Image Segmentation with Distance Transform and Watershed Algorithm

Prev Tutorial: Point Polygon Test

Next Tutorial: Out-of-focus Deblur Filter

Goal

In this tutorial you will learn how to:

- Use the OpenCV function cv::filter2D in order to perform some laplacian filtering for image sharpening
- Use the OpenCV function cv::distanceTransform in order to obtain the derived representation of a binary image, where the value of each pixel is replaced by its distance to the nearest background pixel
- Use the OpenCV function cv::watershed in order to isolate objects in the image from the background

Theory

Code

C++ | Java | Python

This tutorial code's is shown lines below. You can also download it from here.

```
#include <opencv2/core.hpp>
#include <opencv2/imgproc.hpp>
#include <opencv2/highgui.hpp>
#include <iostream>

using namespace std;
using namespace cv;

int main(int argc, char *argv[])
{
    // Load the image
    CommandLineParser parser( argc, argv, "{@input | ../data/cards.png | input image}" );
    Mat src = imread( parser.get<String>( "@input" ) );
    if( src.empty() )
    {
        cout << "Could not open or find the image\n" << endl;
        cout << "Usage: " << argv[0] << " <input image>" << endl;
        return -1;
    }

    // Show source image
    imshow("Source Image", src);

    // Change the background from white to black, since that will help later to extract
    // better results during the use of Distance Transform
    for ( int x = 0; x < src.rows; x++ ) {
        for ( int y = 0; y < src.cols; y++ ) {
            if ( src.at<Vec3b>(x, y) == Vec3b(255,255,255) )
            {
                src.at<Vec3b>(x, y)[0] = 0;
                src.at<Vec3b>(x, y)[1] = 0;
                src.at<Vec3b>(x, y)[2] = 0;
            }
        }
    }

    // Show output image
    imshow("Black Background Image", src);

    // Create a kernel that we will use to sharpen our image
    Mat kernel = (Mat_<float>(3,3) <<
                  1,  1,  1,
                  1, -8,  1,
                  1,  1,  1); // an approximation of second derivative, a quite strong kernel

    // do the laplacian filtering as it is
    // well, we need to convert everything in something more deeper than CV_8U
    // because the kernel has some negative values,
    // and we can expect in general to have a Laplacian image with negative values
    // BTW a 8bits unsigned int (the one we are working with) can contain values from 0 to 255
    // so the possible negative number will be truncated
    Mat imgLaplacian;
    filter2D(src, imgLaplacian, CV_32F, kernel);
    Mat sharp;
    src.convertTo(sharp, CV_32F);
    Mat imgResult = sharp - imgLaplacian;

    // convert back to 8bits gray scale
    imgResult.convertTo(imgResult, CV_8UC3);
    imgLaplacian.convertTo(imgLaplacian, CV_8UC3);

    // imshow("Laplace Filtered Image", imgLaplacian );
    imshow("New Sharped Image", imgResult );

    // Create binary image from source image
    Mat bw;
    cvtColor(imgResult, bw, COLOR_BGR2GRAY);
    threshold(bw, bw, 40, 255, THRESH_BINARY | THRESH_OTSU);
    imshow("Binary Image", bw);

    // Perform the distance transform algorithm
    Mat dist;
    distanceTransform(bw, dist, DIST_L2, 3);

    // Normalize the distance image for range = {0.0, 1.0}
    // so we can visualize and threshold it
    normalize(dist, dist, 0, 1.0, NORM_MINMAX);
    imshow("Distance Transform Image", dist);

    // Threshold to obtain the peaks
    // This will be the markers for the foreground objects
    threshold(dist, dist, 0.4, 1.0, THRESH_BINARY);

    // Dilate a bit the dist image
    Mat kernel1 = Mat::ones(3, 3, CV_8U);
    dilate(dist, dist, kernel1);
    imshow("Peaks", dist);

    // Create the CV_8U version of the distance image
    // It is needed for findContours()
    Mat dist_8u;
    dist.convertTo(dist_8u, CV_8U);

    // Find total markers
    vector<vector<Point> > contours;
    findContours(dist_8u, contours, RETR_EXTERNAL, CHAIN_APPROX_SIMPLE);

    // Create the marker image for the watershed algorithm
    Mat markers = Mat::zeros(dist.size(), CV_32SC1);

    // Draw the foreground markers
    for (size_t i = 0; i < contours.size(); i++)
    {
        drawContours(markers, contours, static_cast<int>(i), Scalar(static_cast<int>(i)+1), -1);
    }

    // Draw the background marker
    circle(markers, Point(5,5), 3, Scalar(255), -1);
    imshow("Markers", markers*10000);

    // Perform the watershed algorithm
    watershed(imgResult, markers);

    Mat mark;
    markers.convertTo(mark, CV_8U);
    bitwise_not(mark, mark);
    //  imshow("Markers_v2", mark); // uncomment this if you want to see how the mark
    // image looks like at that point

    // Generate random colors
    vector<Vec3b> colors;
    for (size_t i = 0; i < contours.size(); i++)
    {
        int b = theRNG().uniform(0, 256);
        int g = theRNG().uniform(0, 256);
        int r = theRNG().uniform(0, 256);

        colors.push_back(Vec3b((uchar)b, (uchar)g, (uchar)r));
    }

    // Create the result image
    Mat dst = Mat::zeros(markers.size(), CV_8UC3);

    // Fill labeled objects with random colors
    for (int i = 0; i < markers.rows; i++)
    {
        for (int j = 0; j < markers.cols; j++)
        {
            int index = markers.at<int>(i,j);
            if (index > 0 && index <= static_cast<int>(contours.size()))
            {
                dst.at<Vec3b>(i,j) = colors[index-1];
            }
        }
    }

    // Visualize the final image
    imshow("Final Result", dst);

    waitKey();
    return 0;
}
```

Explanation / Result

C++ | Java | Python

- Load the source image and check if it is loaded without any problem, then show it:

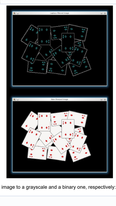
```
// Load the image
CommandLineParser parser( argc, argv, "{@input | ../data/cards.png | input image}" );
Mat src = imread( parser.get<String>( "@input" ) );
if( src.empty() )
{
    cout << "Could not open or find the image\n" << endl;
    cout << "Usage: " << argv[0] << " <input image>" << endl;
    return -1;
}

// Show source image
imshow("Source Image", src);
```

- Then if we have an image with a white background, it is good to transform it to black. This will help us to discriminate the foreground objects easier when we will apply the Distance Transform:

```
// Change the background from white to black, since that will help later to extract
// better results during the use of Distance Transform
for ( int x = 0; x < src.rows; x++ ) {
    for ( int y = 0; y < src.cols; y++ ) {
        if ( src.at<Vec3b>(x, y) == Vec3b(255,255,255) )
        {
            src.at<Vec3b>(x, y)[0] = 0;
            src.at<Vec3b>(x, y)[1] = 0;
            src.at<Vec3b>(x, y)[2] = 0;
        }
    }
}

// Show output image
imshow("Black Background Image", src);
```

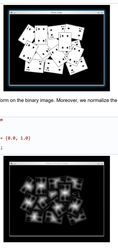
- Afterwards we will sharpen our image in order to acute the edges of the foreground objects. We will apply a laplacian filter with a quite strong filter (an approximation of second derivative):

```
// Create a kernel that we will use to sharpen our image
Mat kernel = (Mat_<float>(3,3) <<
              1,  1,  1,
              1, -8,  1,
              1,  1,  1); // an approximation of second derivative, a quite strong kernel

// do the laplacian filtering as it is
// well, we need to convert everything in something more deeper than CV_8U
// because the kernel has some negative values,
// and we can expect in general to have a Laplacian image with negative values
// BTW a 8bits unsigned int (the one we are working with) can contain values from 0 to 255
// so the possible negative number will be truncated
Mat imgLaplacian;
filter2D(src, imgLaplacian, CV_32F, kernel);
Mat sharp;
src.convertTo(sharp, CV_32F);
Mat imgResult = sharp - imgLaplacian;

// convert back to 8bits gray scale
imgResult.convertTo(imgResult, CV_8UC3);
imgLaplacian.convertTo(imgLaplacian, CV_8UC3);

// imshow("Laplace Filtered Image", imgLaplacian );
imshow("New Sharped Image", imgResult );
```



- Now we transform our new sharpened source image to a grayscale and a binary one, respectively:

```
// Create binary image from source image
Mat bw;
cvtColor(imgResult, bw, COLOR_BGR2GRAY);
threshold(bw, bw, 40, 255, THRESH_BINARY | THRESH_OTSU);
imshow("Binary Image", bw);
```



- We are ready now to apply the Distance Transform on the binary image. Moreover, we normalize the output image in order to be able visualize and threshold the result:

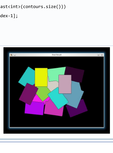
```
// Perform the distance transform algorithm
Mat dist;
distanceTransform(bw, dist, DIST_L2, 3);

// Normalize the distance image for range = {0.0, 1.0}
// so we can visualize and threshold it
normalize(dist, dist, 0, 1.0, NORM_MINMAX);
imshow("Distance Transform Image", dist);
```

- We threshold the *dist* image and then perform some morphology operation (i.e. dilation) in order to extract the peaks from the above image:

```
// Threshold to obtain the peaks
// This will be the markers for the foreground objects
threshold(dist, dist, 0.4, 1.0, THRESH_BINARY);

// Dilate a bit the dist image
Mat kernel1 = Mat::ones(3, 3, CV_8U);
dilate(dist, dist, kernel1);
imshow("Peaks", dist);
```

- From each blob then we create a seed/marker for the watershed algorithm with the help of the cv::findContours function:

```
// Create the CV_8U version of the distance image
// It is needed for findContours()
Mat dist_8u;
dist.convertTo(dist_8u, CV_8U);

// Find total markers
vector<vector<Point> > contours;
findContours(dist_8u, contours, RETR_EXTERNAL, CHAIN_APPROX_SIMPLE);

// Create the marker image for the watershed algorithm
Mat markers = Mat::zeros(dist.size(), CV_32SC1);

// Draw the foreground markers
for (size_t i = 0; i < contours.size(); i++)
{
    drawContours(markers, contours, static_cast<int>(i), Scalar(static_cast<int>(i)+1), -1);
}

// Draw the background marker
circle(markers, Point(5,5), 3, Scalar(255), -1);
imshow("Markers", markers*10000);
```



- Finally, we can apply the watershed algorithm, and visualize the result:

```
// Perform the watershed algorithm
watershed(imgResult, markers);

Mat mark;
markers.convertTo(mark, CV_8U);
bitwise_not(mark, mark);
//  imshow("Markers_v2", mark); // uncomment this if you want to see how the mark
// image looks like at that point

// Generate random colors
vector<Vec3b> colors;
for (size_t i = 0; i < contours.size(); i++)
{
    int b = theRNG().uniform(0, 256);
    int g = theRNG().uniform(0, 256);
    int r = theRNG().uniform(0, 256);

    colors.push_back(Vec3b((uchar)b, (uchar)g, (uchar)r));
}

// Create the result image
Mat dst = Mat::zeros(markers.size(), CV_8UC3);

// Fill labeled objects with random colors
for (int i = 0; i < markers.rows; i++)
{
    for (int j = 0; j < markers.cols; j++)
    {
        int index = markers.at<int>(i,j);
        if (index > 0 && index <= static_cast<int>(contours.size()))
        {
            dst.at<Vec3b>(i,j) = colors[index-1];
        }
    }
}

// Visualize the final image
imshow("Final Result", dst);
```