Traffic Sign
Detection and Recognition

Student: Noureldien Huseein
Supervisor, first examiner: Dr Jonathon S. Hare
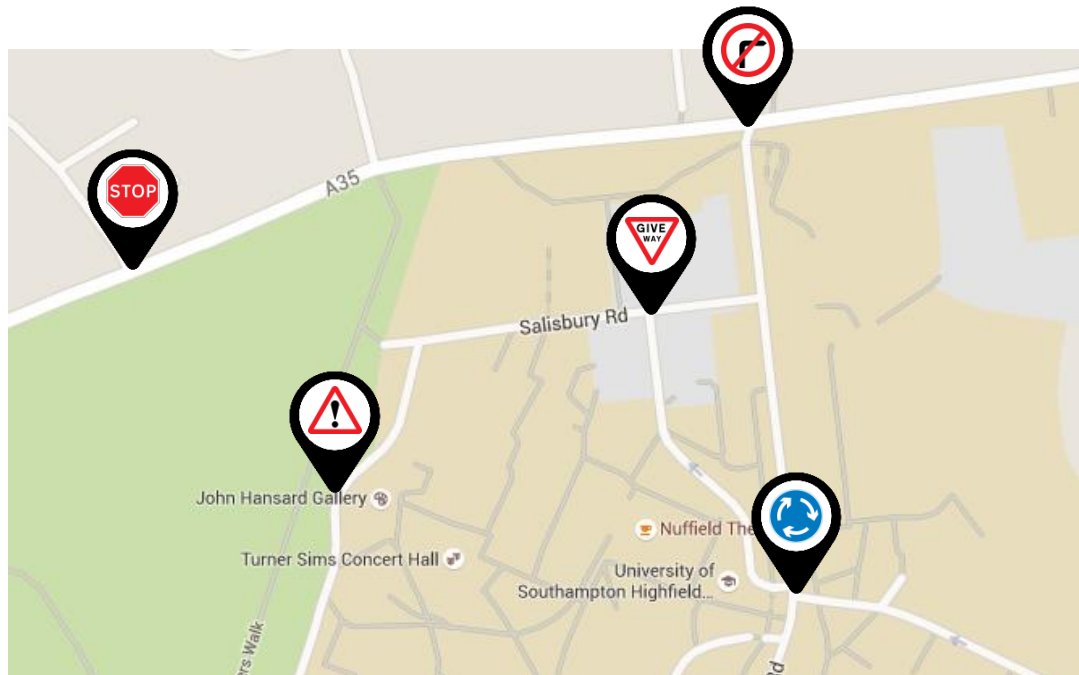Second examiner: Dr Adam Prügel-Bennett

Business Goal

- Video/image coupled with geo-location

- Automatic locator for traffic sign

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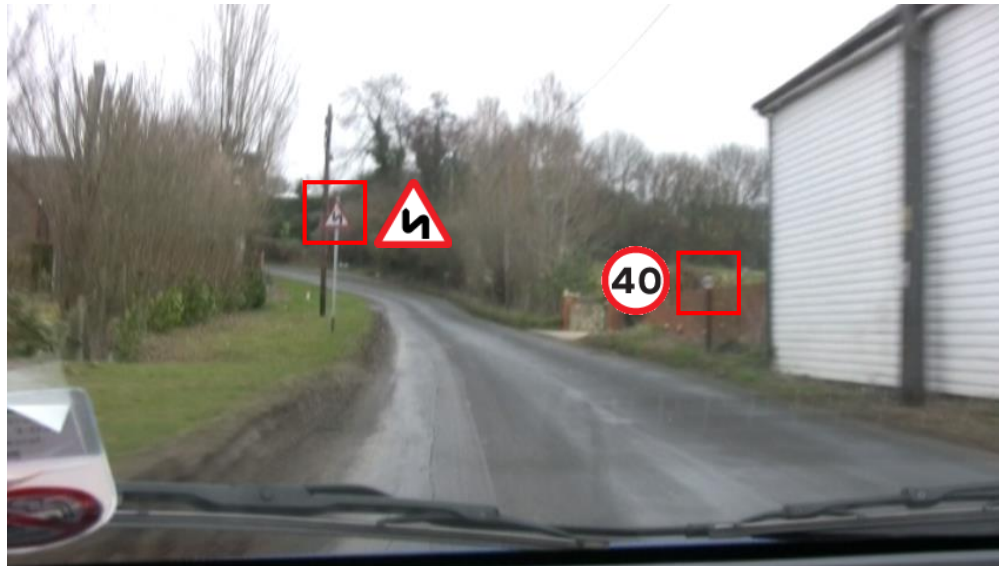
- Enrich maps with information

