Future Computer Vision Algorithms for Traffic Sign Recognition Systems

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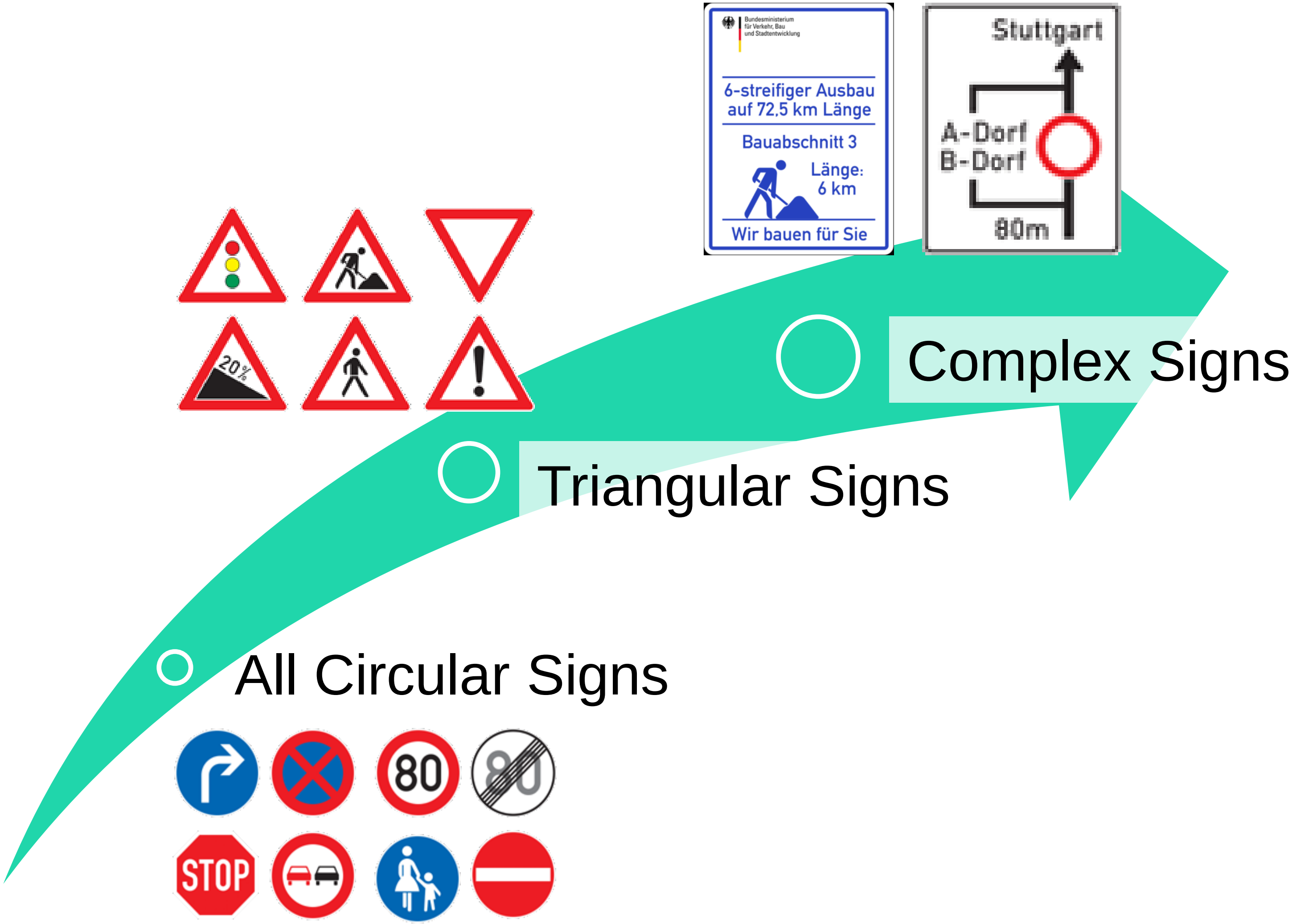
Future of Traffic Sign Recognition



Recognition of Circular Traffic Signs

TSR-System

Image from Camera → Detection of traffic signs → Recognition of traffic signs → Recognized traffic sign

Detection of traffic signs

- Detects traffic signs in the image
- Very fast algorithm required
- All relevant traffic signs are circular (speed signs)
- Fast circle detector

Recognition of traffic signs

- Recognizes the detected signs
- Rejection of false detection
- A slow algorithm acceptable

