Canny Edge Detector

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Goal

In this tutorial you will learn how to:

- Use the OpenCV function **cv::Canny** to implement the Canny Edge Detector.

Theory

The *Canny Edge detector* **[41]** was developed by John F. Canny in 1986. Also known to many as the *optimal detector*, the Canny algorithm aims to satisfy three main criteria:

- **Low error rate:** Meaning a good detection of only existent edges.
- **Good localization:** The distance between edge pixels detected and real edge pixels have to be minimized.
- **Minimal response:** Only one detector response per edge.

Steps

1. Filter out any noise. The Gaussian filter is used for this purpose. An example of a Gaussian kernel of $size = 5$ that might be used is shown below:

$$K = \frac{1}{159}\begin{bmatrix} 2 & 4 & 5 & 4 & 2 \\ 4 & 9 & 12 & 9 & 4 \\ 5 & 12 & 15 & 12 & 5 \\ 4 & 9 & 12 & 9 & 4 \\ 2 & 4 & 5 & 4 & 2 \end{bmatrix}$$

2. Find the intensity gradient of the image. For this, we follow a procedure analogous to Sobel:
   a. Apply a pair of convolution masks (in x and y directions:

$$G_x = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix}$$

$$G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix}$$

   b. Find the gradient strength and direction with:

$$G = \sqrt{G_x^2 + G_y^2}$$

$$\theta = \arctan(\frac{G_y}{G_x})$$

   The direction is rounded to one of four possible angles (namely 0, 45, 90 or 135)
3. *Non-maximum* suppression is applied. This removes pixels that are not considered to be part of an edge. Hence, only thin lines (candidate edges) will remain.
4. *Hysteresis*: The final step. Canny does use two thresholds (upper and lower):

   a. If a pixel gradient is higher than the *upper* threshold, the pixel is accepted as an edge
   b. If a pixel gradient value is below the *lower* threshold, then it is rejected.
   c. If the pixel gradient is between the two thresholds, then it will be accepted only if it is connected to a pixel that is above the *upper* threshold.

   Canny recommended a *upper:lower* ratio between 2:1 and 3:1.
5. For more details, you can always consult your favorite Computer Vision book.

Code

C++ Java Python

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

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

using namespace cv;
```

```
Mat src, src_gray;
Mat dst, detected_edges;

int lowThreshold = 0;
const int max_lowThreshold = 100;
const int ratio = 3;
const int kernel_size = 3;
const char* window_name = "Edge Map";

static void CannyThreshold(int, void*)
{
    blur( src_gray, detected_edges, Size(3,3) );

    Canny( detected_edges, detected_edges, lowThreshold, lowThreshold*ratio, kernel_size );

    dst = Scalar::all(0);

    src.copyTo( dst, detected_edges);

    imshow( window_name, dst );
}


int main( int argc, char** argv )
{
  CommandLineParser parser( argc, argv, "{@input | fruits.jpg | input image}" );
  src = imread( samples::findFile( parser.get<String>( "@input" ) ), IMREAD_COLOR ); // Load an image

  if( src.empty() )
  {
    std::cout << "Could not open or find the image!\n" << std::endl;
    std::cout << "Usage: " << argv[0] << " <Input image>" << std::endl;
    return -1;
  }

  dst.create( src.size(), src.type() );

  cvtColor( src, src_gray, COLOR_BGR2GRAY );

  namedWindow( window_name, WINDOW_AUTOSIZE );

  createTrackbar( "Min Threshold:", window_name, &lowThreshold, max_lowThreshold, CannyThreshold );

  CannyThreshold(0, 0);

  waitKey(0);

  return 0;
}
```

- **What does this program do?**
  - Asks the user to enter a numerical value to set the lower threshold for our *Canny Edge Detector* (by means of a Trackbar).
  - Applies the *Canny Detector* and generates a **mask** (bright lines representing the edges on a black background).
  - Applies the mask obtained on the original image and display it in a window.

Explanation (C++ code)

1. Create some needed variables:

   ```
   Mat src, src_gray;
   Mat dst, detected_edges;