Scientific Problem

- Localisation and detection

Scientific Problem

- Localisation and detection

- Recognition
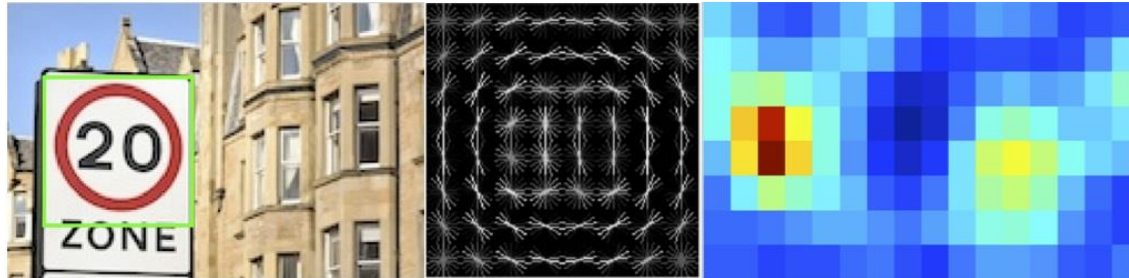
Scientific Problem

- Localisation and detection

- Recognition

- Tracking

Recognition
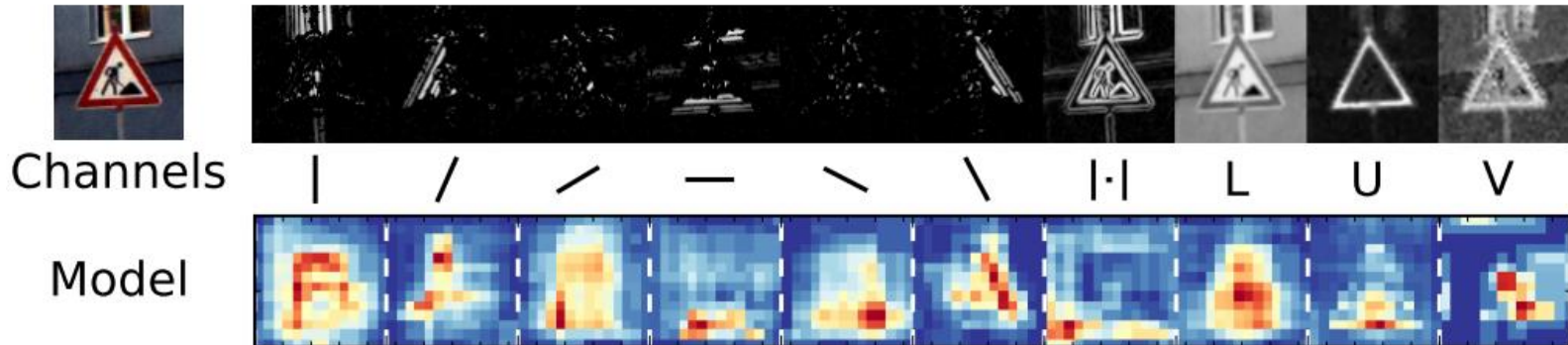
Recognition: Previous Work

- Handcrafted feature detectors and extractors
    - Histogram of Oriented Gradients (HOG) - [Greenhalgh 2012, Zaklouta 2011]

Source: http://www.robots.ox.ac.uk/~vgg/practicals/category-detection/index.html

Recognition: Previous Work

- Handcrafted feature detectors and extractors
    - Histogram of Oriented Gradients (HOG) - [Greenhalgh 2012, Zaklouta 2011]
    - Integral Channel Features (ICF) - [Mathias 2013]

Source: [Mathias 2013]
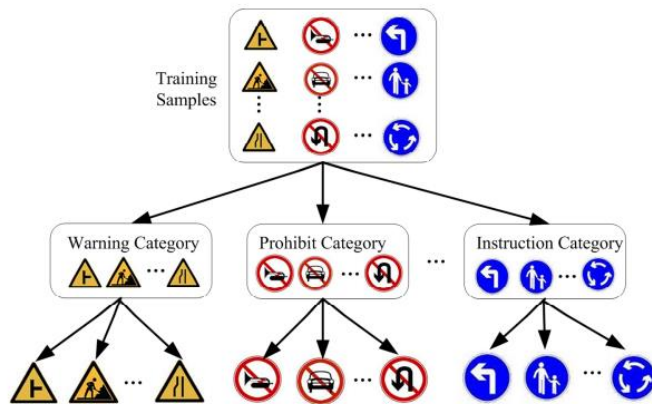
Recognition: Previous Work

- Handcrafted feature detectors and extractors
  - Histogram of Oriented Gradients (HOG) - [Greenhalgh 2012, Zaklouta 2011]
  - Integral Channel Features (ICF) - [Mathias 2013]
  - Categories-first-assigned Tree (CTA-Tree) - [Liu 2013]
  - Split-Flow Cascade Tree (SFC-Tree) - [Liu 2014]

CTA-Tree, source: [Liu 2013]

SFC-Tree, source: [Liu 2014]

Recognition: Previous Work

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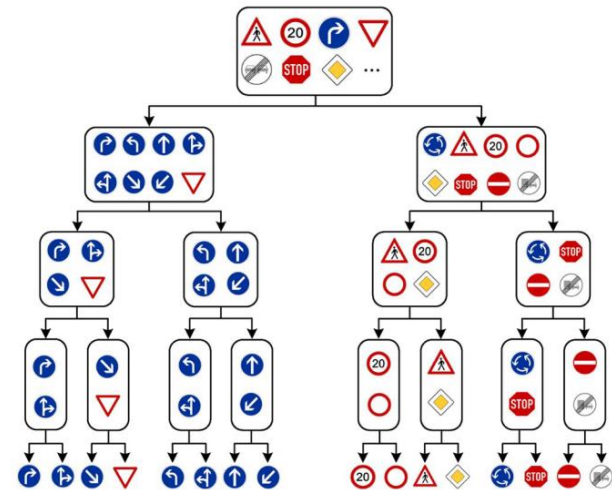
  - Integral Channel Features (ICF) - [Mathias 2013]

  - Categories-first-assigned Tree (CTA-Tree) - [Liu 2013]

  - Split-Flow Cascade Tree (SFC-Tree) - [Liu 2014]

- Followed by feature classifiers

  - Random Forest - [Zaklouta 2011]

  - SVM, Hierarchical SVM, Kernel SVM [Greenhalgh 2012]

  - Multi-layer Perceptron (MLP)
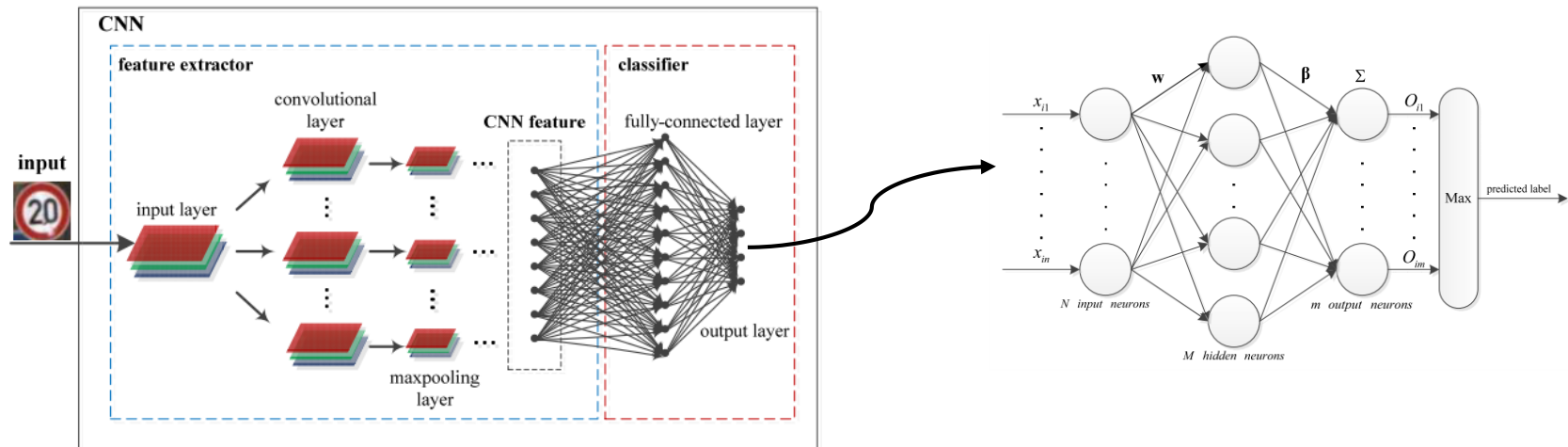
Recognition: Previous Work

