognized as : 8

6. Image ( Computer Input Image 8 )

(i) Input: Image A



```

Problems  Javadoc  Declaration  Search  Console
<terminated> ImageProcessing [Java Application] C:\Program Files\Ja
[Console output redirected to file:G:\Console.txt]
      IMAGE INPUT DETAILS
Input image height:      250
Input image width:       250
  
```

(ii) **Size Normalization:** Output: Image after converting to binary and size normalization

```

      BINARY IMAGE AFTER SIZE NORMALIZATION ( 30H x 25W )
      Alpha :      0.11999999731779099
      Beta  :      0.10000000149011612

Length and width after size normalization
Binary Image length:  30
Binary Image width :  25

      1111
      11111
      11111
      111111
      1111111
      111 111
      1111 111
      1111 1111
      111 111
      1111 111
      1111 1111
      111 1111
      111111111111
      1111111111111
      1111111111111
      1111111111111
      1111      1111
      111      1111
      111      111
      1111      1111
      1111      1111
  
```

(iii) **Skeletonization: Image after Zhang-Suen Skeletonization**

```

      _____
      BINARY IMAGE AFTER ZHANG-SUEN THINNING
      _____
Binary Image length:  30
Binary Image width  :  25

      11
     11 1
    1  1
    1  1
   1  1
  1  1
 1  1
1  1
1  1
11111111
1  11
1  1
1  1
1  1
1  1
1  1

```

(iv) **Feature Extraction and classification:** Features extracted from Skeletonized image and image Classification

```

      _____
      EXTRACTED FEATURES
      _____
Starter Pixel Count      : 2
Intersection Count       : 2
Horizontal Line Count    : 1
Vertical Line Count      : 0
Character's Hole Count   : 1
Left Diagonal Line Count : 1
Right Diagonal Line Count: 1

      _____
      IMAGE CLASSIFICATION
      _____
Image is recognized as  : A

```

7. Image ( Hand written Image A )

(i) Input: Image A



```

Problems @ Javadoc Declaration Search Console
<terminated> ImageProcessing [Java Application] C:\Program Files\Java\
[Console output redirected to file:G:\Console.txt]
IMAGE INPUT DETAILS
Input image height: 900
Input image width: 900

```

(ii) **Size Normalization:** Output: Image after converting to binary and size normalization

```

_____ BINARY IMAGE AFTER SIZE NORMALIZATION ( 30H x 25W ) _____

Alpha : 0.03333333507180214
Beta : 0.02777777798473835

Length and width after size normalization
Binary Image length: 30
Binary Image width : 25

      11
     111
    1111
   11 11
  11 111
 11  11
11  11
11  11
111  11
111111111111
11111111111111
11111111 11111
 11      11
 11      11
 11      11
111      11
11      11
      1

```

(iii) **Skeletonization:** Image after **Zhang-Suen Skeletonization**

BINARY IMAGE AFTER ZHANG-SUEN THINNING	
Binary Image length:	30
Binary Image width :	25

```

      111
     1 1
    1   1
   1     1
  1       1
 1         1
1           1
1111111111111111
 1             1
 1             1
 1             1
 1             1
1             1
             1
             1

```

(iv) **Feature Extraction and classification:** Features extracted from Skeletonized image and image Classification

EXTRACTED FEATURES

```

Starter Pixel Count      : 2
Intersection Count       : 2
Horizontal Line Count    : 1
Vertical Line Count      : 0
Character's Hole Count   : 1
Left Diagonal Line Count : 1
Right Diagonal Line Count: 1

```

## IMAGE CLASSIFICATION

Image is recognized as : A

8. Image ( Standard Computer input Image B )

(i) Input: Image B

B

```
Problems @ Javadoc Declaration Search Console
<terminated> ImageProcessing [Java Application] C:\Program Files\Java
[Console output redirected to file:G:\Console.txt]
IMAGE INPUT DETAILS
Input image height: 250
Input image width: 250
```