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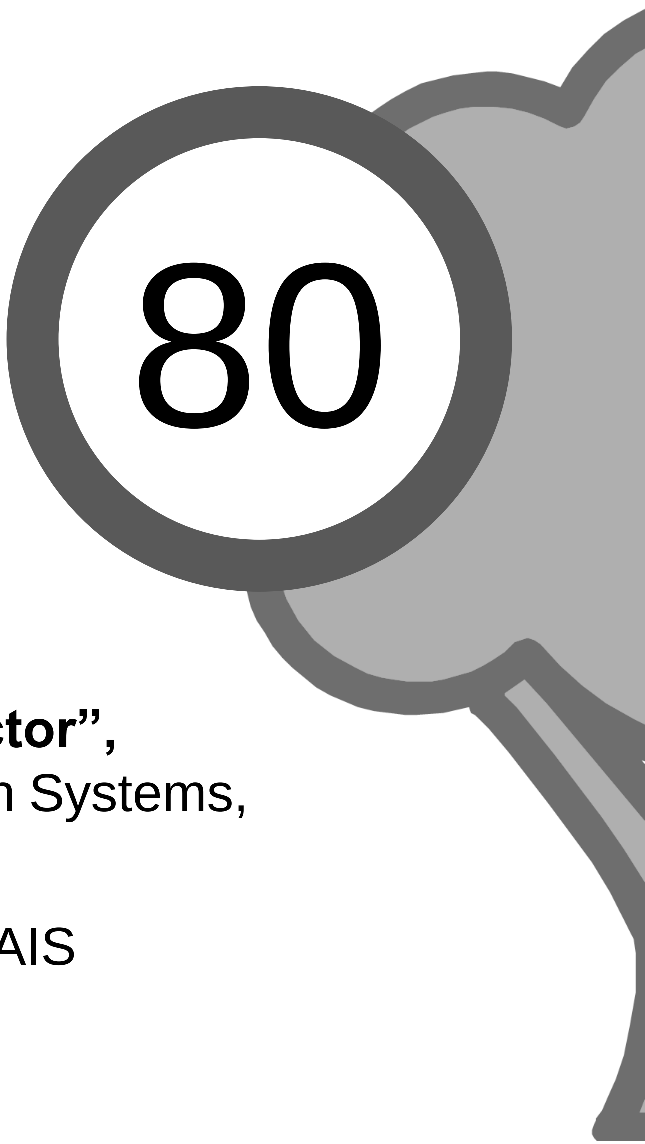
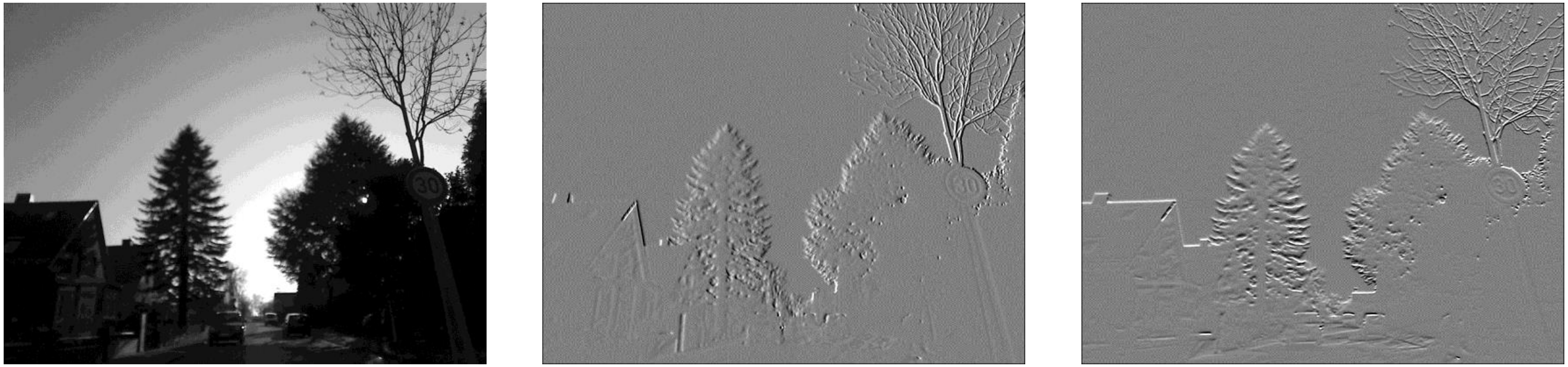
Radial Symmetry Detector



- Detection of the inner (and outer) circle of speed limit signs
- Fast circle detector
- Nick Barnes, Alexander Zelinsky, Luke S. Fletcher, **“Real-Time Speed Sign Detection Using the Radial Symmetry Detector”,** IEEE Transactions on Intelligent Transportation Systems, vol. 9, no. 2, pp. 322-332, 2008
- Improved algorithm developed by Fraunhofer IAIS

Edge Detection Using the Sobel Operator

$$\mathbf{G}_v = \begin{pmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{pmatrix} * \mathbf{I} \qquad \mathbf{G}_h = \begin{pmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{pmatrix} * \mathbf{I}$$

