5.3 LETTERFORM TEMPLATE.

To ensure that the output represents a balanced and legible set of characters when constructed, data gleaned from the input samples, such as the x-height, cap-height, and slant, will be applied to a template of letterforms. This template can then be translated / manipulated to the specification provided by extracted attributes of the handwritten text.

The application of manipulating the template requires that:
- The template be in a vector format allowing for points to be adjusted rather then individual pixels.
- points of the letterform template are required to be relational / relative measures ensuring the balance is maintained throughout each character of the template and the subsequent output.
- Relative measures will need to be applied to the global letter set to account for the requirement of letter width and kerning to be of a consistent balance.

Due to the importance of the letter width and kerning on the presentation of a typed text the template will be based on a professionally developed typeface.

5.3.1 LETTER FORM POINT EXTRACTION.

The creation of the template will start with the extraction of point information from a skeletonised bitmap representation of a professional developed typeface.

5.3.1.1 CONTOUR AND LINE TRACING.

Inquiry into tracing algorithms has present 4 possible implementations.

- Moore-neighbor,
- Square tracing,
- Pavlidis algorithm,
- radial sweep.

Moore-neighbor, and Square tracing will ignore holes, however as the current requirement is to trace the contours of a skeletonised representation of letterforms the shape of inner holes will be equivalent to the outer shape.

The square tracing algorithm will fail to to trace an 8-connected structures that isn’t 4 connected.

Both the Moore-neighbor and the square tracing algorithms follow the same principle actions:

1. Find the start point.
2. Trace the contour of the image.
3. Stop at a given condition.

Where these algorithms differ is in action 2.

MOORE-NEIGHBOR ALGORITHM.

The Moore-neighbor algorithm named as such due to its use of the Moore neighborhood being the 8 connected neighbors (p1, p2 …, p8) around a point (p0).

```
p1  p2 p3
p8  p0 p4
p7  p6 p5
```

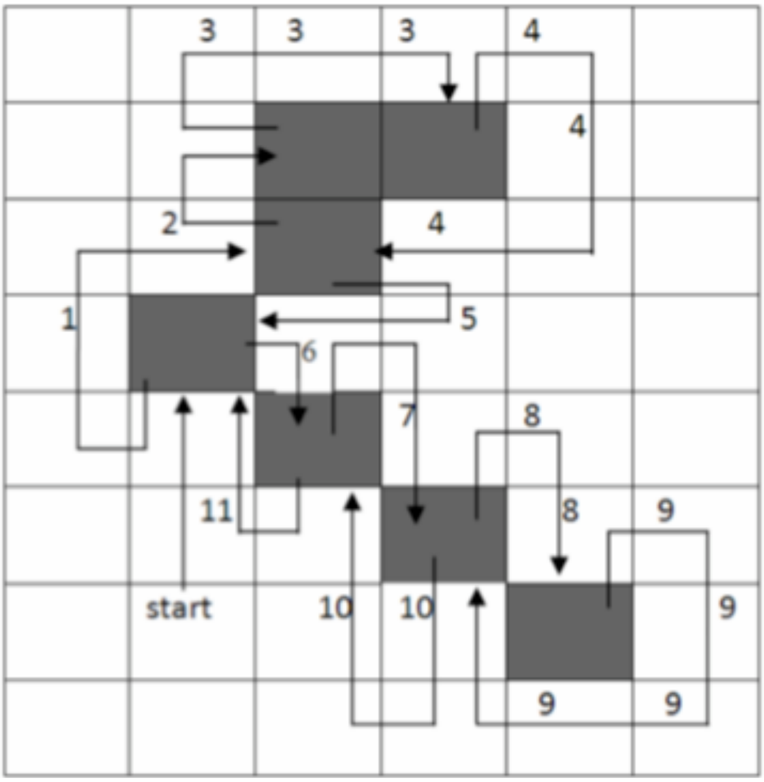
Figure 78: Moore Neighborhood

As a high-level representation of the algorithm the following presents the key steps as provided by the full algorithm in figure 79.

