Efficient Stop & Warning Sign and Pedestrian Detection

Castleberry, Cherry, and Firth

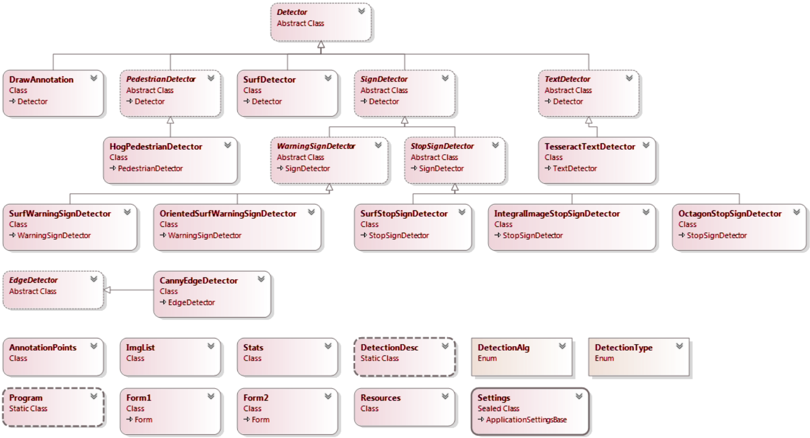
December 6, 2012

Overview

- We implemented the following:
  - Stop-sign detector, using the notion of integral images from SURF
  - Warning sign detector, using perspective transformation on a model image, then SURF

Wrappers

- We created a wrapper to the pedestrian detector to gain familiarity with the EmguCV library.
- We also created a wrapper to the built-in EmguCV SURF detector to use as a basis of comparison for our own methods.


Detector
Abstract Class
DrawAnnotation
Class
Detector
PedestrianDetector
Abstract Class
Detector
SurfDetector
Class
Detector
SignDetector
Abstract Class
Detector
TextDetector
Abstract Class
Detector
HogPedestrianDetector
Class
PedestrianDetector
WarningSignDetector
Abstract Class
SignDetector
StopSignDetector
Abstract Class
SignDetector
TesseractTextDetector
Class
TextDetector
SurfWarningSignDetector
Class
WarningSignDetector
OrientedSurfWarningSignDetector
Class
WarningSignDetector
SurfStopSignDetector
Class
StopSignDetector
IntegralImageStopSignDetector
Class
StopSignDetector
OctagonStopSignDetector
Class
StopSignDetector
EdgeDetector
Abstract Class
CannyEdgeDetector
Class
EdgeDetector
AnnotationPoints
Class
ImgList
Class
Stats
Class
DetectionDesc
Static Class
DetectionAlg
Enum
DetectionType
Enum
Program
Static Class
Form1
Class
Form
Form2
Class
Form
Resources
Class
Settings
Sealed Class
ApplicationSettingsBase


STOP
ONE WAY


DO NOT
ENTER

Stop Sign Detection, Integral Images

- We developed a method for detecting stop signs based upon the use of integral images which we encountered in the SURF algorithm.
- To summarize the method, we use integral images from both the left-hand side (top left) and the right-hand side (bottom right) on only the R channel. Then we consider only the LHS and RHS integral images along the diagonal of the image. We difference these, then fit a Gaussian curve to the resulting vector. We threshold the curve at the points of inflection to generate a bounding box for the sign.


STOP
ONE
WAY

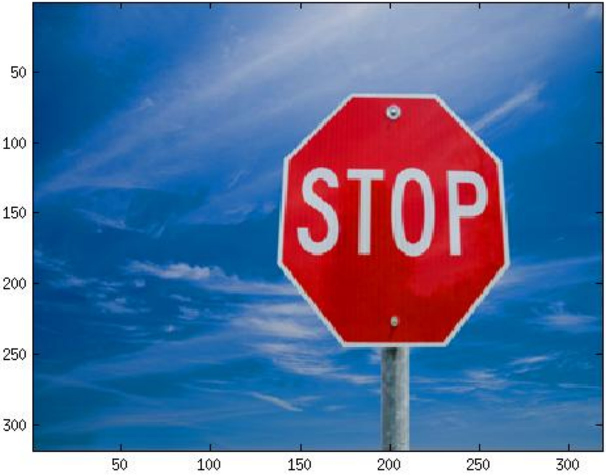
Stop Sign Detection, Integral Images

- To begin our method, we scale the $N \times M$ image to $N \times N$ for $N < M$, $M \times M$ for $M < N$. We require a square matrix to extract a particular vector.
- Recall that the formula for computing the integral image $\mathcal{I}_{-}$ at a pixel (x, y) with intensity value $I(x, y)$ is:

$$\mathcal{I}_{-}(x, y) = \sum_{i=0}^{n_x} \sum_{j=0}^{n_y} I(x, y) \tag{1}$$

- We compute the integral image at a pixel using the following formula:

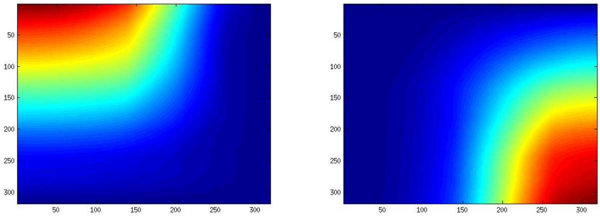
$$\mathcal{I}_{x,y} = \mathcal{I}_{x-1,y} + \mathcal{I}_{x,y-1} - \mathcal{I}_{x-1,y-1} \tag{2}$$


STOP
50
100
150
200
250
300

Stop Sign Detection, Integral Images

- Likewise, we compute an RHS integral image $\mathcal{I}_+$ at a pixel (x, y) with intensity value $I(x, y)$ as:

$$\mathcal{I}_+(x, y) = \sum_{i=N}^{n_x} \sum_{j=N}^{n_y} I(x, y) \tag{3}$$


50
100
150
200
250
300
50
100
150
200
250
300
50
100
150
200
250
300
50
100
150
200
250
300

Stop Sign Detection, Integral Images

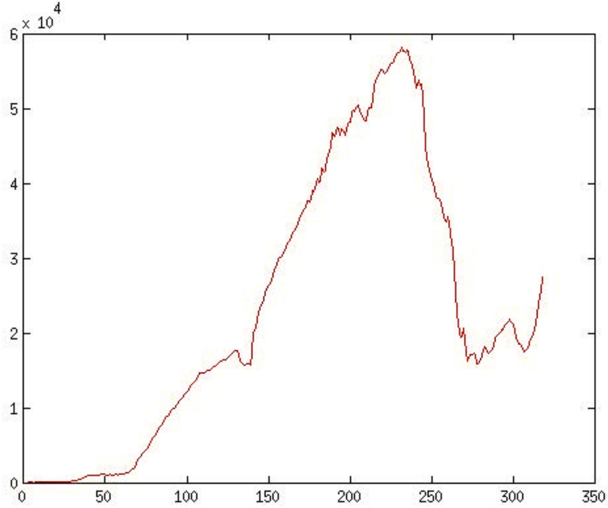
- After obtaining the integral image, we copy its diagonal into a vector u.
- We then apply a finite-difference method to the elements in u and store it in v, as follows:

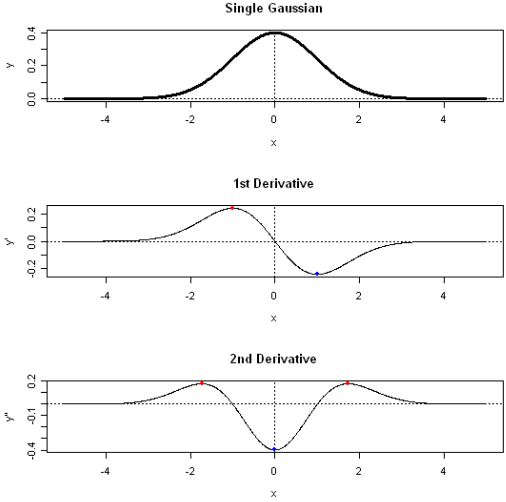
$$v_n = u_n - u_{n-1} \tag{4}$$

The vector v gives the LHS crosshair of the R-channel. For images which have stop signs, v has a Gauss distribution.