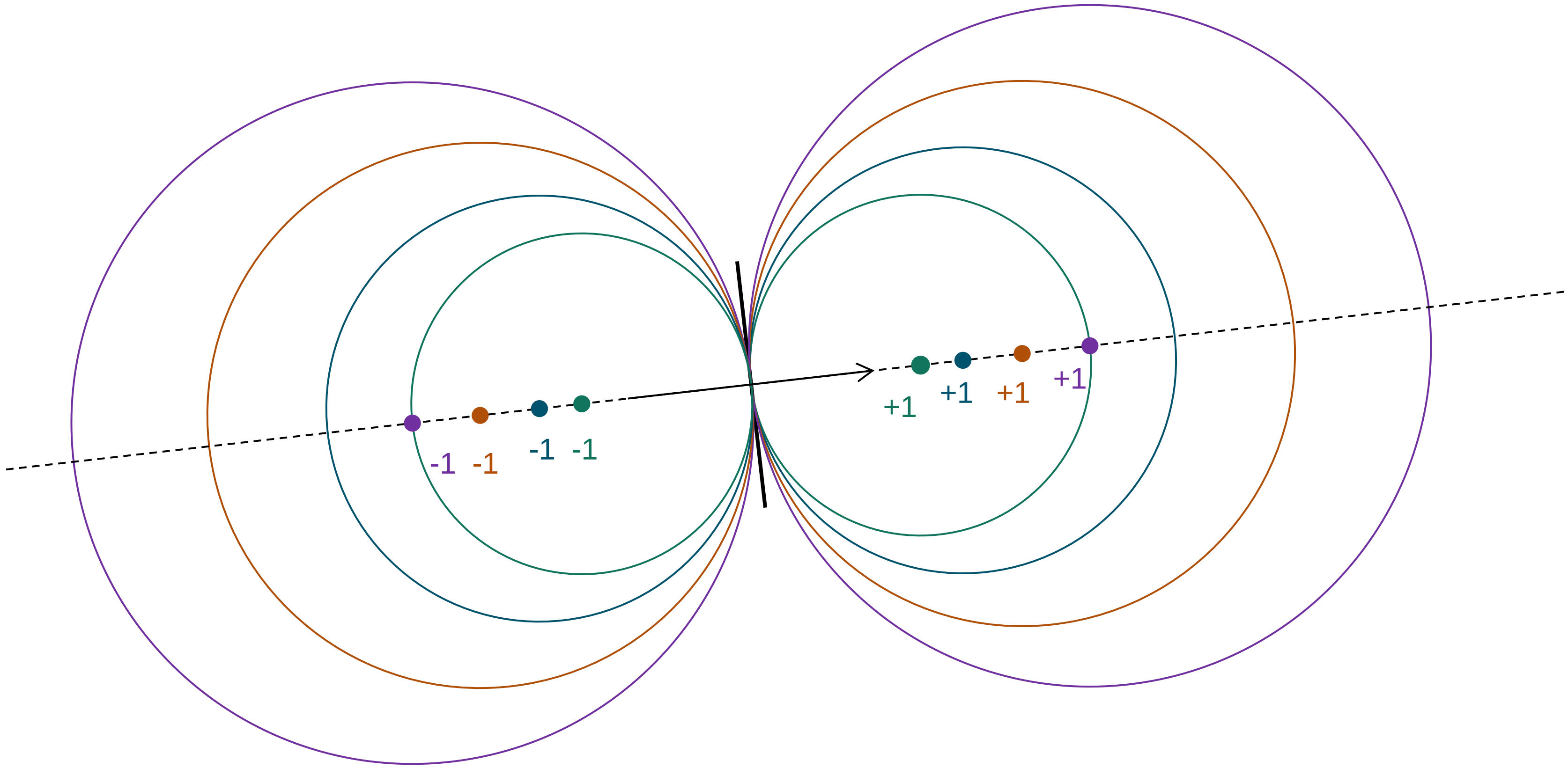


For each pixel of the image a normalize gradient vector is calculated:

$$\mathbf{g}(x,y) = \frac{1}{\sqrt{\mathbf{g}_v{}^2(x,y) + \mathbf{g}_h{}^2(x,y)}} \begin{pmatrix} \mathbf{g}_v(x,y) \\ \mathbf{g}_h(x,y) \end{pmatrix}$$

The gradient vector points in the direction of the maximum ilumination change. In case of circles it points to the center.