- Deep Learning and ConvNets (CNN)
  - Committee of DNN (Muti-Column DNN) - [Cireșan 2012]
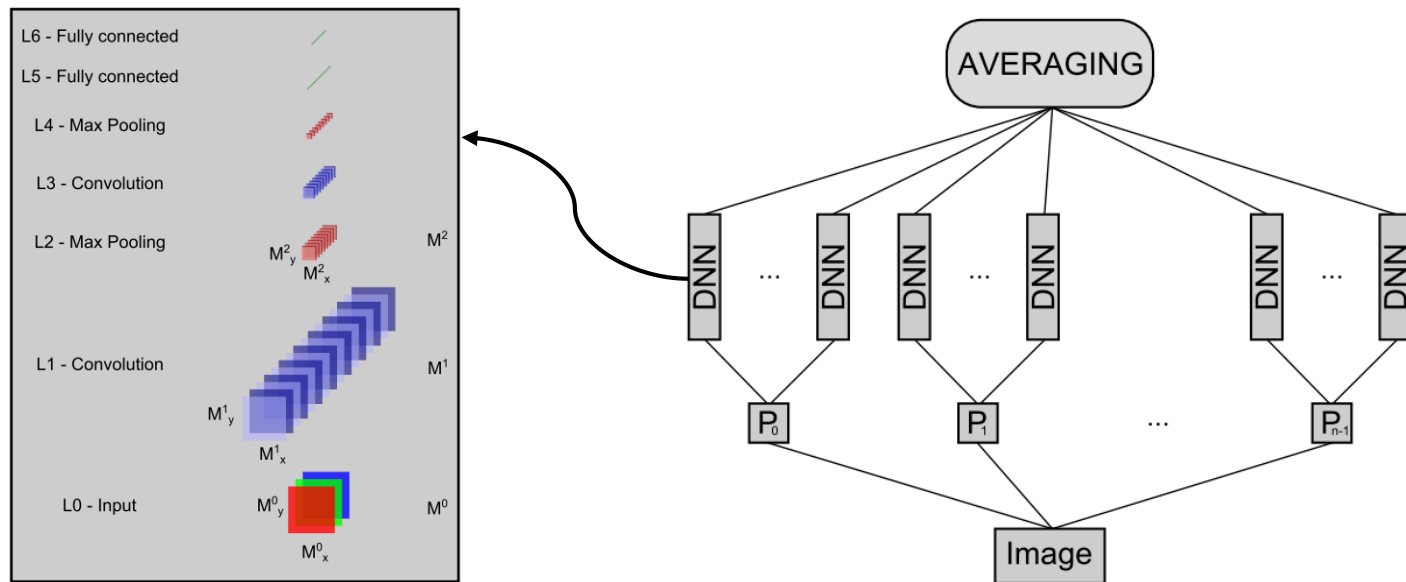
Source: [Cireșan 2012]

Recognition: Previous Work

- Deep Learning and ConvNets (CNN)
    - Committee of DNN (Muti-Column DNN) - [Cireşan 2012]
    - Extreme Learning Classifier (ELC) with CNN - [Zeng 2015]

Source: [Zeng 2015]

Recognition: Previous Work
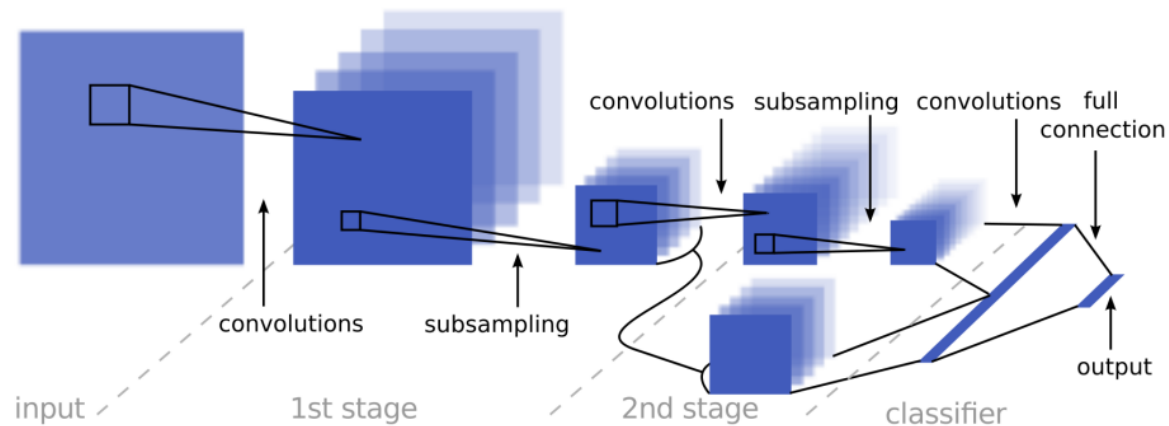
- Deep Learning and ConvNets (CNN)
    - Committee of DNN (Muti-Column DNN) - [Cireșan 2012]
    - Extreme Learning Classifier (ELC) with CNN - [Zeng 2015]
    - Multi-Scale CNN - [Sermanet 2011]

Source: [Sermanet 2011]

Recognition: Limitations

- Handcrafted features

  – Feature engineering comes with a price - [Brkic 2010, Filkovic 2014]

Source: [Brkic 2010]

Recognition: Limitations

- Handcrafted features

  - Feature engineering comes with a price - [Brkic 2010, Filkovic 2014]

  - Shallow features, less discriminant, struggle with large dataset [Razavian 2014]

  - Outperformed by CNN in large-scale problems - [Razavian 2014]
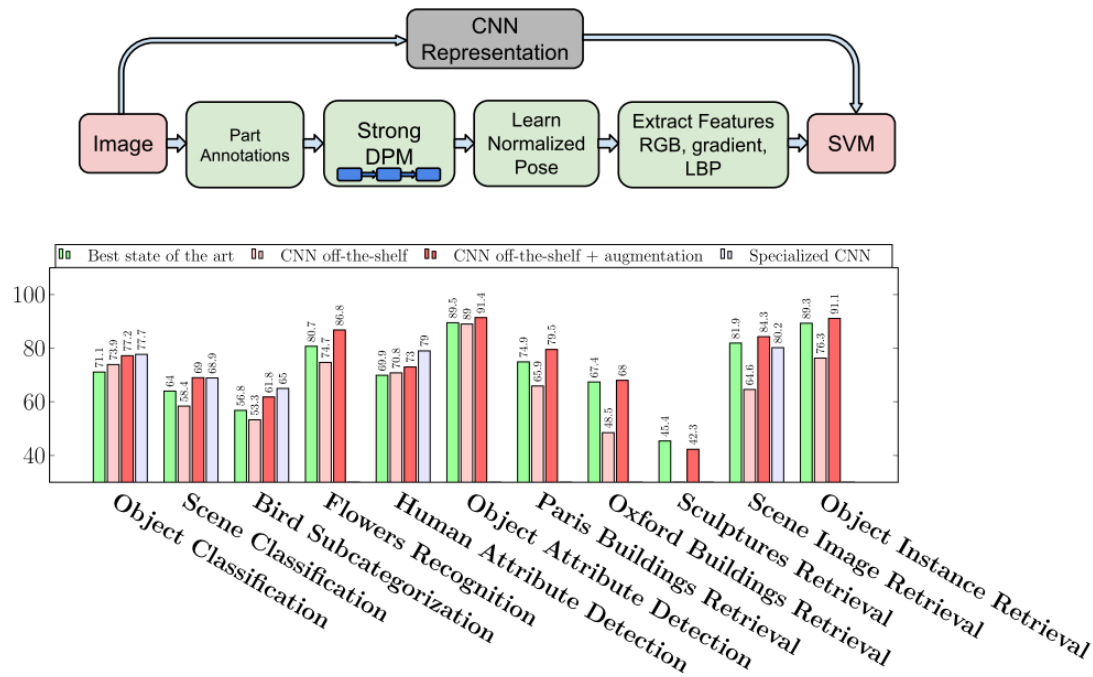
Source: [Razavian 2014]

Recognition: Limitations

- Deep Learning (CNN)
  - Complexity of training for large scale datasets (100+ classes)

Recognition: Limitations

- Deep Learning (CNN)
  - Complexity of training for large scale datasets (100+ classes)
  - German Traffic Sign Recognition Benchmark (GTSRB) – 43 classes

Source: http://benchmark.ini.rub.de/?section=gtsrb

Recognition: Limitations

- Deep Learning (CNN)

    - Complexity of training for large scale datasets (100+ classes)

    - German Traffic Sign Recognition Benchmark (GTSRB) – 43 classes

    - Belgium Traffic Sign dataset (BelgiumTS) – 63 classes
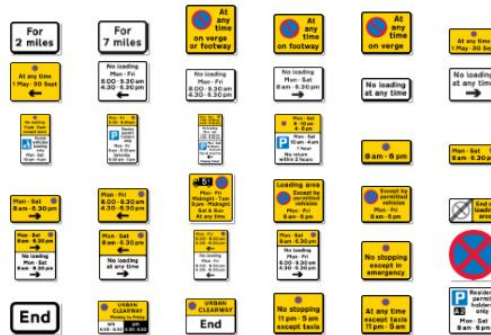
Source: http://btsd.ethz.ch/shareddata/

Recognition: Limitations

- Large-scale Dataset (100+ Classes)
  - How far are we from the solution? - [Mathias, 2013]

Road Work

On-street Parking

Motorway Signs

Source: https://www.gov.uk/government/publications/the-highway-code-traffic-signs

Recognition: Methods

- Hierarchical CNN (H-CNN)
  - Exploit the visual features (shapes)
  - Solution to address large-scale classification

Reproduced from: http://deeplearning.net/tutorial/lenet.html
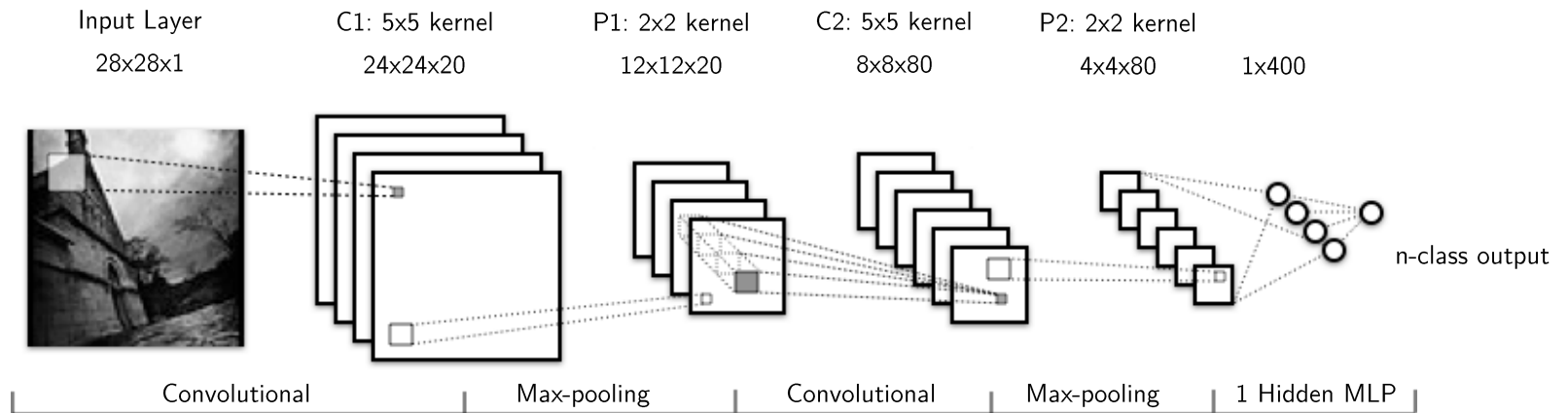
Recognition: Methods