Stop Sign Detection, Integral Images

- We apply this finite-difference method for both vectors u_- and u_+ to obtain v_- and v_+.
- Then, we add v_- and v_+ to obtain a vector m.
- Finally, we compute the standard deviation σ of the vector m and its centroid c, then apply a Gaussian fit to the data in m. We call the Gaussian fit G.
- We then apply finite-differencing to the Gaussian fit G to obtain G', then find the indices at $min(G')$ and $max(G')$.
- These indices form the bounding box for the image.


x 10^4
6
5
4
3
2
1
0
0
50
100
150
200
250
300
350


Single Gaussian
y
0.0
0.2
0.4
-4
-2
0
2
4
x
1st Derivative
y'
-0.2
0.0
0.2
-4
-2
0
2
4
x
2nd Derivative
y''
-0.4
-0.1
0.2
-4
-2
0
2
4
x

Warning Signs

- For our warning sign detection, we experimented with SURF in combination with perspective transformations on out-of-plane-rotated signs.
- In particular, we assume that we know the perspective information of an out-of-plane-rotated sign. We apply a perspective transform to a model sign, then apply SURF to the two images, then match.


FreeFoto.com

Warning Signs

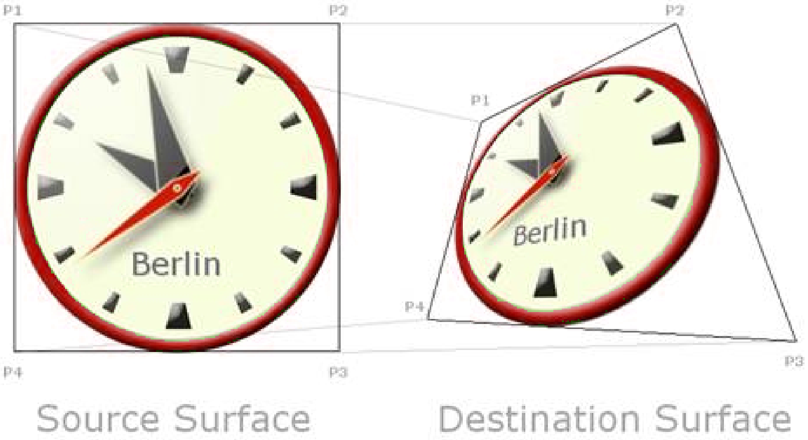
- We first hand-annotated N images using a MATLAB code.
- From this, we extracted a set of $4N$ points which give the vertices of the warning sign. We then applied `getPerspectiveTransform()` on the points, which returns a perspective transform matrix `M`.
- We apply this perspective transform matrix to the model with the function `warpPerspective()`.
- We then run SURF on the two images, then compare their feature descriptors to obtain a match within a threshold of t_ϵ.

Perspective Transform

- If $a_{x,y,z}$ is the point to be projected, $c_{x,y,z}$ is the camera, $\theta_{x,y,z}$ is the camera orientation and $e_{x,y,z}$ is the position of the viewer relative to the display surface then $b_{x,y}$, the 2D projection of a, is given by:

$$\begin{bmatrix} d_x \\ d_y \\ d_z \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & cos(\theta_x) & -sin(\theta_x) \\ 0 & sin(\theta_x) & cos(\theta_x) \end{bmatrix} \begin{bmatrix} cos(\theta_y) & 0 & sin(\theta_y) \\ 0 & 1 & 0 \\ -sin(\theta_y) & 0 & cos(\theta_y) \end{bmatrix} \begin{bmatrix} cos(\theta_z) & -sin(\theta_z) & 0 \\ sin(\theta_z) & cos(\theta_z) & 0 \\ 0 & 0 & 1 \end{bmatrix} \left(\begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix} - \begin{bmatrix} c_x \\ c_y \\ c_z \end{bmatrix} \right). \tag{5}$$

- A visual example follows.


P1
P2
P4
P3
Berlin
P1
P2
P4
P3
Berlin
Source Surface
Destination Surface

Results

- We considered there to be a match if at least 50% of the sign fell within the area of the bounding box.
- The following table summarizes our results:

Surf Stop Sign Detector
Integral Images Stop Sign Detector
Surf Warning Sign Detector
Oriented Surf Warning Sign Detector

- As is evident in the above, our accuracy for . . . was an abysmal N%.

Conclusion

- Bearing in mind that the accuracy for our integral image detector was much less than the accuracy for the built-in SURF algorithm, we conclude that in the development of computer vision algorithms, one should:
  1. Not over-utilize heuristics, and
  2. Develop the algorithm starting from optimized versions of existing algorithms.