Estimation of the Circle Centers



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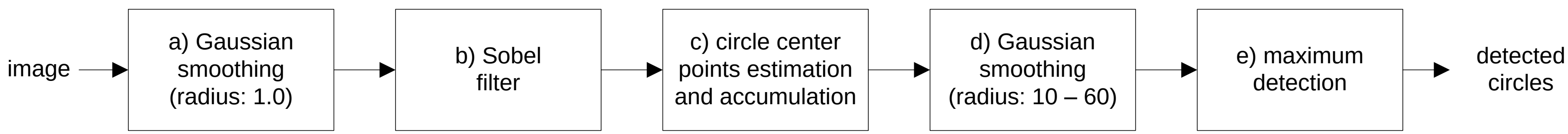
Original Processing Chain



• Reduction of noise in image • similar to Canny edge detector • small radius, very fast	• Calculation of edges and gradients	• Estimation of circle centers • Accumulator arrays • one cell for each pixel and scale	• Smoothing for maximum detection • large radii, very slow • more than **90%** of the overall processing time	• Detection of maxima

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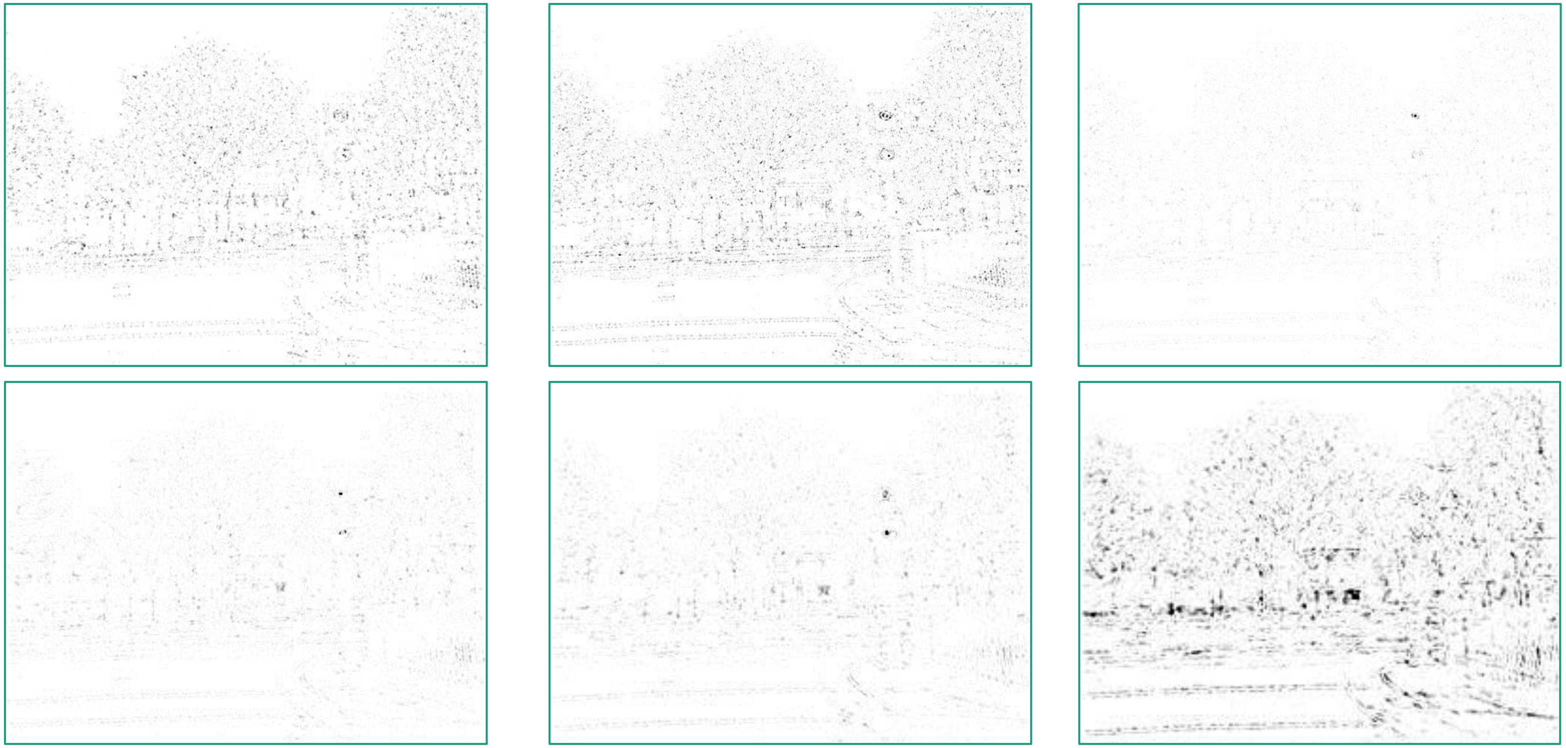
Original Algorithm