- Hierarchical CNN (H-CNN)
  - Exploit the visual features (shapes)
  - Solution to address large-scale classification

Super-class Classifier

Superclass-specific Classifiers

Prohibitory

Mandatory

Warning

Misc.
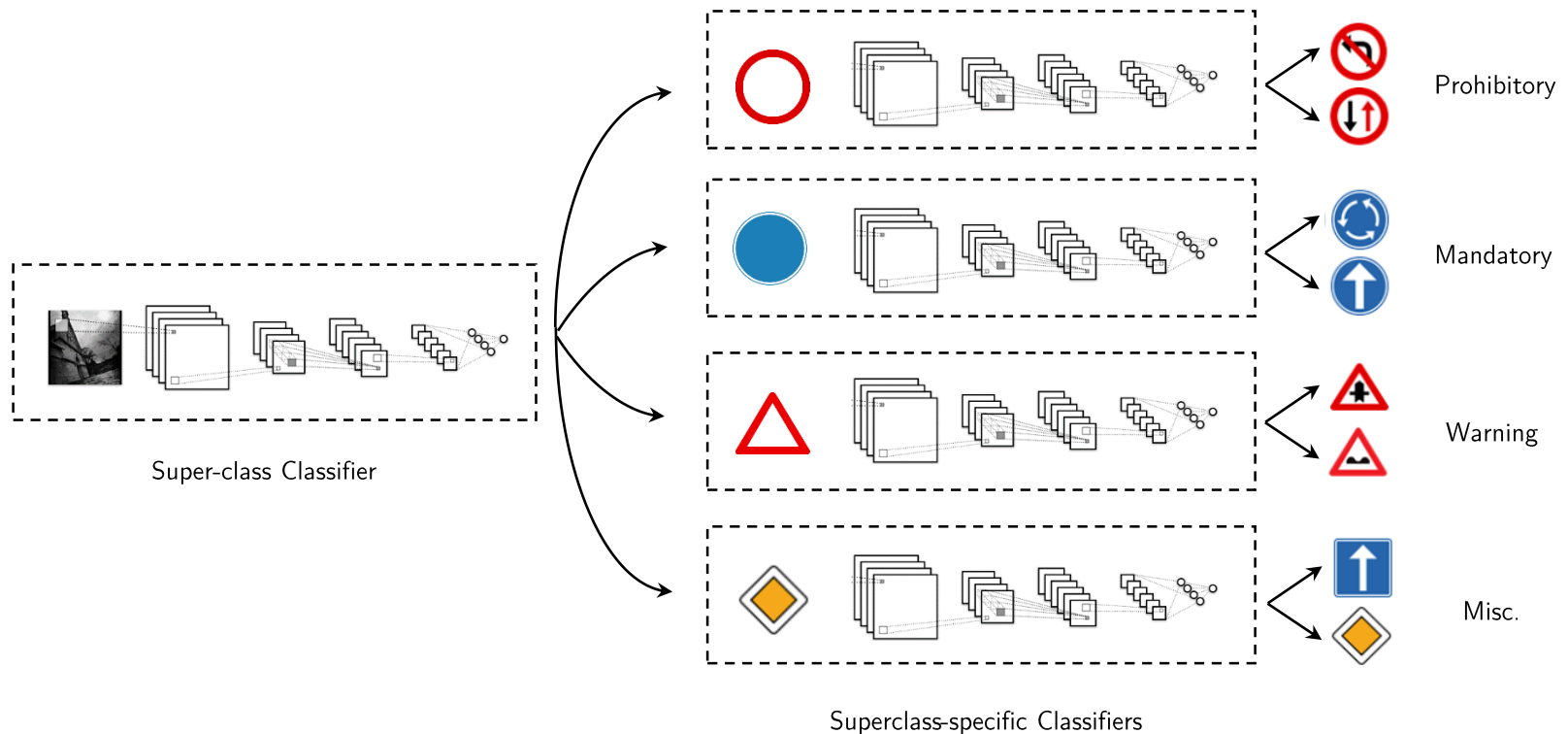
Recognition: Methods

- Super-class hypothesis
  - Will the super-class network develop a shape-based filters (i.e. feature maps)?
  - Will these filters be extensible to non-represented classes?

GTSRB Dataset

BelgiumTS Dataset

Recognition: Results

- GTSRB Competition

Method	Accuracy
2-stage HOG+SVM [Yang 2014]	99.52%
Committee of CNNs [Ciresan 2012]	99.46%
Benchmark – Human Performance	98.84%
Multi-Scale CNNs [Sermanet 2011]	98.31%
Random Forests [Zaklouta 2011]	96.14%
Our Method – Hierarchical CNN	**94.98%**

Recognition: Results

- GTSRB Competition

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Recognition: Results

- GTSRB Competition

Method	Architecture	Parameters	Input
Committee of CNNs [Ciresan 2012]	3 Conv [20, 40, 800] − 2 Hidden Layers * 8 CNN	40e6	48x48
Multi-Scale CNNs [Sermanet 2011]	2 Conv [104, 8640] − 2 Hidden Layers	5e6	32x32
Hierarchical CNN [Our Method]	2 Conv [20, 80] − 1 Hidden Layer [400]	0.75e6	28x28

Detection

Detection: Previous Work

- Detection Proposals

  – Colour based, probability maps - [Yang 2014]

CPM

+

Colour Probability Map (CPM) into red and blue
Image reproduced from [Yang 2012]

Detection: Previous Work

- Detection Proposals

  – Colour based, probability maps - [Yang 2014]

  – Shape based, Maximally Stable Extremal Regions (MSER) - [Zaklouta 2011, Yang 2014]
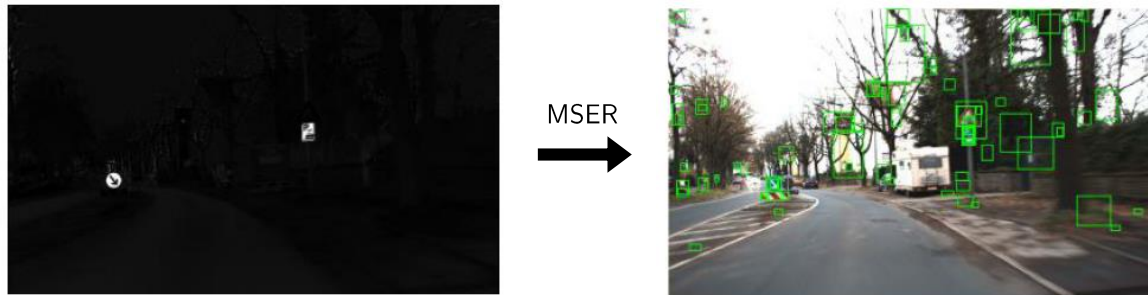
MSER