(ii) Size Normalization: Output: Image after converting to binary and size normalization

```
_____BINARY IMAGE AFTER SIZE NORMALIZATION ( 30H x 25W ) _____
Alpha : 0.11999999731779099
Beta : 0.10000000149011612

Length and width after size normalization
Binary Image length: 30
Binary Image width : 25

111111111111
111111111111
1111 1111
1111 111
1111 1111
1111 1111
1111 1111
1111 111
1111 1111
111111111111
111111111111
1111 11111
1111 1111
1111 111
1111 1111
1111 1111
1111 1111
1111 111
1111 1111
1111 11111
111111111111
111111111111
```



(iii) **Skeletonization:** Image after **Zhang-Suen Skeletonization**

---

BINARY IMAGE AFTER ZHANG-SUEN THINNING

---

Binary Image length: 30  
Binary Image width : 25

```
111 111111
  11    11
  1      1
  1      1
  1      1
  1      1
  1      1
  1      1
  1      1
  1      1
1111111 1
  1      11
  1      11
  1      1
  1      1
  1      1
  1      1
  1      1
  1      1
  1      11
111111111
111
```

(iv) **Feature Extraction and classification:** Features extracted from Skeletonized image and image Classification

---

EXTRACTED FEATURES

---

Starter Pixel Count : 2  
Intersection Count : 4  
Horizontal Line Count : 3  
Vertical Line Count : 3  
Character's Hole Count : 1  
Left Diagonal Line Count : 0  
Right Diagonal Line Count: 2

---

IMAGE CLASSIFICATION

---

Image is recognized as : B

9. Image ( Hand written input Image B )

(i) Input: Image B



```
Problems @ Javadoc Declaration Search Console
<terminated> ImageProcessing [Java Application] C:\Program Files\Java
[[Console output redirected to file:G:\Console.txt]
IMAGE INPUT DETAILS
Input image height: 900
Input image width: 900
```

(ii) **Size Normalization:** Output: Image after converting to binary and size normalization

```
_____ BINARY IMAGE AFTER SIZE NORMALIZATION ( 30H x 25W ) _____

Alpha : 0.03333333507180214
Beta : 0.02777777798473835

Length and width after size normalization
Binary Image length: 30
Binary Image width : 25

1111111111
111111111111
111 111
11 11
11 11
11 1111
11 1111
11 11111
1111111111
111111111111
11 1111
11 11
1 11
11 111
11 111
11 11111
1111111111
11111
```

(iii) **Skeletonization:** Image after **Zhang-Suen Skeletonization**

```
_____  
      BINARY IMAGE AFTER ZHANG-SUEN THINNING  
_____  
Binary Image length:   30  
Binary Image width  :   25
```

```
      1111111  
     11      11  
    11      1  
   1      1  
  1      1  
 1      11  
1      1  
1      1  
1      1  
11111111  
1      11  
1      1  
1      1  
1      1  
1      1  
1      1  
1      1  
1      111  
111111
```

(iv) **Feature Extraction and classification:** Features extracted from Skeletonized image and image Classification

```
_____  
      EXTRACTED FEATURES  
_____  
Starter Pixel Count      : 0  
Intersection Count       : 2  
Horizontal Line Count    : 3  
Vertical Line Count      : 1  
Character's Hole Count   : 2  
Left Diagonal Line Count : 0  
Right Diagonal Line Count: 1
```

```
_____  
      IMAGE CLASSIFICATION  
_____  
Image is recognized as   : B
```

10. Image (Hand written input Image B )

(i) Input: Image B



```
<terminated> ImageProcessing [Java Application] C:\Program Files\  
[[Console output redirected to file:G:\Console.txt]  
IMAGE INPUT DETAILS  
Input image height: 900  
Input image width: 900
```

(ii) **Size Normalization:** Output: Image after converting to binary and size normalization

```
_____  
BINARY IMAGE AFTER SIZE NORMALIZATION ( 30H x 25W ) _____  
  
Alpha : 0.03333333507180214  
Beta : 0.02777777798473835  
  
Length and width after size normalization  
Binary Image length: 30  
Binary Image width : 25  
  
11111  
11111111  
111111 11  
111 11 111  
11111  
11111  
1 1111  
11 11  
11 11  
11 11  
11 11  
11 111  
1111111  
11111111  
111111
```