One accumulator array for each radius



Original Algorithm

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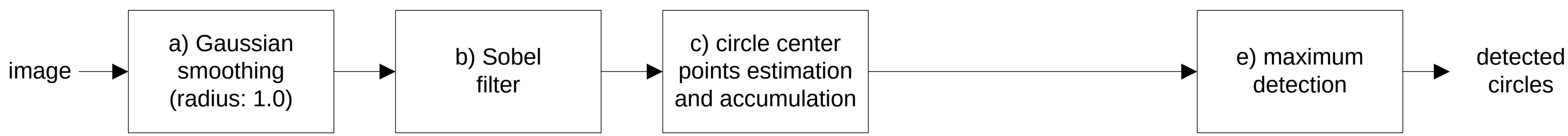
Improved Processing Chain



a) Gaussian smoothing
- Reduction of noise in image
- similar to canny edge detector
- small radius → very fast

b) Sobel filter
- Calculation of edges and gradients

c) circle center points estimation and accumulation
- Estimation of circle centers
- Accumulator arrays
- Reduced array sizes at larger circle diameters

e) maximum detection
- Detection of maxima

Improved Algorithm

Reduction of the size of the accumulator arrays at larger circle diameters

Improved Algorithm

Results

Preliminary Results

Implementation	Institute	Technology	Resolution	Frame rate	Pixel / Second
Barnes, Zelinsky, Fletcher, 2008	ICT Centre (Canberra), MIT (Cambridge)	Multi-processing MMX	320 x 240	30 fps	2.3 M
Glavtchev, Muyan-Özcelik, Ota, Owens, 2011	BMW Technology Office, University of California (Davis)	GPU	640 x 480	33 fps	10.1 M
This approach 2012	Fraunhofer IAIS	C++ Single threaded (1 CPU)	800 x 600	55 fps	26.4 M