Detection: Previous Work

- Detection Proposals
    - Colour based, probability maps - [Yang 2014]
    - Shape based, Maximally Stable Extremal Regions (MSER) - [Zaklouta 2011, Yang 2014]
    - Sliding Window at multiple scales

Detection: Previous Work

- Detection Proposals

    – Colour based, probability maps - [Yang 2014]

    – Shape based, Maximally Stable Extremal Regions (MSER) - [Zaklouta 2011, Yang 2014]

    – Sliding Window at multiple scales

- Handcrafted Detectors

    – Same as classifier feature detectors, HOG, IFC - [Yang 2014]

Detection: Previous Work

- Detection Proposals
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- Handcrafted Detectors
  - Same as classifier feature detectors, HOG, IFC - [Yang 2014]
  - Multi-block Normalized Locale Binary Pattern (MN-LBP) - [Liu 2014]

Image source [Liu 2014]

Detection: Previous Work

Left: MN-LBP, right: Tilted MN-LBP
Image source [Liu 2014]

Extended Haar-like features
Image source [Liu 2013]

Detection: Previous Work

- Detection Proposals

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  - Shape based, Maximally Stable Extremal Regions (MSER) - [Zaklouta 2011, Yang 2014]

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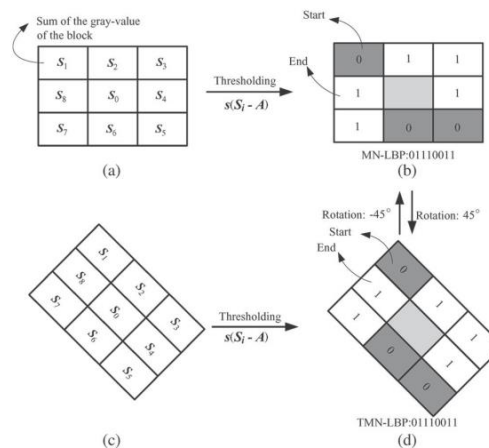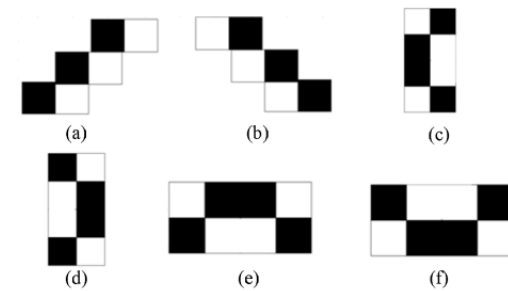 - Multi-block Normalized Locale Binary Pattern (MN-LBP) - [Liu 2014]

- Suppression

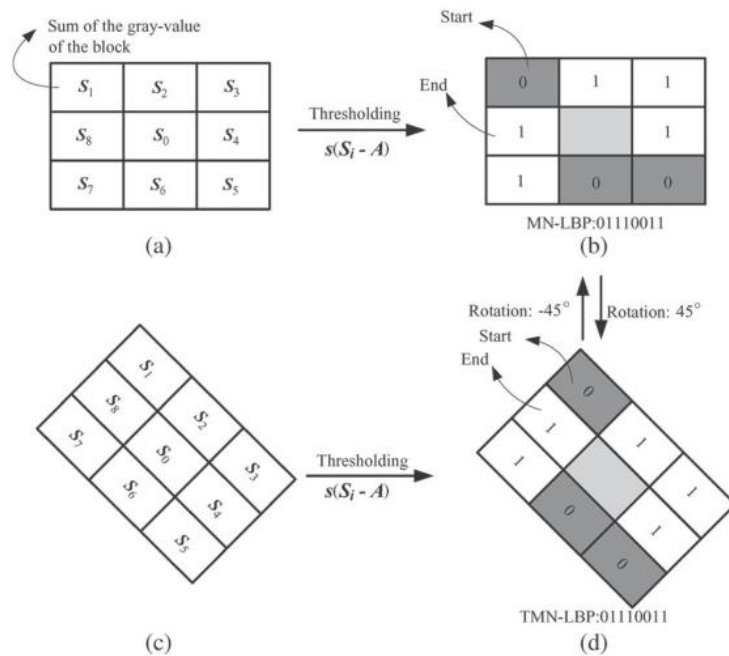 - Non-Maximum Suppression
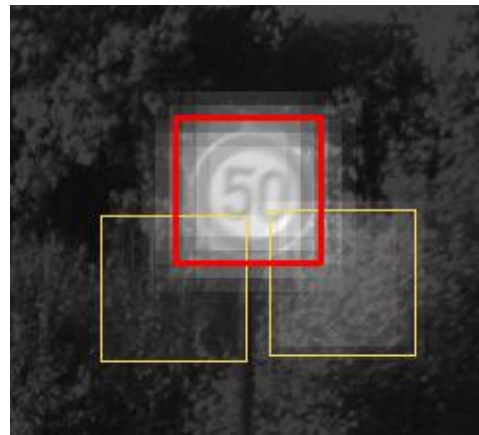
Detection: Previous Work

- Deep Learning Detectors
    - CNN classifier, sliding window at different scales - [Kobchaisawat 2014, Wang 2012, Coates 2011]
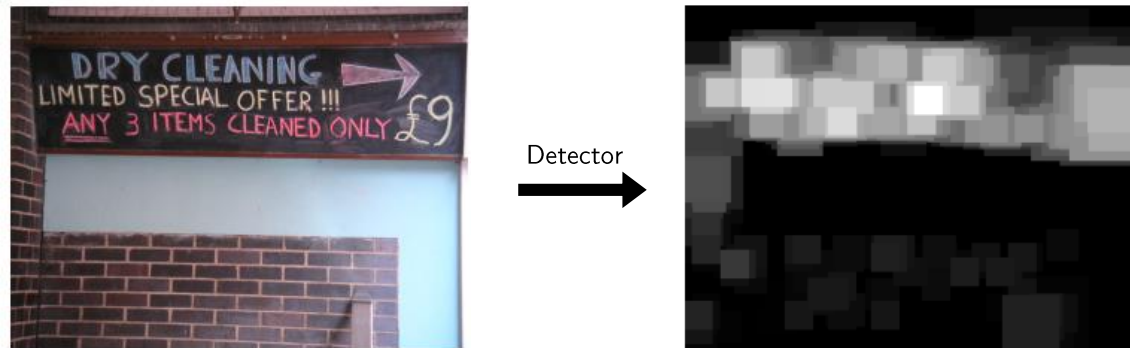
Confidence map of the detector
Reporduced from: [Coates 2014]