(iii) **Skeletonization:** Image after **Zhang-Suen Skeletonization**

```
_____
                BINARY IMAGE AFTER ZHANG-SUEN THINNING
_____
Binary Image length:  30
Binary Image width  :  25

      111
     11 1
    1111 1
     1  1
     1  1
    1111
     1  11
     1  1
     1  1
     1  1
     1  1
     1  11
     1 111
    11111
```

(iv) **Feature Extraction and classification:** Features extracted from Skeletonized image and image Classification

```
_____
                EXTRACTED FEATURES
_____
Starter Pixel Count      : 2
Intersection Count       : 4
Horizontal Line Count    : 1
Vertical Line Count      : 3
Character's Hole Count   : 2
Left Diagonal Line Count : 0
Right Diagonal Line Count: 1

_____
                IMAGE CLASSIFICATION
_____
Image is recognized as  : B
```

Summary of Features classified according to the input images

Features	Start/End pixels	Intersections	Horizontal lines	Vertical lines	No of Holes	Left diagonals	Right Diagonals
Images							
Computer Input Image 4	3	2	1	2	1	1	0
Hand written Image 4	3	2	1	1	1	1	0
Hand written Image 4	3	1	1	2	0	0	0
Classifying features for Image 4	EXACT 3	1 to 2	EXACT 1	1 to 2	0 to 1	0 to 1	EXACT 0
Computer Input Image 8	0	2	2	3	2	0	1
Hand written Image 8	1	3	2	0	2	0	1
Classifying features for Image 8	0 to 1	2 to 3	EXACT 2	0 to 3	EXACT 2	EXACT 0	0 to 1
Computer Input Image A	2	2	1	0	1	1	1
Hand written Image A	2	2	1	0	1	1	1
Classifying features for Image A	EXACT 2	EXACT 2	EXACT 1	EXACT 0	EXACT 1	EXACT 1	EXACT 1
Computer Input Image B	2	4	3	3	1	0	2
Hand written Image B	0	2	3	1	2	0	1
Hand written Image B	2	4	1	3	2	0	1
Classifying features for Image B	0 TO 2	2 TO 4	1 TO 3	1 TO 3	1 TO 2	EXACT 0	1 TO 2

### Observations:

1. Able to convert image to binary array.
2. Geometric features are extracted successfully from the images.
3. Successful in classifying the images to their characters with the features extracted.
4. Successfully able to recognize the input images as the characters by extracting the geometric features.
5. Successful in using **Zhang-Suen Skeletonization** algorithm to skeletonize the standard input and hand written images.

### Drawbacks:

1. Geometric features are not consistent in hand written characters. Hence, Features extracted from hand written images may vary from image to image.
2. Hand written images with cursive writing can be tough to recognize.
3. Low density pixelated images have a problem in skeletonizing and extracting the features.
4. Geometric features may vary according to the persons hand writing.

### Character recognition system can be made more successful and accurate by:

1. Feature extraction can be made more accurate by increasing the Threshold values of number of pixels to consider as a feature for horizontal, vertical and right, left diagonals.

```
private static final int pixelThresholdH = 5;  
private static final int pixelThresholdV = 5;  
private static final int pixelThresholdRightDiag = 3;  
private static final int pixelThresholdLeftDiag = 5;  
private String classifiedImage = "";
```

2. Extracting more geometric features such as:
  - a. **Length of all horizontal lines**
  - b. **Length of all vertical lines**
  - c. **Length of all right diagonal lines**
  - d. **Length of all left diagonal lines**
  - e. **Minor starters:** created when pixel under consideration have more than two neighbors.
  - f. **Convex Area:** Scalar that specifies the number of pixels in Convex Image.
  - g. **Orientation:** It is the angle (in degrees ranging from -90 to 90 degrees) between the x-axis and the major axis of the ellipse that has the same second-moments as the region.
3. Cursive hand written images can be recognized more by boxing the boundaries of each images character and rotating the image by an angle to extract features more accurately.
4. Skeleton with broken lines can be extracted as feature to increase the accuracy of the image recognition.

### REFERENCES

- I) Character Recognition Systems: A Guide for Students and Practitioners, by Mohamed Cheriet, Nawwaf Kharma, Cheng-Lin Liu, Ching Suen, Hoboken, New Jersey: John Wiley & Sons, Inc., 2007.