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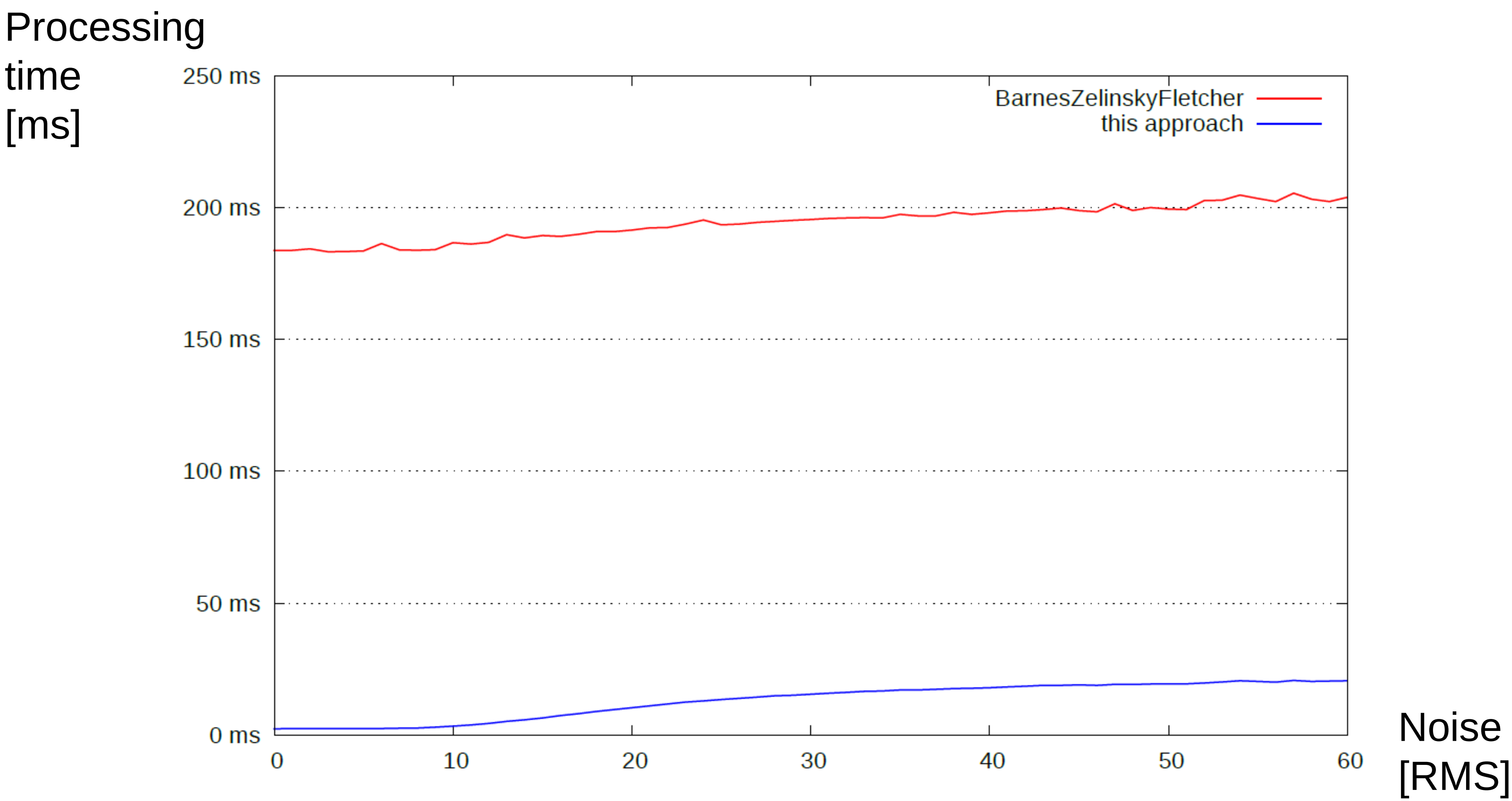
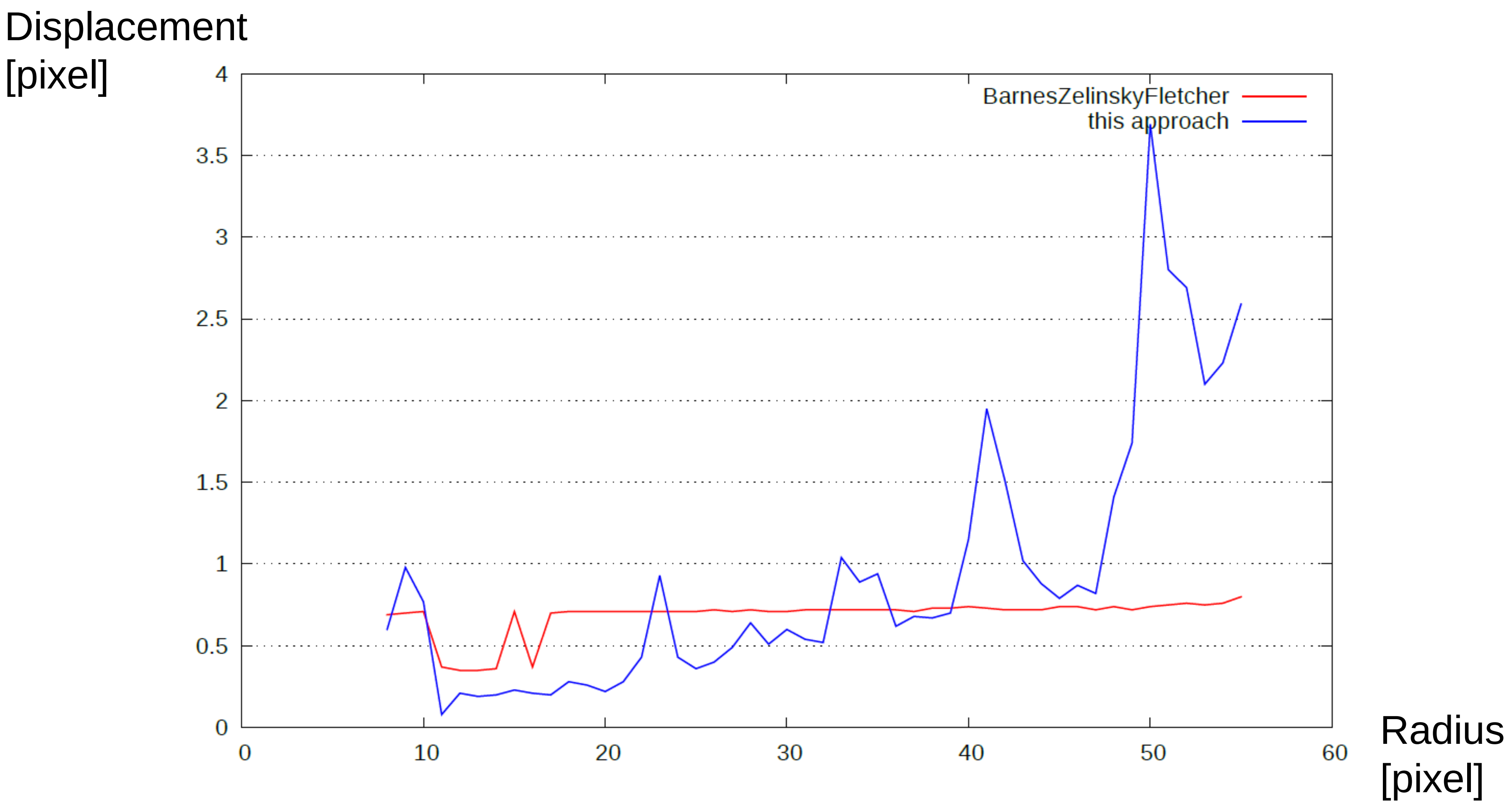
Results on Artificial Images (Processing Time)



Results on Artificial Images (Spatial Accuracy)



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Current Results

- 55 fps (26.4 Mpixel/s) on Intel i7-2620M @ 2,7 GHz
- plain C++, single treaded
- simple configuration (tied parameters)
- integer processing (no FPU needed)
- real time on ARM7 embedded system (one core)