Detection: Previous Work

- Deep Learning Detectors

  – CNN classifier, sliding window at different scales – [Kobchaisawat 2014, Wang 2012, Coates 2011]

  – Overfeat: CNN classifier with region detector (regressor) - [Sermanet 2013]

Detection: Methods
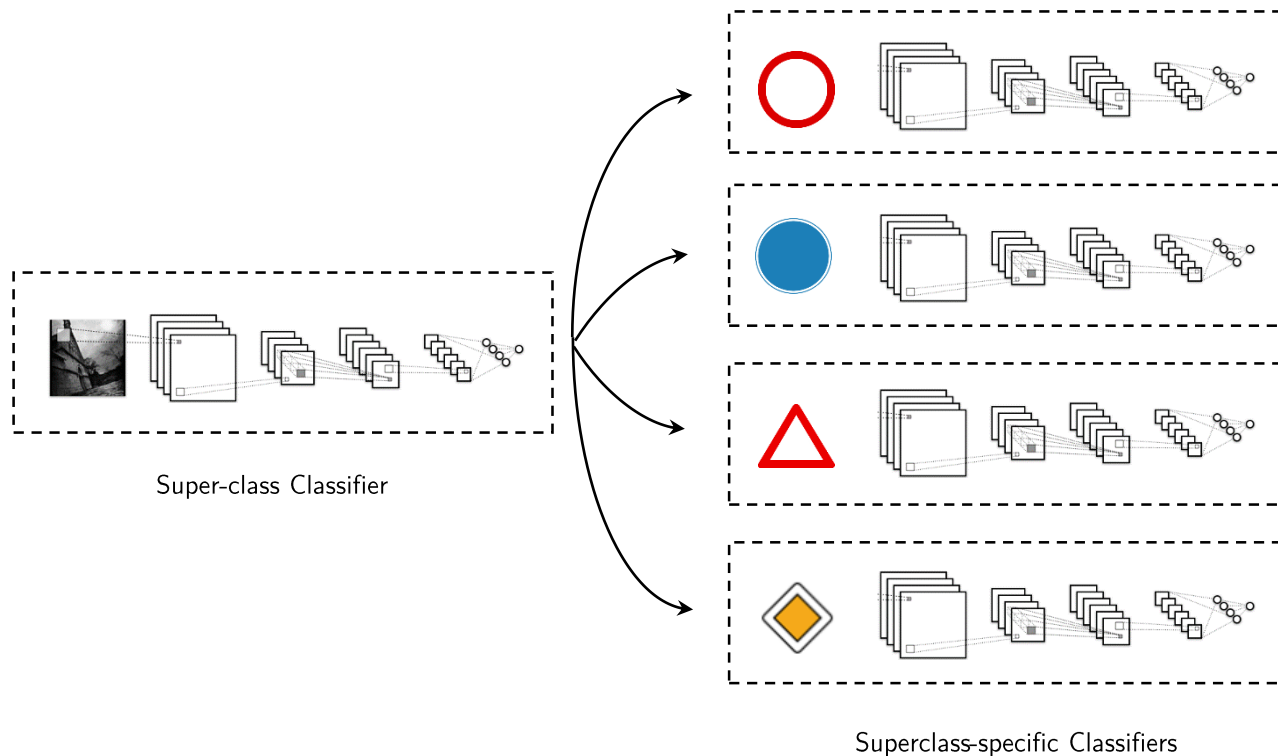
- Superclass-specific Detector
  - Use convolutional features learned from the classifier
  - Train MLP to predict location of traffic sign within the window

Super-class Classifier

Superclass-specific Classifiers

Detection: Methods

- Superclass-specific Detector
  - Use convolutional features learned from the classifier
  - Train MLP to predict location of traffic sign within the window

Superclass-specific Classifiers

MLP: 2 hidden layers, output layers
Image reproduced from Wikimedia

Detection: Methods

- Superclass-specific Detector
  - Use convolutional features learned from the classifier
  - Train MLP to predict location of traffic sign within the window
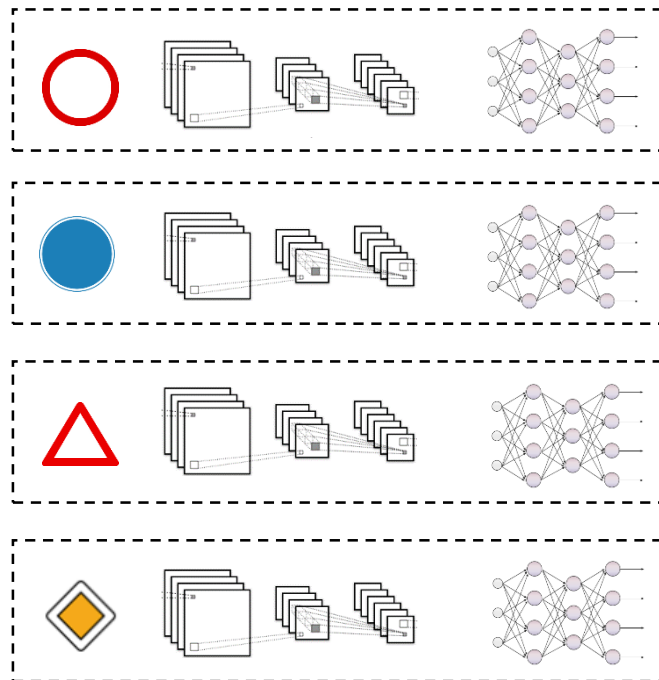
Superclass-specific Detectors