   int lowThreshold = 0;
   const int max_lowThreshold = 100;
   const int ratio = 3;
   const int kernel_size = 3;
   const char* window_name = "Edge Map";
   ```

   Note the following:

   a. We establish a ratio of lower:upper threshold of 3:1 (with the variable *ratio*).

   b. We set the kernel size of 3 (for the Sobel operations to be performed internally by the Canny function).

   c. We set a maximum value for the lower Threshold of 100.

2. Loads the source image:

   ```
   CommandLineParser parser( argc, argv, "{@input | fruits.jpg | input image}" );
   src = imread( samples::findFile( parser.get<String>( "@input" ) ), IMREAD_COLOR ); // Load an image

   if( src.empty() )
   {
     std::cout << "Could not open or find the image!\n" << std::endl;
     std::cout << "Usage: " << argv[0] << " <Input image>" << std::endl;
     return -1;
   }
   ```

3. Create a matrix of the same type and size of *src* (to be *dst*):

   ```
   dst.create( src.size(), src.type() );
   ```

4. Convert the image to grayscale (using the function **cv::cvtColor**):

```
cvtColor( src, src_gray, COLOR_BGR2GRAY );
```

5. Create a window to display the results:

```
namedWindow( window_name, WINDOW_AUTOSIZE );
```

6. Create a Trackbar for the user to enter the lower threshold for our Canny detector:

```
createTrackbar( "Min Threshold:", window_name, &lowThreshold, max_lowThreshold, CannyThreshold );
```

Observe the following:

a. The variable to be controlled by the Trackbar is *lowThreshold* with a limit of *max_lowThreshold* (which we set to 100 previously)

b. Each time the Trackbar registers an action, the callback function *CannyThreshold* will be invoked.

7. Let's check the *CannyThreshold* function, step by step:

a. First, we blur the image with a filter of kernel size 3:

```
blur( src_gray, detected_edges, Size(3,3) );
```

b. Second, we apply the OpenCV function **cv::Canny** :

```
Canny( detected_edges, detected_edges, lowThreshold, lowThreshold*ratio, kernel_size );
```

where the arguments are:

- *detected_edges*: Source image, grayscale
- *detected_edges*: Output of the detector (can be the same as the input)
- *lowThreshold*: The value entered by the user moving the Trackbar
- *highThreshold*: Set in the program as three times the lower threshold (following Canny's recommendation)
- *kernel_size*: We defined it to be 3 (the size of the Sobel kernel to be used internally)

8. We fill a *dst* image with zeros (meaning the image is completely black).

```
dst = Scalar::all(0);
```

9. Finally, we will use the function **cv::Mat::copyTo** to map only the areas of the image that are identified as edges (on a black background).
cv::Mat::copyTo copy the *src* image onto *dst*. However, it will only copy the pixels in the locations where they have non-zero values. Since the output of the Canny detector is the edge contours on a black background, the resulting *dst* will be black in all the area but the detected edges.

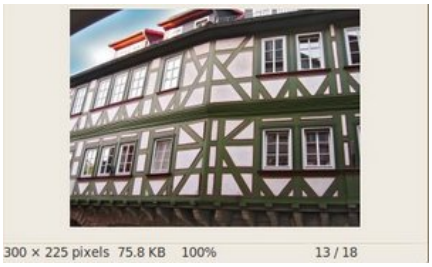
```
src.copyTo( dst, detected_edges);
```

10. We display our result:

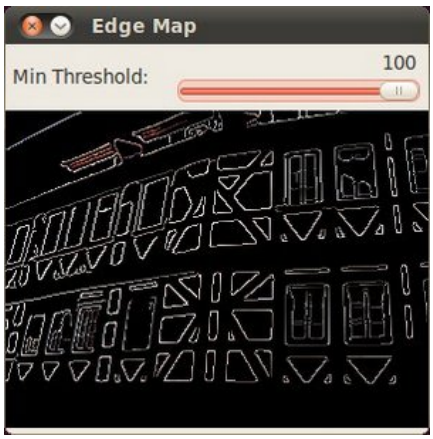
```
imshow( window_name, dst );
```

Result

- After compiling the code above, we can run it giving as argument the path to an image. For example, using as an input the following image:



- Moving the slider, trying different threshold, we obtain the following result:



- Notice how the image is superposed to the black background on the edge regions.