TSR-System

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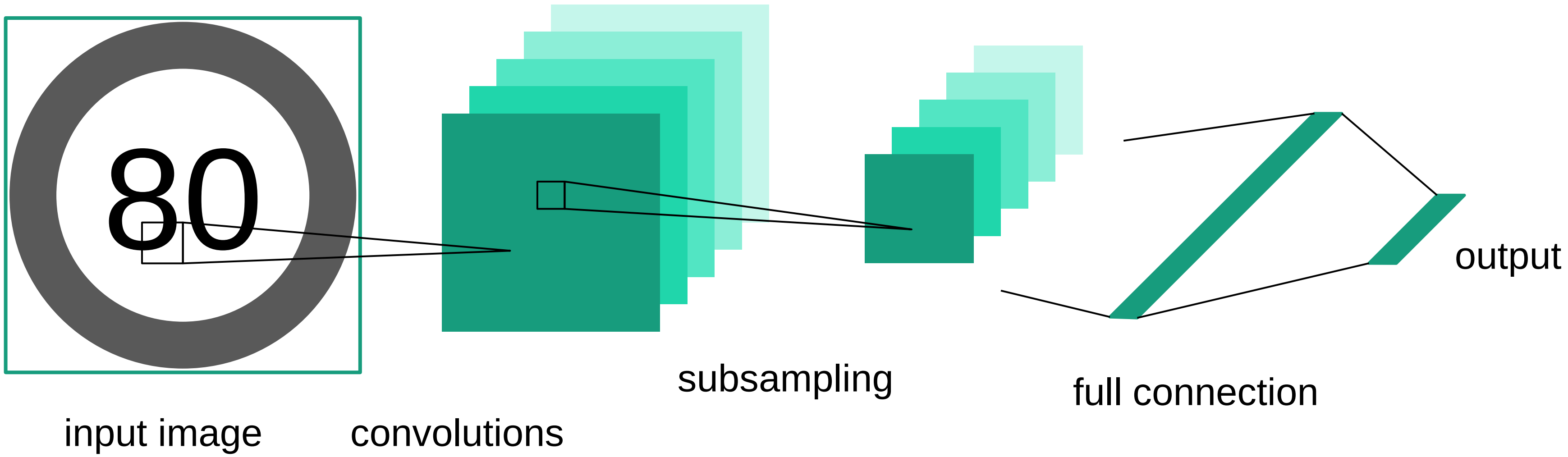
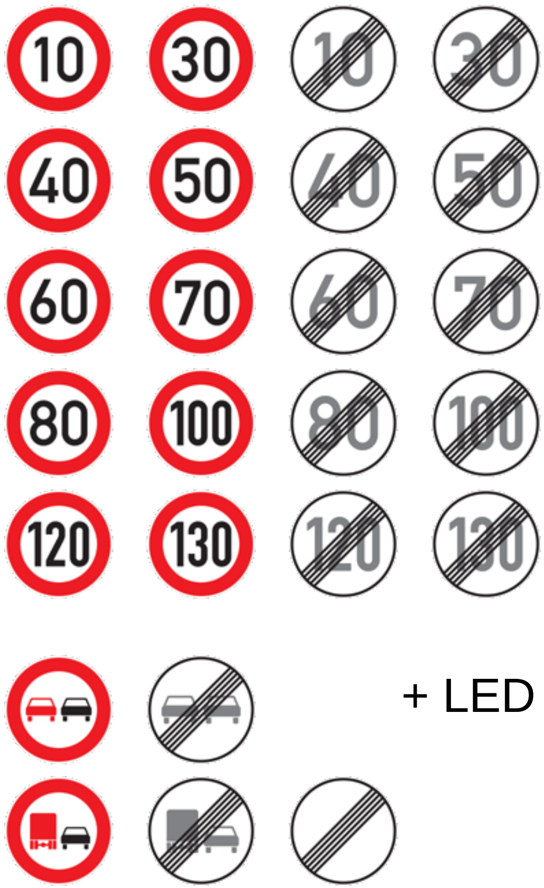
Convolutional Neural Networks



- feed-forward artificial neural network
- based on receptive fields
- network is trained on samples: traffic signs and circles
- large computational cost for training, low cost for recognition

First Results (grayscale)



+ LED

Precision	Recall	Recognition Rate
99,2%	98,8%	98,6%

Garbage

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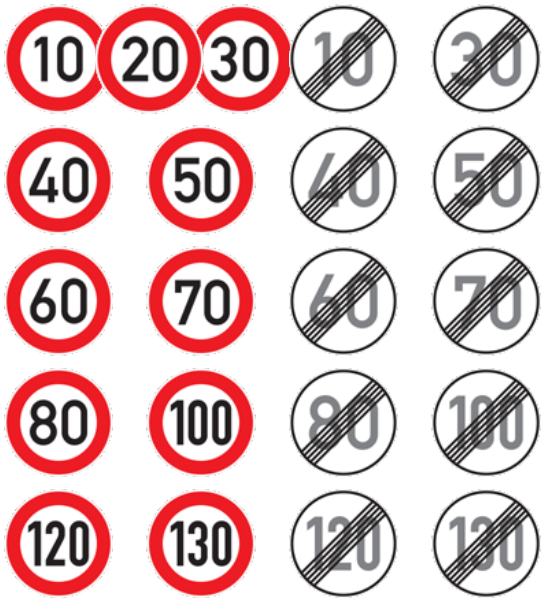
Current Results (YCbCr)