Detection: Methods

- Superclass-specific Detector
  - Sample true positives at different positions/scales within the window
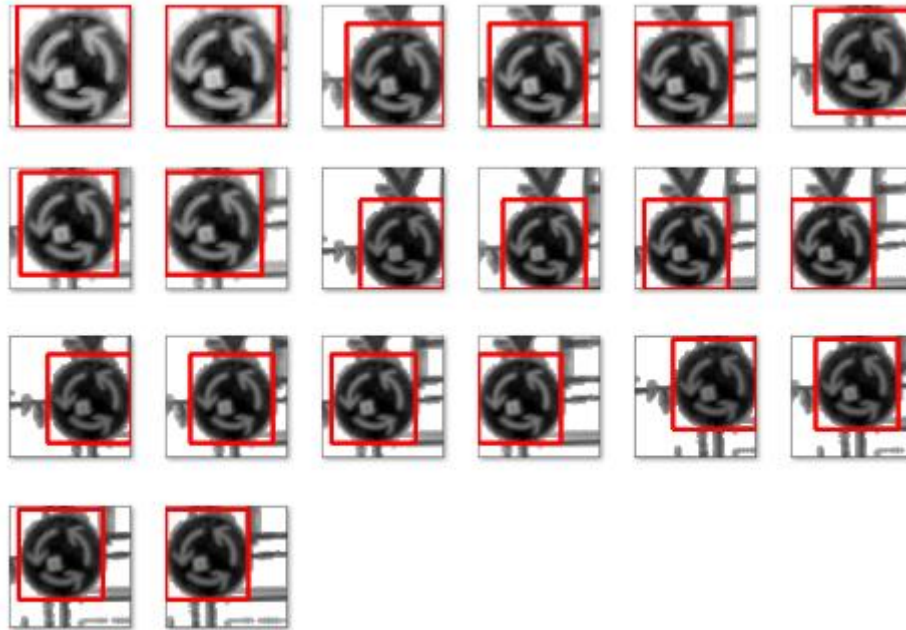
Detection: Methods

- Superclass-specific Detector
  - Sample true positives at different positions/scales within the window
  - Sample true negatives from the natural image background
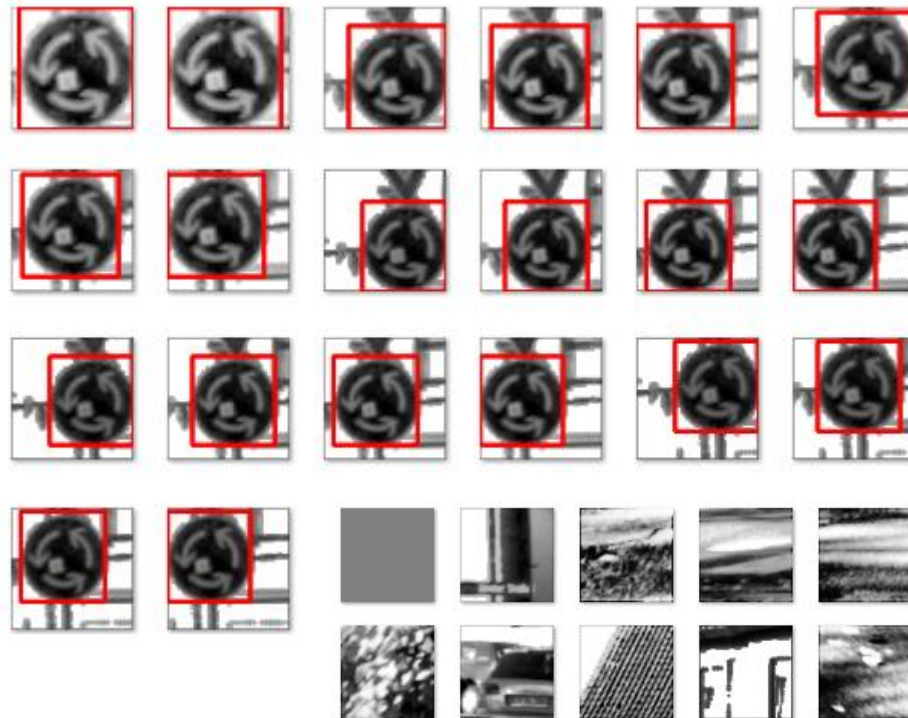
Detection: Methods

- Experiments
  - Sampling only true positives

1
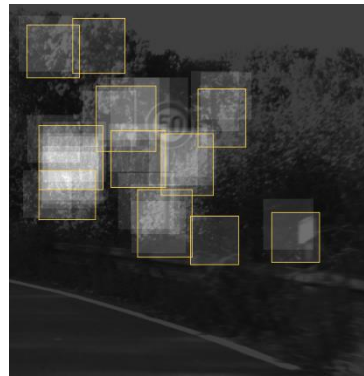
2
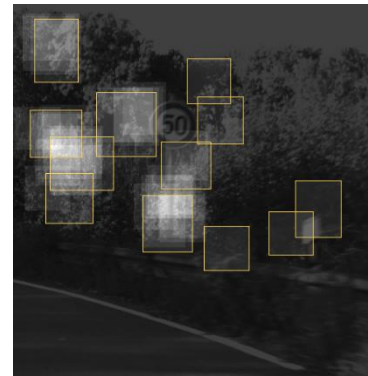
3
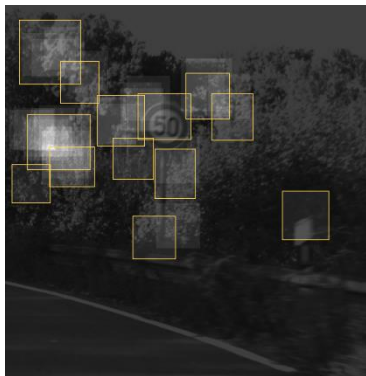
4

5

6

Detection: Methods

- Experiments
  - Huge search space (natural images)

Detection: Results

- Currently, only circle-shaped super-classes
  - Prohibitory, Mandatory

Conclusion

- Recognition

  - CNN has potential to address large-scale datasets (100+ classes)

  - Scalable/extensible to un-seen unseen classes during training

- Detection

  - If well-trained, overcome the problem of hand-crafted

  - With more effort, possible potential to reach state-of-the art performance

- Tracking

  - Enabling the real-time system to locate the position of the traffic sign on the map

- Trade-off

  - GTSRB and GTSDB competitions favour accuracy and complexity

  - Real-time systems favour simplicity and speed

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Thank you

Questions