1. Iterate of the binary image until a black pixel is found.
2. Store the start pixel for later reference to be involved in the stopping criteria.
3. Set the start pixel as centre of Moore neighborhood
4. Go back to the pixel previous to the start pixel was found.
5. Move in a clockwise(or anticlockwise) direction around the centre pixel of the neighborhood considering each pixel.
6. Should the considered pixel be the start pixel, conciser exiting the procedure.
7. Where the considered pixel is black, make this the centre pixel and set the considered pixel to the previously considered pixel.
8. repeat 4.

Figure 79: Moore Neighbor Algorithm interpretation

Figure shows the 8 neighbors of p0 are ordered p1, p2, …, p8 and represents the order in which considered pixels around p0 are visited.



80: Working of Moore Neighbor tracing algorithm. (Samet and Hancer, 2012)

(Rajashekar Reddy, Amarnadh, and Bhaskar, 2012) details the following algorithm.

```
Input: A square tessellation, T, containing a connected component P of black cells.
Output: A sequence B (b 1 , b 2 ,..., b k ) of boundary pixels i.e. the contour.

Define (a) to be the Moore neighborhood of pixel a.
Let p denote the current boundary pixel.
Let c denote the current pixel under consideration i.e. c is in M (p).

Begin
Set B to be empty.

From bottom to top and left to right scan the cells of T until a black pixel, s, of
P is found.

    Insert s in B.
    Set the current boundary point p to s i.e. p=s
    Backtrack i.e. move to the pixel from which s was entered.

    Set c to be the next clockwise pixel in M(p).
        While c not equal to s
        do
            If c is black
                insert c in B
                set p=c
                backtrack (move the current pixel c to the pixel from which p was
entered)
            else
             advance the current pixel c to the next clockwise pixel in M(p)
        end while
End
```

Figure 81: Moore's Neighbor tracing algorithm (Rajashekar Reddy, Amarnadh, and Bhaskar, 2012)

From this algorithm the following pseudo code has been developed.

```
// Moore Neighborhood Offsets.
Offsets[] = {(-1,1), (0,1),  (1,1),
             (-1,0), (0,0),  (1,0)
             (-1,-1),(0,-1), (1,-1)}

traced = [];

for each pixel x, y
    if pixel == black
        matched? = yes
        start = pixel
        traced[0] = start
    else
        last = pixel

    if matched? exit loop

center = start
consideration = last
consideration offset = last - start.

while stopping criteria has not be met
    if consideration is black
        traced add consideration
        center = consideration
        consideration = current + next offset.
    else
        backtrack = consideration
        consideration = current + next offset.
```

Figure 81: Moore Neighbor Pseudo Code

IMPLEMENTATION.

The first part of the implementation of this algorithm represents step 1 and 2 detailed in table:

As with spatial filtered developed and detailed on 5.2, a representation is made from the provided subject. Each pixel of the representation is scrutinized in order to find the first black pixel, the coordinates of which are stored. At each unsuccessful pass, reference is maintained to the last unsuccessful pixel match, this will determine the first backtrack position.

```
- (NSArray*) mooreNeighborContourTraceOfImage:(NSImage*)image
{
    /* get the bitmap data from image representation. */

    int width = image.size.width;
    int height = image.size.height;
    int searchPixel = 0; // to find black pixels.
    BOOL match = NO;
    int x = 0, y = 0;

    NSPoint start, last;
    NSMutableArray* points = [[NSMutableArray alloc] init];

    for (y = 0; y < height; y++ )
    {
        for (x = 0; x < width; x++ )
        {
            index = x + y * width;

            if ( data[index] == searchPixel )
            {
                match = YES;
                start = NSMakePoint(x, y);
                NSValue *p = [NSValue valueWithPoint:start];
                [points addObject:p];
                break;
            } else {
                last = NSMakePoint(x, y);
            }

        }
        if ( match ) break;
    }
```

Figure 82: Moore Neighbor Implementation.

Once the first black pixels has been found, the starting values for the trace are determined. The `backtrackOffset` is calculated as the difference between the matched pixel and the last successful pixel and is used to find the current position in the p1, p2, p3, …, p8 offset order, this will determine the next offset around p0 that will be scrutinised. Here step 3 and 4 of table: are represented.

```
    int next = 0;
    NSPoint offsets[] = {NSMakePoint(-1, -1),
                         NSMakePoint(-1, 0),
                         NSMakePoint(-1, 1),
                         NSMakePoint(0, 1),
                         NSMakePoint(1, 1),
                         NSMakePoint(1, 0),
                         NSMakePoint(1, -1),
                         NSMakePoint(0, -1)};

    NSPoint current = start;
    NSPoint consider = last;
    NSPoint backtrackPosition = last;
    NSPoint backtrackOffset = NSMakePoint(last.x - start.x, last.y - start.y);

    // find the position
    for ( int i = 0; i < 8; i++ )
    {
        if ( CGPointEqualToPoint(backtrackOffset, offsets[i]) )
        {
            next = i;
        }
    }
```

Figure 83: Moore Neighbor Implementation Continued

The trace will now begin and continue until the stopping criteria is met, representing steps 4 and 5.

At each successful match of a black pixel the points of the pixel are collected. Although duplicate points are not wanted for the purpose of creating the letterform template, rather then query the collection at each successful match, the collection will be reduced to a ordered set before being returned. Collecting each point regardless of duplication also ensures the order in which pixels are collected will be maintained, this will be an important factor when reducing the collected points from a set of pixel coordinates to bezier curves.

```
    BOOL run = YES;
    while ( run )
    {
        index = consider.x + consider.y * width;

        if ( data[index] == searchPixel )
        {
            // stopping criteria
```

```
            // stopping criteria
            if ( CGPointEqualToPoint(start, consider) )
            {
                run = NO;
                break;
            }

            // collect the point.
            NSValue *val = [[NSValue alloc] init];
            val = [NSValue valueWithPoint:consider];
            [points addObject:val];

            // reset the center
            current = consider;
            backtrackOffset = NSMakePoint(backtrackPosition.x - current.x,
backtrackPosition.y - current.y);

            // find the offset for the backtrack position
            for ( int i = 0; i < 8; i++ )
            {
                if ( CGPointEqualToPoint(backtrackOffset, offsets[i]) )
                {
                    next = i;
                    break;
                }
            }
            consider = NSMakePoint(current.x + offsets[next].x, current.y +
offsets[next].y);
        } else {
            // store the last position to concider
            backtrackPosition = consider;

            // move to the next offset
            next++;
            if ( next == 8 ) next = 0;
            consider = NSMakePoint(current.x + offsets[next].x, current.y +
offsets[next].y);
        }
    }
```

Figure 84: Moore Neighbor Trace Loop Implementation

In order to remove duplicate values `[NSOrderedSet orderedSetWithArray:points]` provides unique values while maintaining order.

```
    NSOrderedSet* set = [NSOrderedSet orderedSetWithArray:points];
    NSArray* distinctPoints = [set array];

    return distinctPoints;
```

Figure 85: Reducing to distinct points.

RESULT.

To test the result of this implementation a subject letterform from the typeface set that will be the basis of the letterform template is thresholded in order to remove aliasing. The subject is then thinned using the Zhang Suen algorithm to reduce the subject representation down to a single pixel width.

Figure 86: Starting letterform subject (thresholded to remove aliasing)

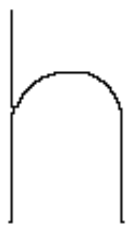


Figure 87: Thinned subject

The data produced from the trace has been drawn to the screen point by point using the `NSBezierPath` class of the Cocoa framework in order to understand the success of the trace.

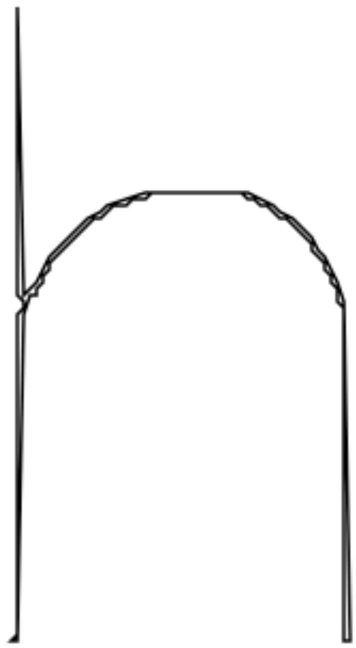


Figure 88: Traced result

As shown in figure 88 although the application of the tracing algorithms has correctly traced the thinned subject, the result has not been as desired. As stated … the desired was to produce a single line representation of the subject, this would then be used as a template from manipulation. However, due to failure to fully consider the results produced by the thinning of the original thresholded subject and data collected from the trace. As clearly displayed in Figure 89, the structure supplied by the thinning operation where curves and diagonal lines make up the structure these are joined by a two pixel thickness.

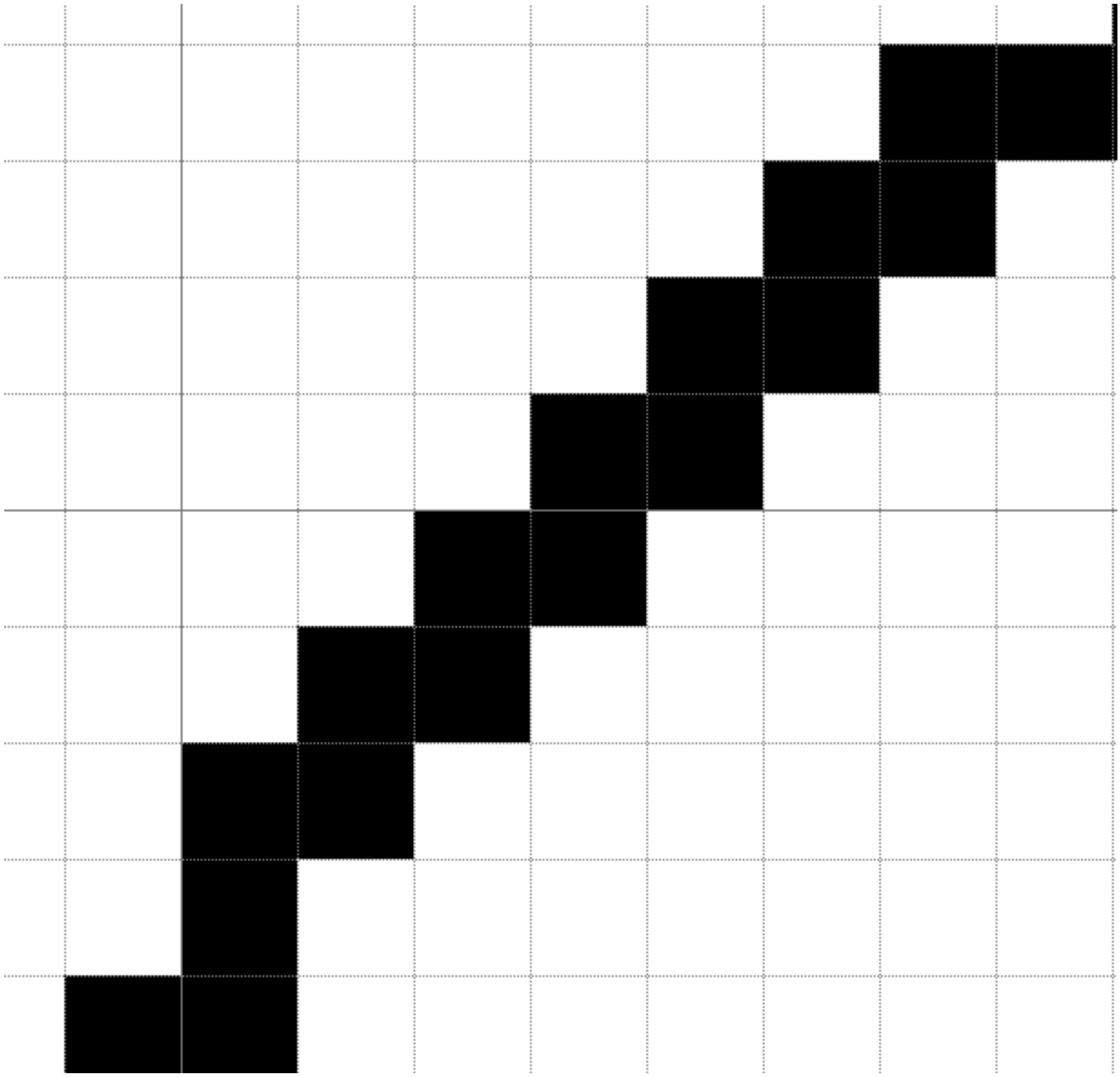


Figure 89: Thinned subject

Therefore, the tracing of along one side of the structure and then the other side of the structure would not meet on duplicate points, meaning both sets of points would be maintained after removal of duplicate points. (Figure 90)