+ LED

	Precision	Recall	Recognition Rate
Speedlimits	98,25%	99,40%	98,65%
All	98,57 %	98,92 %	98,11 %

Garbage

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German Traffic Sign Detection Benchmark

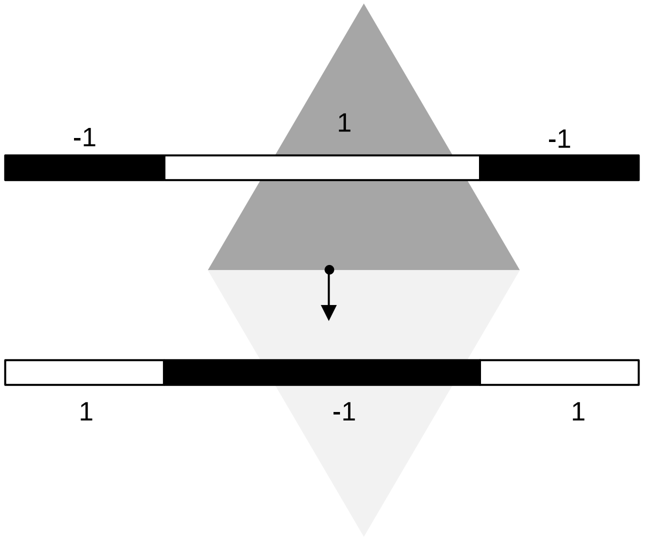
- data set of annotated traffic images
- University of Bochum
- 600 Training, 300 Test
- Size of traffic signs: 16 – 70 Pixel
- **Prohibitory**, Danger, Mandatory

Recall	Precision	Recognition Rate
99,4%	96,3%	97,5%

Recognition of Triangular Traffic Signs

Triangle Detection

- Extension of fast circle detector
- Nick Barnes, Garret Loy,
  "Real-Time Regular Polygonal Sign Detection",
  Field and Service Robotics, 2006



Triangle Detector

complex values in accumulator arrays

Triangle Detector

Current Results

- 6x slower than circle detector
- Optimization is still work in progress
- Expected processing time after optimization:
  2-3x slower than circle detector
- Data collection phase for training of neural network

Recognition of Complex Traffic Signs

Text Detection

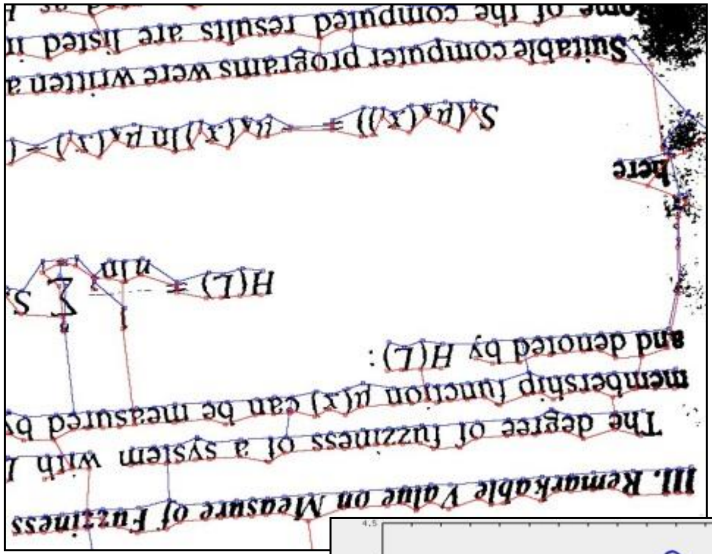
Correction or Skewed Documents

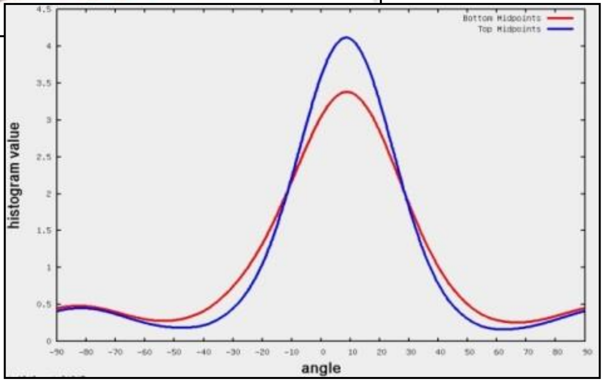
Correction of Rotation 0°-360°

- Arbitrary rotation angles of text are recognized
- Efficient calculation
- Correction of skew

Application Areas

- Feed scanner
- Tabloid pages in bound newspaper volumes





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Application for Traffic Signs

Current/Future Research

Recognition of
complex traffic signs

Applications:

- temporary signs
- supplementary signs
- directional signs

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