# Semi-supervised incremental learning of hierarchical appearance models

Susanne Wenzel

## Problem

- Number and nature of visual categories or object classes are often not initially known
- In general there is no fixed set of training images that perfectly describes the classes and is observable in its entirety
- **Given:**
  - One example of an object
  - Prior knowledge that it is repeatedly present in an image
- **Goal:**
  - Automatically identifying prototypes
  - Build up an object class hierarchy guided by user's judgement
  - Train classifiers that are capable of incremental learning
  - *Develop a system, which can improve its capabilities of learning continuously.*

## Incremental learning scheme

- Initialize the system with the prototype discovery (1)
  $\longrightarrow$ Initialize the prototype representations, the class hierarchy and the classifiers
- **Repeat**
  - Use prototypes to detect probable new instances in new image
  - Classify probable new instances using current object model (2)
  - Ask user for the meaning of uncertain classifications
  - Let the user correct miss-classifications
  - Update prototypes, class hierarchy and classifiers (3)
- **Until** User satisfied or images exhausted

## 1 Getting Prototypes

1. Getting clusters
   - Recursive search procedure to get a set of similar objects
   - $\longrightarrow$ Allows to reach all instances bridged by the chaining effect
   - Clustering based on a reduced similarity graph, cf. (Van Gool et al., 2007)
   - Instances in one connected component are assumed to belong to the same subclass
2. Supervised labelling of found clusters
   - Identification of the subclasses based on the user's judgement:
   - Cluster represents
     - Subclass of the class envisaged,
     - Another class not yet envisaged or
     - Rejection class
3. Representation of prototypes
   - Mean feature vector
   - Use prototypes to find new instances in other images

## 2 Classification

- Generative models: easy incremental learning
- Discriminative models: higher efficiency

$\Rightarrow$ Integration of both representations

$\Rightarrow$ PCAaLDA gets feature vectors $\boldsymbol{y}$ for every image patch in classification subspace of dimension $C$, cf. (Fidler, 2006).

- Classification in subspace via bayes classificator

$$p(c|\boldsymbol{y}) = \text{argmax}_c\, p\left(\boldsymbol{y}|\mu_c, \Sigma_c\right) p\left(c\right)$$

with uni-modal gaussian $p\left(\boldsymbol{y}|\mu_c, \Sigma_c\right)$ for every subclass $c$

- likelihood ratio approximate 1 $\Rightarrow$ user decides whether to accept the sample or to reject it

## 3 Incremental update

- Use prototypes for detecting new instance in a new image
- Start the recursive search procedure again
- Classification according learned models
- Update prototypes by adding the mean $\boldsymbol{p}_c$ of new images
- Evaluate batch LDAaPCA on all data gathered

## Future Work

- Improve clustering, find optimal thresholds for clustering guided by the data
- Adapt the current subspace methods to incremental LDA, cf. (Uray et al., 2007)
- Include depth information

## Experiments - Initialisation

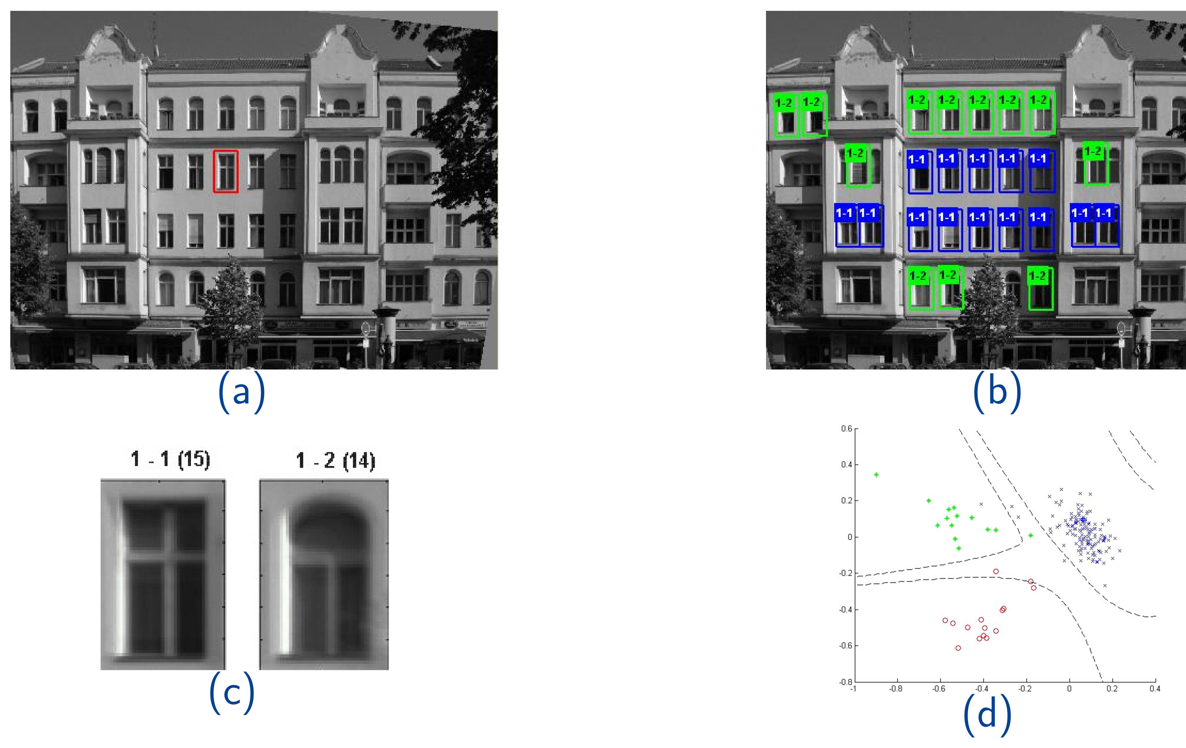
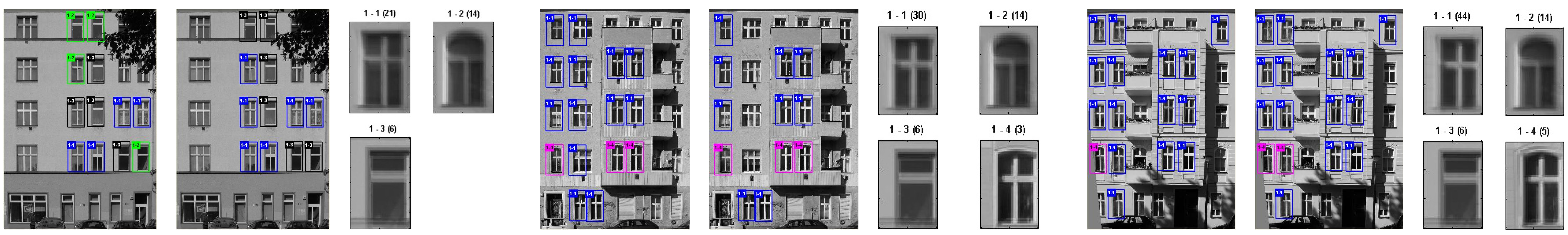



Figure: Initialisation: (a) Initial example. (b) Result of detecting new instances. (c) Prototypes ($1^{st}$ number: class, $2^{nd}$ number: subclass, clamped number: number of associated samples). (d) Samples projected into the PCAaLDA subspace. