CS4670 Final Report

Hand Gesture Detection and Recognition for Human-Computer Interaction

By,

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I. Abstract:

This project deals with the detection and recognition of hand gestures. Images of the hand gestures are taken using a Nokia N900 cell phone and matched with the images in the database and the best match is returned. Gesture recognition is one of the essential techniques to build user-friendly interfaces. For example, a robot that can recognize hand gestures can take commands from humans, and for those who are unable to speak or hear, having a robot that can recognize sign language would allow them to communicate with it. Hand gesture recognition could help in video gaming by allowing players to interact with the game using gestures instead of using a controller. However, such an algorithm needs to be more robust to account for the myriad of possible hand positions in three-dimensional space. It also needs to work with video rather than static images. That is beyond the scope of our project.

II. Overview:

Distance Transform: The distance transform is an operator normally only applied to binary images. The result of the transform is a grayscale image that looks similar to the input image, except that the intensities of points inside foreground regions are changed to show the distance to the closest boundary from each point.

For example,

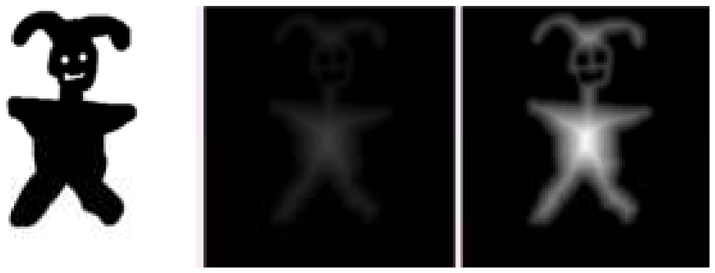


Image was taken from "Distance Transform." David Coeurjolly.

In the above image, each pixel *p* of the object is labeled by the distance to the closest point *q* in the background.

Contours: Contours are sequences of points defining a line/curve in an image. Contour matching can be used to classify image objects.

Database: Contains the images of various hand gestures.

Moments: Image moments are useful to describe objects after segmentation. Simple properties of the image, which are found via image moments, include area (or total intensity), its centroid and information about its orientation.

Ratio of the two distance transformed images of the same size = (No of pixels whose difference is zero or less than a certain threshold) / (Total number of pixels in the distance transformed image)

III. Design:

Step 1: User takes a picture of the hand to be tested either through the cell phone camera or from the Internet.

Step 2: The image is converted into gray scale and smoothed using a Gaussian kernel.

Step 3: Convert the gray scale image into a binary image. Set a threshold so that the pixels that are above a certain intensity are set to white and those below are set to black.

Step 4: Find contours, then remove noise and smooth the edges to smooth big contours and melt numerous small contours.

Step 5: The largest contour is selected as a target.

Step 6: The angles of inclination of the contours and also the location of the center of the contour with respect to the center of the image are obtained through the bounding box information around the contour.

Step 7: The hand contours inside the bounding boxes are extracted and rotated in such a way that the bounding boxes are made upright (inclination angle is 0) so that matching becomes easy.

Step 8: Both the images are scaled so that their widths are set to the greater of the two widths and their heights are set to the greater of the two heights. This is done so that the images are the same size.

Step 9: The distance transform of both the query image and the candidate images are computed and the best match is returned.

IV. Constraints:

1. The picture of the hand must be taken against a dark background

2. The program recognizes a limited number of gestures as long as there are gestures similar to them in the database.

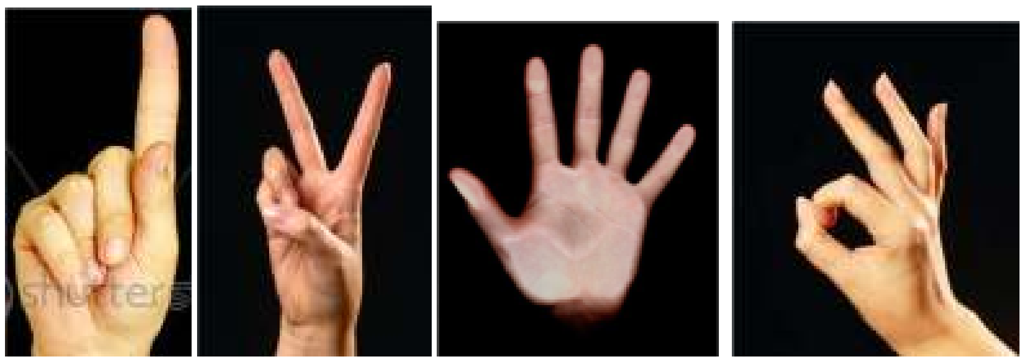
3. We must have each gesture with at least four orientations at 90 degrees each to return the best match.

V. Sample Images contained in the Database:

In our experiment, we will be identifying limited number of gestures, which is shown as below. The query image even with slight orientation (+ or – 30 degrees) will be able to match with one of the image contained in the database.

Images with different orientations are present within the database. In order to maintain performance, we have a limited number of gesture images in our database.

New gesture images can be added to the database without any pre-processing.

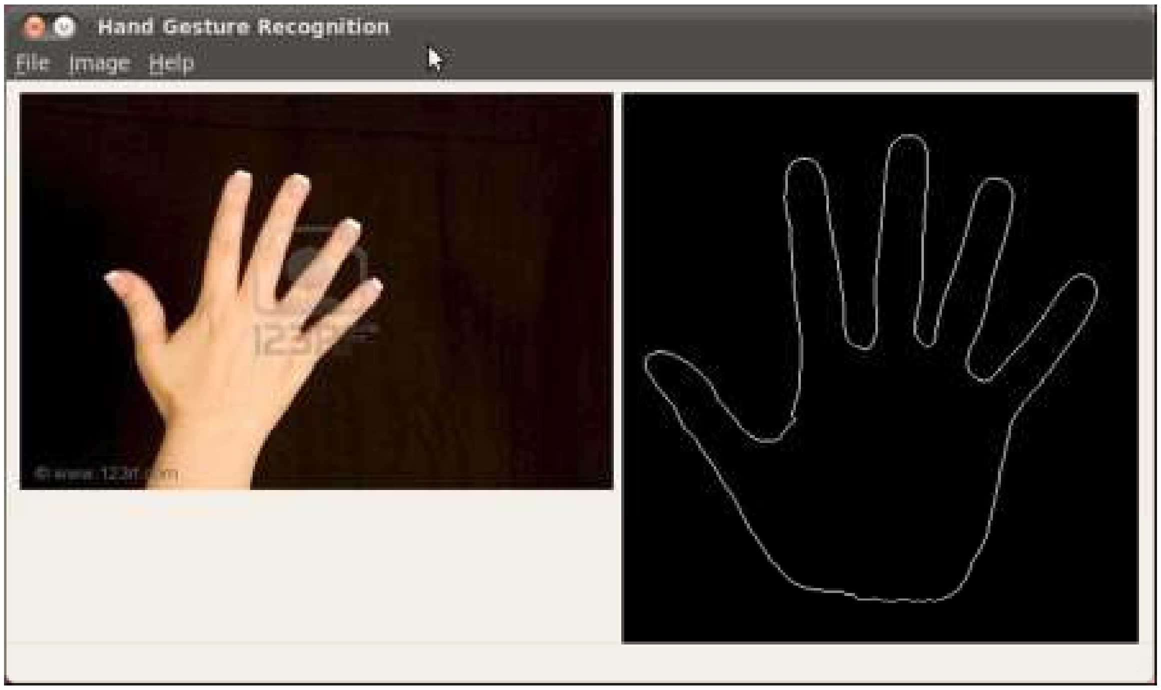


(a) Few of the images in the database.

VI. Results:

Case 1:

(A)



In the above case, we can see the query image on the left hand side and the matched candidate image from the database on the right.

(a) Candidate Image in the database

Both the images are converted to binary images and the contours are computed. Using the bounding box information obtained from the contours, we get the angle of inclination of the contours and also, the center, height, and width of the bounding box. The results obtained after rotating and scaling the query and candidate images are:

(a) Rotated and scaled query image

(b) Rotated and scaled candidate image

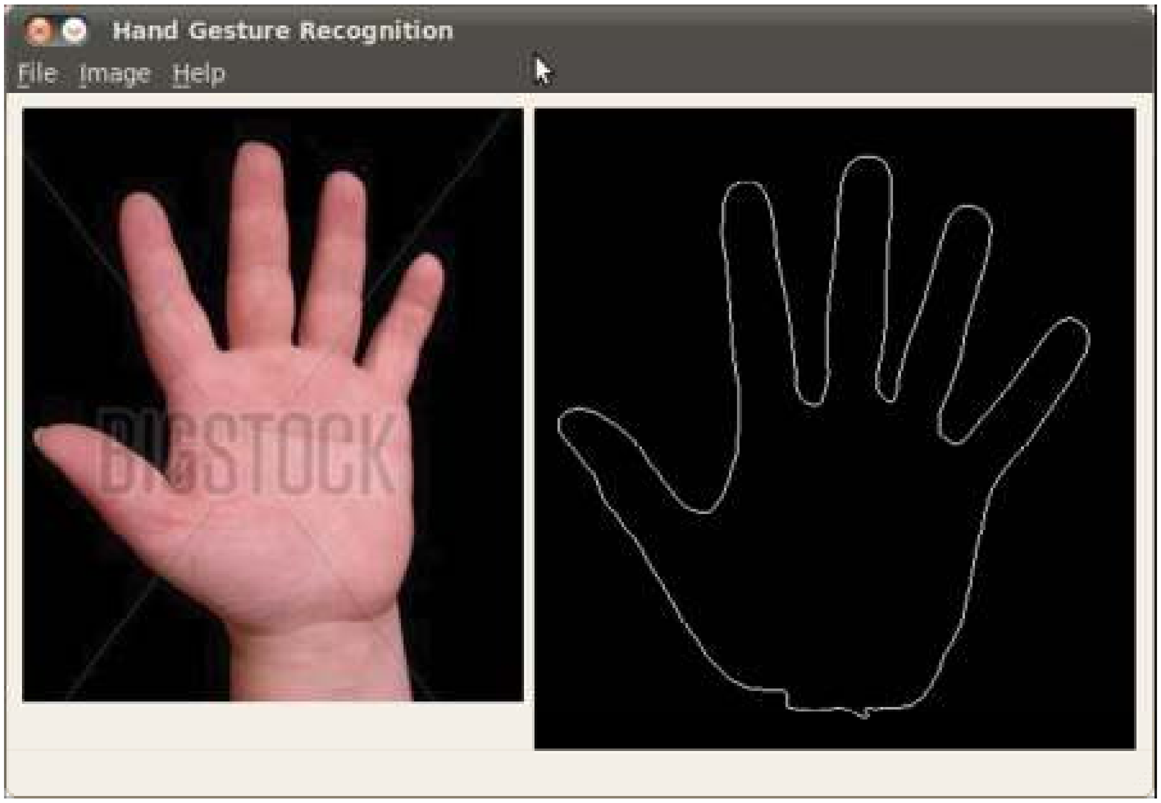
Now, the distance transforms of both the query image and the candidate images are computed as follows:

(a) Distance Transform of the query image

(b) Distance Transform of the candidate image

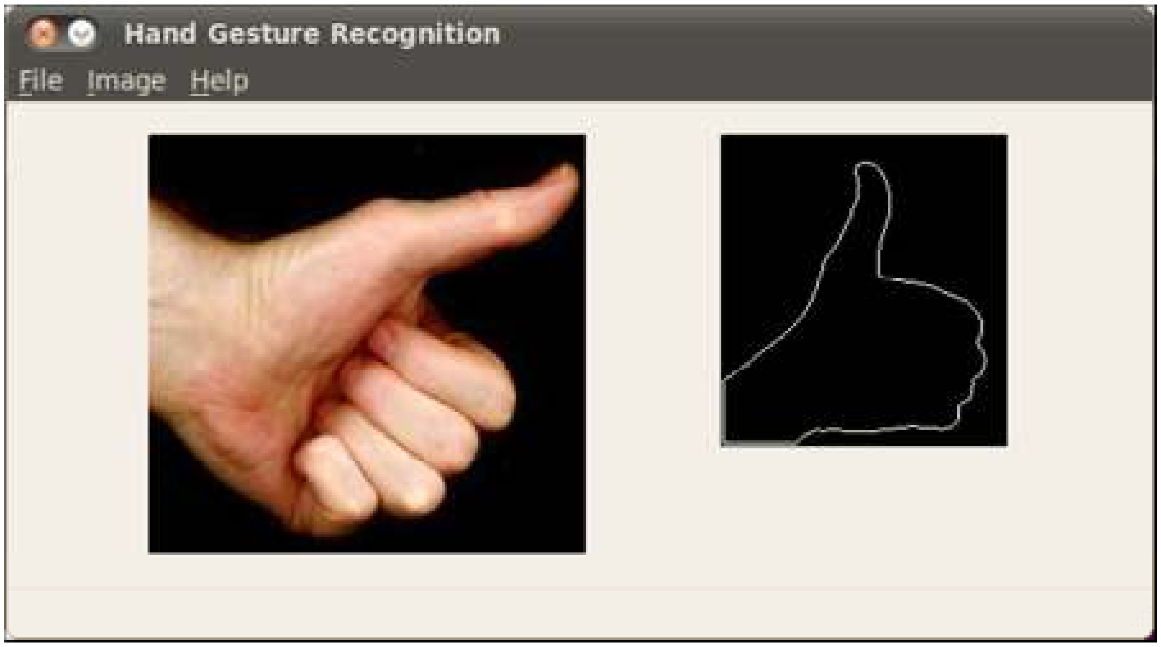
Now, the difference of the two image images is computed and the ratio of the match is found by the number of pixels whose difference between the two corresponding pixels is zero or below a certain threshold divided by the total number of pixels in one of the image. If the ratio is above 65% then the candidate image is determined as a match and returned.

(B)

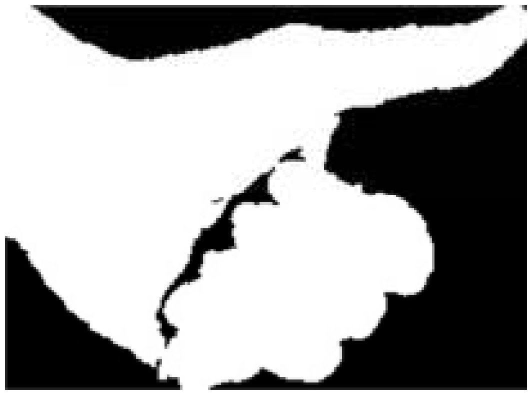


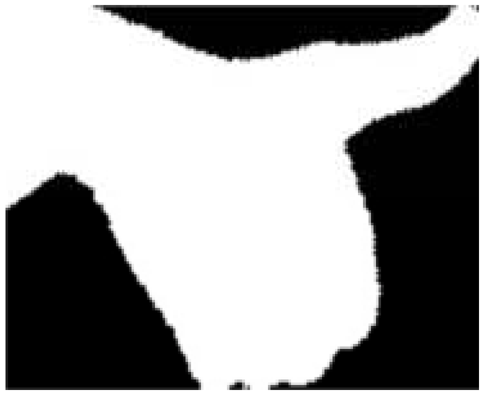
A similar case as Case 1 (A)

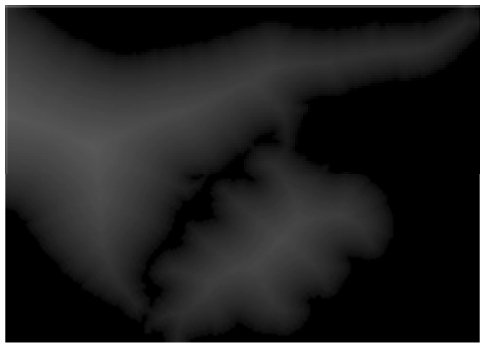
Case 2:

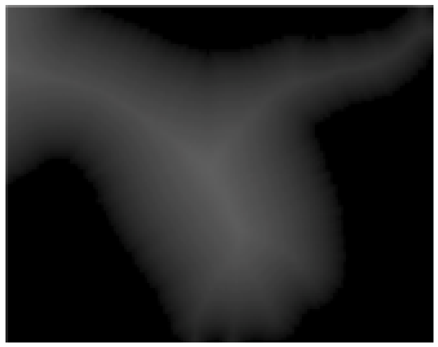


In the above case, the hand gesture on the left hand side is slightly tilted and still the right gesture from the database is returned.

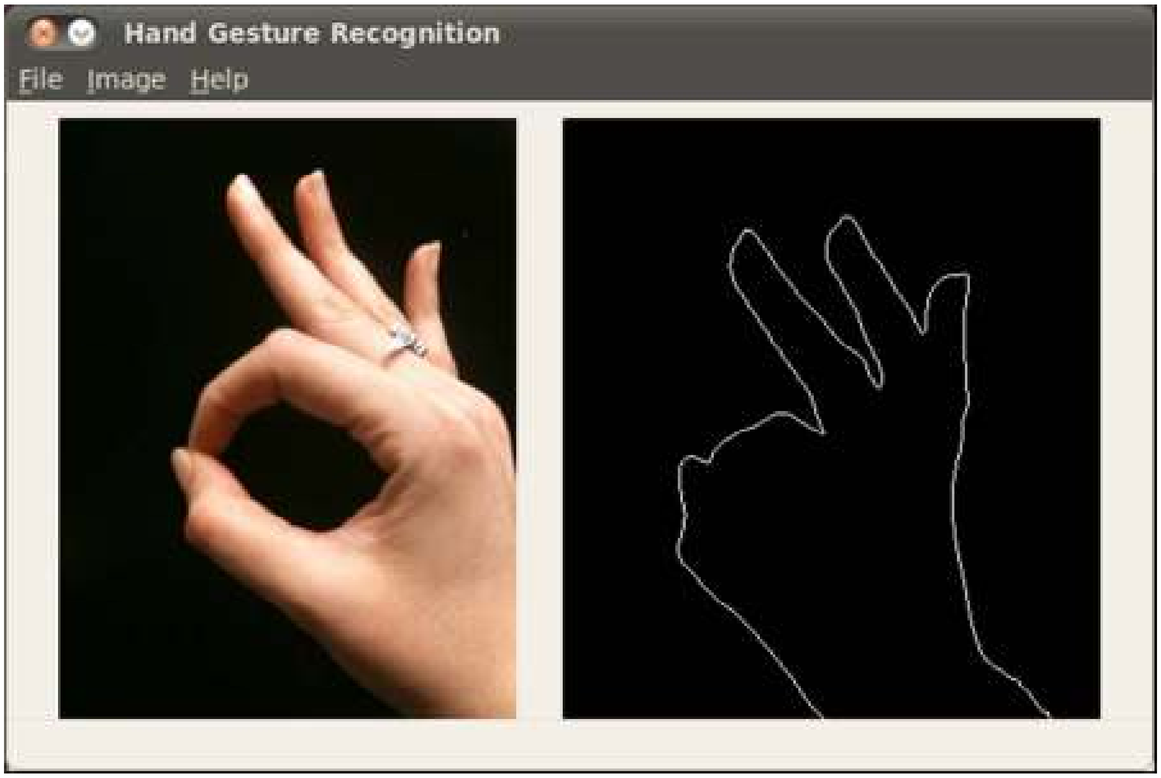

(a) The rotated and scaled image of the query image

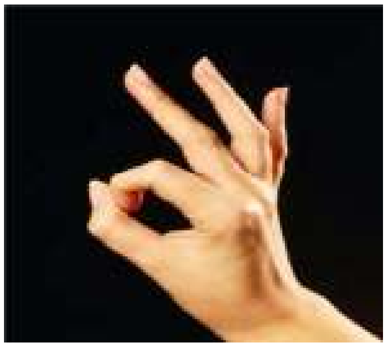

(b) The rotated and scaled image of the candidate image


(a) Distance Transform of the query image


(b) Distance Transform of the candidate image

Case 3:





(a) Candidate image in the database

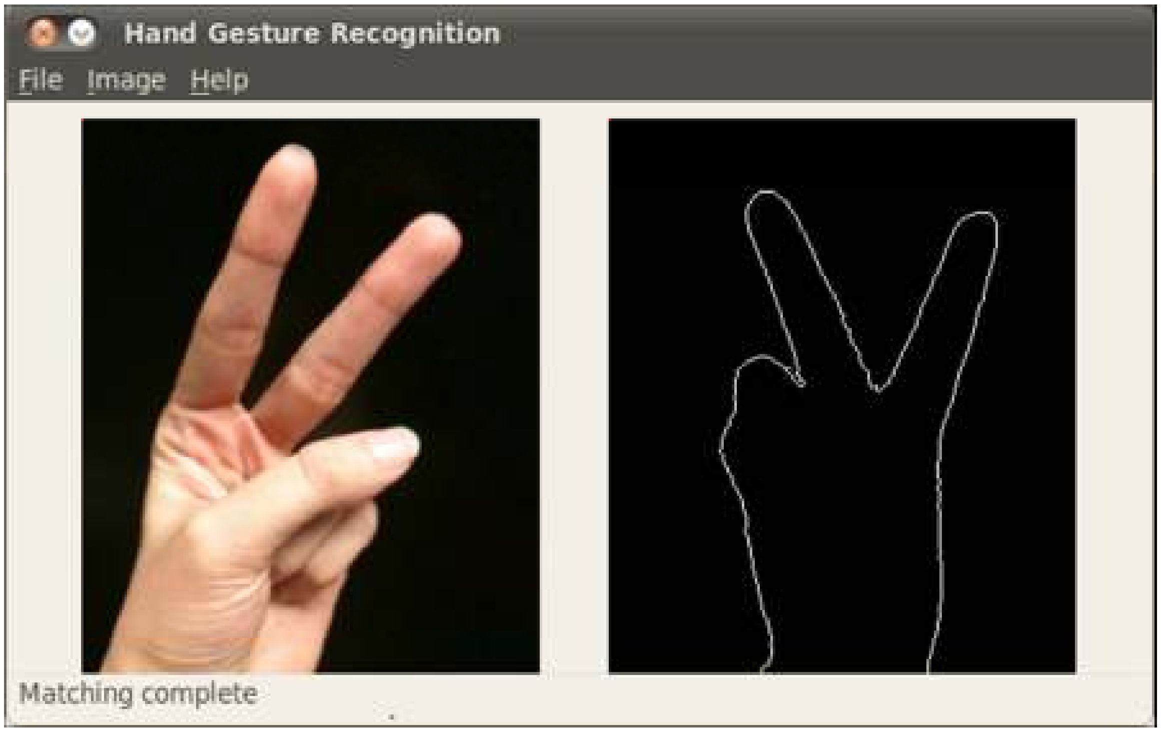
(a) Rotated and scaled image of the query image

(b) Rotated and scaled image of the candidate image

(a) Distance Transform image of the query image

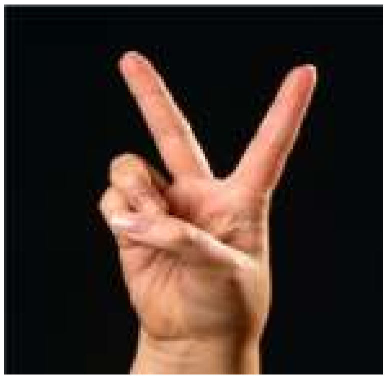
(b) Distance Transform image of the candidate image

Case 4:

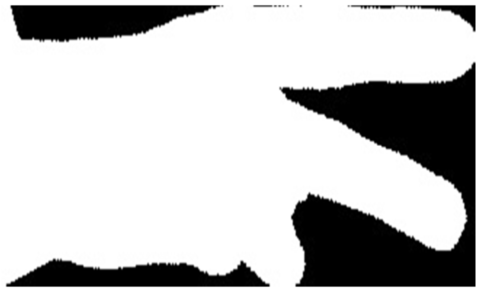


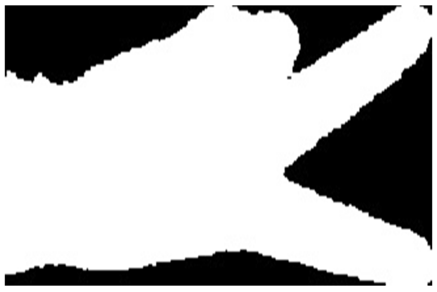
Matching complete

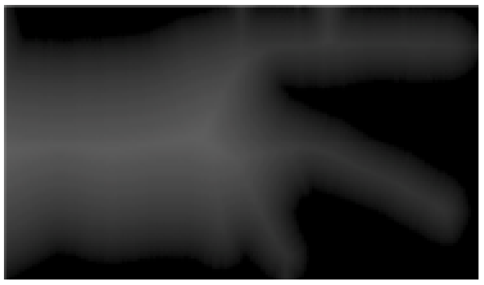
In the above case, the program returns the right gesture image, even though the database doesn't contain the left hand gesture as in the query image because, the candidate image passes the ratio test.

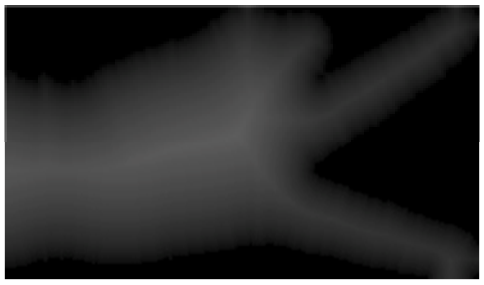


(a) Candidate image in the database

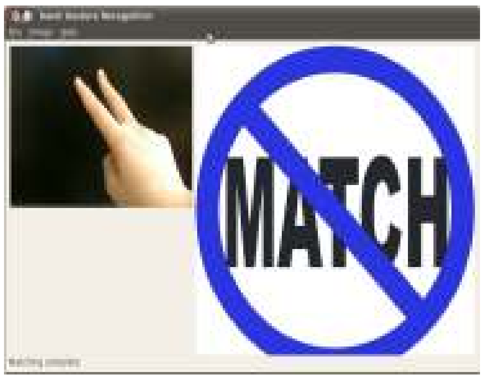

(a) Rotated and scaled query image


(b) Rotated and scaled candidate image


(a) Distance Transform of the query image

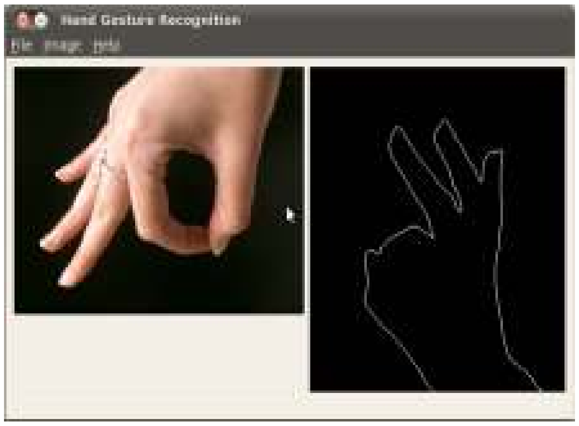

(b) Distance Transform of the candidate image

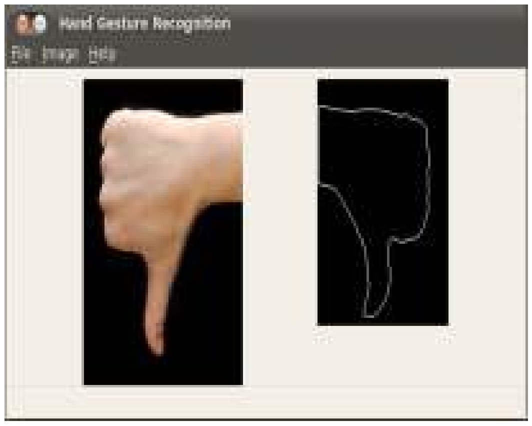
Case 5:



If a similar gesture as the query image is not present in the database then a no-match is returned.

Case 6:



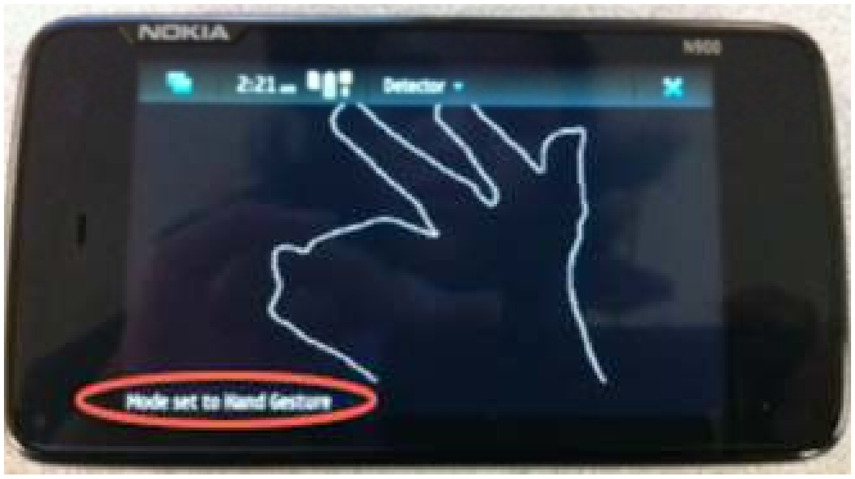


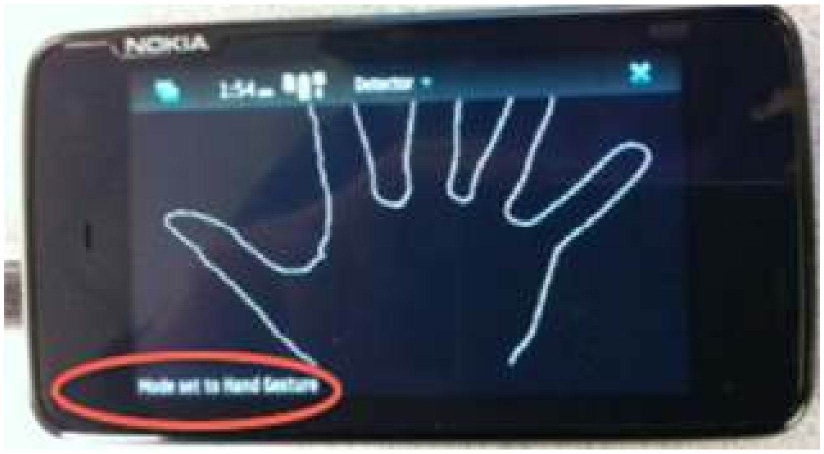
Cases of False Positives. The right gesture is returned but not logical.

VII. Results on the Cell Phone:

We got similar results on the cell phone as well and the performed almost close to that on the desktop.

Screenshots on the cell phone:





The cell phone code was adapted from Project 2b.

VIII. Conclusion:

Based on our observation, we can conclude that the results mainly depend on:

1. Threshold, while converting the gray image to the binary image and finding contours. For example found that uneven lighting across the picture of the hand caused the algorithm to draw contours around the darkened areas in addition to the contour around the hand. Changing the threshold prevented that from happening.

2. The threshold for the Ratio test while matching the distance transformed images. The ratio we used

3. The background, which must preferably be black to get accurate results.

4. An additional check on moments is useful to check if the contours of both the query image and the candidate image have the same shape.

5. In order to maintain performance the database contains images of small dimensions.

IX. Program description:

We have adapted our code from the code of Project 2b.

FeaturesUI.cpp: has been customized to get the GUI as shown in the above images.

FeaturesDoc.cpp: contains the actual logic required for this project.

Features.cpp: contains the logic for the cell phone

The main functions in the program are described below.

X. Future Work:

1. Skin segmentation algorithm can be implemented to extract the skin pixels

2. Can have more images of gestures added to the database for the program to recognize

3. Captions can be added to the gestures recognized

XI. OpenCV Functions used in the program:

1. To compute the distance transform

void cvDistanceTransform(. . .)

2. To find the number of Contours in the image

int cvFindContours(. . .)

2. To compute the moments

double cvMatchShapes (. . .)

3. To find bounding box's height, width and center

cvMinAreaRect2(. . .)

4. To find the area of the contour

cvContourArea (…)

XII. Functions implemented by our own:

1. rotate_inverse_warp()

This function extracts the image contained within the bounding box, rotates the image in the negative direction (the angle is obtained from the bounding box) and creates a new image.

2. distance transform

This function uses the algorithm described in "Euclidean Distance Transform," which replaces binary image pixel intensities with values equal to their Euclidean distance from the nearest edge. While we implemented this function, we were unable to get it to work completely, so we ended up using OpenCV's cvDistTransform().

XIII. Distribution of Work

Work done by Jonathan:

Wrote functions for rotation, scaling, and distance transform. Debugged code, worked on the report, the presentation slides, and presented the slides during the final presentation.

Work done by Roopa:

Wrote the main pipeline for the project and also, got the program working on the cell phone. Debugged code, worked on the report, the presentation slides, and presented the slides during the final presentation.

XIV: Platform

Ubuntu, OpenCV, C++, Nokia900 (phone device)

XV: Outside Sources

1. The hand gesture images were taken from Google Images.
2. "Distance Transform." David Coeurjolly.
3. Euclidean Distance Transform, from http://www.cs.auckland.ac.nz/~rklette

4. Learning OpenCV. O'Reilly
5. “Hand Gesture Recognition for Human-Machine Interaction.” Journal of WSCG, Vol.12, No.1-3, ISSN 1213-6972

Acknowledgements

We’d like to thank Professor Noah Snavely and Kevin Matzen for guiding and assisting us during this project and the course.

XVI. Program Listing:

All the openCV functions that are used are marked in blue.

```
/* metric to compute the distance transform */

int found = 0;
int dist_type = CV_DIST_L2;
int mask_size = CV_DIST_MASK_5;

/* This is the main function that computes the matches. The query image
//and  the  database  image  are  pre-processed.  Both  the  images  are
//converted to binary images and the contours are computed. The openCV
//function  is  used  to  compute  the  contours  and  it  also  returns  the
//bounding  box  information  like  the  height  and  the  width  of  the
//bounding box and also the center of the bounding box with respect to
//the  image.  In  addition  it  also  returns  the  angle  of  inclination  of
//the bounding box. This information is used to rotate the binary image
//in  order  to  compute  the  distance  transform  of  the  images.  The  pixel
//values  of  the  distance-transformed  images  are  subtracted  to  compute
//the  match.  If  the  pixel  difference  is  zero  or  less  than  a  certain
//threshold,  then  it  is  determined  as  a  match.  The  number  of  such
//pixels  that  satisfy  this  criterion  is  counted  and  the  ratio  of  this
//count  to  the  total  number  of  pixels  in  the  image  gives  us  the  ratio.
//In  our  program  we  have  set  the  threshold  to  be  at  least  65%.  If  the
//ratio  is  greater  than  65%  then  the  candidate  image  in  consideration
//is  selected  as  a  match.  In  addition,  the  moment  value  is  also
//computed and set to between 0.0 and 0.22 to find the best match. */

IplImage* computeMatch(IplImage *src_img, IplImage *cmp_img)
{

    //cvShowImage("src img", src_img);
    //cvShowImage("cmp_img", cmp_img);
    //convert the image to gray
    IplImage* gray_img=0;
    gray_img = cvCreateImage(cvSize(src_img->width, src_img-
>height),IPL_DEPTH_8U,1);
    cvCvtColor ( src_img, gray_img, CV_BGR2GRAY);
    //for another image
    IplImage* gray_img2 = 0;
    gray_img2 = cvCreateImage(cvSize(cmp_img->width, cmp_img-
>height),IPL_DEPTH_8U,1);
    cvCvtColor ( cmp_img, gray_img2, CV_BGR2GRAY);

    /*****************/

    //Smooth the image
    IplImage* gray_smooth_img=0;
    gray_smooth_img = cvCreateImage(cvSize(src_img->width, src_img-
>height),IPL_DEPTH_8U,1);
    cvSmooth( gray_img, gray_smooth_img, CV_GAUSSIAN, 5, 5 );

    //Smooth the other image
    IplImage* gray_smooth_img2=0;
    gray_smooth_img2 = cvCreateImage(cvSize(cmp_img->width, cmp_img-
>height),IPL_DEPTH_8U,1);
    cvSmooth( gray_img2, gray_smooth_img2, CV_GAUSSIAN, 5, 5 );

    /*****************/

    //lets apply threshold
    IplImage* gray_ath_img=0;
    gray_ath_img = cvCreateImage(cvSize(src_img->width, src_img-
>height),IPL_DEPTH_8U,1);
    cvThreshold(gray_smooth_img,gray_ath_img, 10
,255,CV_THRESH_BINARY);
    IplImage *bin_img1 = cvCloneImage(gray_ath_img);

    //lets apply threshold to another image
    IplImage* gray_ath_img2=0;
    gray_ath_img2 = cvCreateImage(cvSize(cmp_img->width, cmp_img-
>height),IPL_DEPTH_8U,1);
    cvThreshold(gray_smooth_img2,gray_ath_img2, 10
,255,CV_THRESH_BINARY);
    IplImage *bin_img2 = cvCloneImage(gray_ath_img2);

    /*******************/

    // lets apply the canny edge detector
    IplImage* can_img=0;
    can_img = cvCreateImage(cvSize(src_img->width, src_img-
>height),IPL_DEPTH_8U,1);
    cvCanny( gray_ath_img, can_img, 50, 100, 3 );
    //cvShowImage("Canny Image", can_img);

    IplImage* can_img2=0;
    can_img2 = cvCreateImage(cvSize(cmp_img->width, cmp_img-
>height),IPL_DEPTH_8U,1);
    cvCanny( gray_ath_img2, can_img2, 50, 100, 3 );
    //cvShowImage("Canny Image", can_img2);

    /******************/
    // We are finding the contours here
    // find the contours of the query image
    CvMemStorage* g_storage = NULL;
    //IplImage* contour_img=0;
    if( g_storage==NULL ) {
      //contour_img = cvCreateImage(cvSize(src_img->width, src_img-
>height),IPL_DEPTH_8U,1);
      g_storage = cvCreateMemStorage(0);
    }
    else
    {
      cvClearMemStorage( g_storage );
    }

    CvSeq* contour = 0;
    CvSeq* first_contour = NULL;
    int nc = 0; // total number of contours -- roopa
    nc = cvFindContours( gray_ath_img, g_storage, &first_contour,
                              sizeof(CvContour), CV_RETR_LIST);

    //printf( "Total Contours Detected in the Query Image: %d\n", nc );

    double max_area = 0.0;
    for( CvSeq* c=first_contour; c!=NULL; c=c->h_next )
    {
      double area = cvContourArea(c, CV_WHOLE_SEQ);
      if (area < max_area)
      {
            max_area = area;
            contour = c;
      }
    }

    //printf("max area = %f\t", max_area);

    cvZero(gray_ath_img);
    if(contour)
    {
      cvDrawContours( gray_ath_img, contour, cvScalarAll(255),
cvScalarAll(255), 100);
    }

    // find the contours of the candidate image
    CvMemStorage* g_storage2 = NULL;
    //IplImage* contour_img2 =0;
    if( g_storage2==NULL ) {
      g_storage2 = cvCreateMemStorage(0);
    }
    else
    {
      cvClearMemStorage( g_storage2 );
    }

    //cvShowImage("Contour Image 1", gray_ath_img);

    CvSeq* contour2 = 0;
    CvSeq* first_contour2 = NULL;
    int nc2 = 0; // total number of contours
    nc2 = cvFindContours( gray_ath_img2, g_storage2, &first_contour2,
sizeof(CvContour), CV_RETR_LIST);
    //printf( "Total Contours Detected in the Candidate Image: %d\n",
nc2 );

    double max_area2 = 0.0;
    for( CvSeq* c2=first_contour2; c2!=NULL; c2=c2->h_next )
    {
      double area2 = cvContourArea(c2, CV_WHOLE_SEQ);
      if (area2 < max_area2)
      {
            max_area2 = area2;
            contour2 = c2;
      }
    }


    //printf("max area = %f\n", max_area2);

    cvZero(gray_ath_img2);

    if(contour2)
    {
      cvDrawContours( gray_ath_img2, contour2, cvScalarAll(255),
cvScalarAll(255), 100);
    }

    /**************************/


    // we get the bounding box information here
    // for the Query Image

    CvBox2D  box;
    box = cvMinAreaRect2(contour, 0);
    float ang;
    ang = box.angle;

    // for size
    CvSize2D32f siz = box.size;
    double wid = siz.width;
    double hei = siz.height;
    /*
    printf("Width and Height of Query_Image Box\n");
    printf("Width : %f     Height : %f  Angle : %f\n", wid, hei, ang);
    */

    //find the center
    CvPoint2D32f cen = box.center;
    double x = cen.x;
    double y = cen.y;
    //printf("Center (x, y) : (%f, %f)", x, y);

    //for the candidate image
    CvBox2D  box2;
    box2 = cvMinAreaRect2(contour2, 0);
    float ang2;
    ang2 = box2.angle;

    // for size
    CvSize2D32f siz2 = box2.size;
    double wid2 = siz2.width;
    double hei2 = siz2.height;
    /*
    printf("Width and Height of Query_Image Box\n");
    printf("Width : %f     Height : %f  Angle : %f\n", wid2, hei2,
ang2);
    */

    //find the center
    CvPoint2D32f cen2 = box2.center;
    double x2 = cen.x;
    double y2 = cen.y;
    //printf("Center (x, y) : (%f, %f)", x2, y2);

    /********************/
    IplImage* res = cvCreateImage(cvSize(cmp_img->width, cmp_img-
>height),IPL_DEPTH_8U,3);
    res = convert3channel(gray_ath_img2);

// rotate and scale the image
IplImage* rot_sc_img = inverse_warp_rotate(bin_img1, box);//.angle);
IplImage* rot_sc_img2 = inverse_warp_rotate(bin_img2, box2);//.angle *
-1);


int sw, sh;

if (rot_sc_img->width > rot_sc_img2->width)
    sw = rot_sc_img->width;
else
    sw = rot_sc_img2->width;


if (rot_sc_img->height > rot_sc_img2->height)
    sh = rot_sc_img->height;
else
    sh = rot_sc_img2->height;


scale_img1 = cvCreateImage(cvSize(sw, sh),rot_sc_img->depth,
rot_sc_img->nChannels);
scale_img2 = cvCreateImage(cvSize(sw, sh),rot_sc_img2->depth,
rot_sc_img2->nChannels);

// resize the rotated image
cvResize(rot_sc_img, scale_img1);
cvResize(rot_sc_img2, scale_img2);

cvSaveImage( "s1.jpg",scale_img1);
cvSaveImage( "s2.jpg",scale_img2);

// we are computing the moments here
```

```
double val = 0.0;
val = cvMatchShapes( contour, contour2, CV_CONTOURS_MATCH_I1,  0);
std :: cout << " moment val : " << val << endl;

// convert the scaled image to 3 channels

IplImage *rotsc1 = convert3channel(scale_img1);
IplImage *rotsc2 = convert3channel(scale_img2);


cvSaveImage("rot1.jpg", rotsc1);
cvSaveImage("rot2.jpg", rotsc2);


//cvShowImage(" rotsc1",  rotsc1);
//cvShowImage(" rotsc2",  rotsc2);

IplImage* dt1 = computeDistTransform(1);
IplImage* dt2 = computeDistTransform(2);

cvSaveImage("dt1.jpg", dt1);
cvSaveImage("dt22.jpg", dt2);


//cvShowImage("dt1", dt1);
//cvShowImage("dt2", dt2);

int count = 0;
int maxcount = dt1->width * dt1->height;


CvScalar sdt1, sdt2;
for (int i=0; i < dt1->height; i++)
{
    for(int j=0; j < dt1->width; j++)
    {

         sdt1 = cvGet2D(dt1, i, j);
         sdt2 = cvGet2D(dt2, i, j);
         if(abs(sdt1.val[0] - sdt2.val[0]) < 35) // threshold
             count ++;


    }
}

float ratio = (float)count/(float)maxcount;
std :: cout << "\tcount : " <<  count;
std :: cout << "\tmaxcount : " <<  maxcount;
std :: cout << "\tratio : " <<  ratio;
std :: cout << endl;

if ( (ratio >= 0.5 and ratio <= 1.0) and (val >= 0.0 and val <=0.4))
//0.2
{
    std::cout << "\nMatch Found with DT";
    found = 1;
    return res;
}
else
{
    std::cout << "No Match Found";
    res = cvLoadImage("no_match.jpg");
    //cvShowImage("no match", res);
    return res;

}

}



/* This function computes the distance transform of the binary image */
IplImage* computeDistTransform(int flag)
{

      IplImage* dist = 0;
      IplImage* dist8u1 = 0;
      IplImage* dist8u2 = 0;
      IplImage* dist8u = 0;
      IplImage* dist32s = 0;
      IplImage* edge = 0;
      IplImage* gray = 0;

      if(flag == 1)
      {
            gray = cvLoadImage("rot1.jpg", 0);
            edge  = cvLoadImage("s1.jpg", 0);
      }
      else
      {
            gray = cvLoadImage("rot2.jpg", 0);
            edge  = cvLoadImage("s2.jpg", 0);
      }

      dist8u1 = cvCloneImage( gray );
      dist8u2 = cvCloneImage( gray );
      dist8u = cvCreateImage( cvGetSize(gray), IPL_DEPTH_8U, 3 );
      dist32s = cvCreateImage( cvGetSize(gray), IPL_DEPTH_32S, 1 );

      dist = cvCreateImage( cvGetSize(scale_img1), IPL_DEPTH_32F, 1 );
      int edge_thresh = 50;
      int msize = mask_size;
      int _dist_type = dist_type;
    cvThreshold( gray, edge, (float)edge_thresh, (float)edge_thresh,
CV_THRESH_BINARY );
    cvDistTransform( edge, dist, _dist_type, msize, NULL, NULL );
/*
Note: This is the distance transform function that we wrote, although
it did not work as expected, so we ended up using cvDistTransform()
above.  The definitions for distanceFunction1() and
distanceFunction2(), which are used in this function, are shown below
the function.
       IplImage* dist_origin = cvCloneImage(edge);
```

```
        dist_origin->depth = dist->depth;
        for(int a = 0; a < dist->height; a++)
        {
            cout << "Row " << a << "/" << dist->height << ": ";
            for(int b = 0; b < dist->width; b++)
            {
                CvScalar dTFvalue = cvGet2D(dist_origin, a, b);
                dTFvalue.val[0] = distanceFunction2(b, a, dist_origin);
                cvSet2D(dist, a, b, dTFvalue);
                cout << dTFvalue.val[0] << " ";
            }
            cout << endl;
        }
*/

    cvConvertScale( dist, dist, 150.0, 0 );
    cvPow( dist, dist, 0.5 );
    cvConvertScale( dist, dist32s, 1.0, 0.5 );
    cvAndS( dist32s, cvScalarAll(255), dist32s, 0 );
    cvConvertScale( dist32s, dist8u1, 1, 0 );

      return dist8u1;

}

/* These functions are used in our implementation of the distance
transform algorithm.
int distanceFunction1(int x, int y, IplImage *Input)
{
    if(x >= 0 && x < Input->width && y >= 0 && y < Input->height)
    {
        CvScalar P = cvGet2D(Input, y, x);
        if(P.val[0] > 0)
        {
            return distanceFunction1(x - 1, y, Input) + 1;
        }
        else
        {
            return 0;
        }
    }
}

int distanceFunction2(int x, int y, IplImage *Input)
{
    int df1 = distanceFunction1(x, y, Input);
    if(df1 != 0)
    {
        return min(df1, distanceFunction2(x + 1, y, Input) + 1);
    }
    else
    {
        return 0;
    }
}*/

/* This function uses the Bounding Box information obtained from the
```

```
//contours. The Bounding Box data structure gives us information about
//center of the bounding box, the angle of inclination and also the
//height and width of the bounding box.
//
// A new image is created which is nothing but the image contained
//within the bounding box.
*/

IplImage* inverse_warp_rotate(IplImage* before, CvBox2D box)
{
    float pi = 3.141592653;
   float angle = box.angle * pi/180;
   //float angle = box.angle;

    IplImage* after = cvCreateImage(cvSize(box.size.height,
box.size.width),before->depth, before->nChannels);
/*
    std::cout << "CLONING COMPLETE: Before " << before->width << " " <<
before->height << std::endl;
    std::cout << "CLONING COMPLETE: After " << after->width << " " <<
after->height << std::endl;
    std::cout << "Box2D angle " << angle << std::endl;
    std::cout << "Box2D width " << box.size.width << std::endl;
    std::cout << "Box2D height " << box.size.height << std::endl;
*/
    // selector chooses between nearest neighbor interpolation (0) or
bilinear interpolation (1).
    //after->width = box.size.width;
    //after->height = box.size.height;

    //double b4centerx = ((double)before->width)/2;
   // double b4centery = ((double)before->height)/2;
    double aftercenterx = ((double)after->width)/2;
    double aftercentery = ((double)after->height)/2;

   // std::cout << "Error between centers: (" << aftercenterx -
box.center.x << ", " << aftercentery - box.center.y << ")" <<
std::endl;

    for(int a = 0; a < after->width; a++)
    {
        for(int b = 0; b < after->height; b++)
        {
            // coordinates in downsampled image corresponding to window
center in original image
            double dscoordx = box.center.x;//u/5; //FIXME: don't know
what this should be
            double dscoordy = box.center.y;//v/5;
            double translatedx = a - aftercenterx;
            double translatedy = b - aftercentery;
        double rotatedx = translatedx * cos(angle) + translatedy *
(sin(angle));
            double rotatedy = translatedx * (-sin(angle)) + translatedy
* cos(angle);
            double transbackx = rotatedx + dscoordx;
            double transbacky = rotatedy + dscoordy;
            // P, Q, R, S coordinates where P, Q, R, S are the nearest
neighboring pixels
            std::vector<int>Nx;
            std::vector<int>Ny;
            int Px = floor(transbackx);
            Nx.push_back(Px);
            int Py = floor(transbacky);
            Ny.push_back(Py);
            int Qx = floor(transbackx)+1;
            Nx.push_back(Qx);
            int Qy = floor(transbacky);
            Ny.push_back(Qy);
            int Rx = floor(transbackx);
            Nx.push_back(Rx);
            int Ry = floor(transbacky)+1;
            Ny.push_back(Ry);
            int Sx = floor(transbackx)+1;
            Nx.push_back(Sx);
            int Sy = floor(transbacky)+1;
            Ny.push_back(Sy);

            for(int o = 0; o < Nx.size(); o++)
            {
              if(Nx[o] < 0)
              {
                Nx[o] = 0;
              }
              else if(Nx[o] >= before->width)
              {
                Nx[o] = before->width-1;
              }
              if(Ny[o] < 0)
              {
                Ny[o] = 0;
              }
              else if(Ny[o] >= before->height)
              {
                Ny[o] = before->height-1;
              }
            }

            double alpha = transbackx - Nx[0];
            double beta = transbacky - Ny[0];

            CvScalar P = cvGet2D(before, Ny[0], Nx[0]);
            CvScalar Q = cvGet2D(before, Ny[1], Nx[1]);
            CvScalar R = cvGet2D(before, Ny[2], Nx[2]);
            CvScalar S = cvGet2D(before, Ny[3], Nx[3]);

            CvScalar MOPSpixel = cvGet2D(before, Ny[3], Nx[3]);
            MOPSpixel.val[0] = (1-alpha)*(1-beta)*P.val[0] + alpha*(1-
beta)*Q.val[0] + (1-alpha)*beta*R.val[0] + alpha*beta*S.val[0];

            cvSet2D(after, b, a, MOPSpixel);
        }
    }
    // apply threshold: those pixels that have intensities > 0 will
have them set to 1.
    for(int a = 0; a < after->height; a++)
    {
        for(int b = 0; b < after->width; b++)
        {
            CvScalar Afterpixel = cvGet2D(after, a, b);
            Afterpixel.val[0] = (Afterpixel.val[0] > 0 ? 255 : 0);
            cvSet2D(after, a, b, Afterpixel);
        }
    }

    //std::cout << "DOWN WITH ROTATING" << std::endl;
    return after;
}

/* This function converts a 1-channel image to a 3-channel image */
IplImage* convert3channel(IplImage *toch)
{
IplImage* rot3ch1 =  cvCreateImage(cvSize(toch->width, toch-
>height),IPL_DEPTH_8U,3);

CvScalar s, s1;

for (int i=0; i < toch->height; i++)
{
    for(int j=0; j < toch->width; j++)
    {

         s = cvGet2D(toch, i, j);
         if(s.val[0] > 0)
         {
             s1.val[0] = 255;
             s1.val[1] = 255;
             s1.val[2] = 255;
         }
         else
        {
            s1.val[0] = 0;
            s1.val[1] = 0;
            s1.val[2] = 0;
        }
         cvSet2D(rot3ch1,i,j,s1);

    }
    //std::cout << std::endl;
}

return rot3ch1;
}
```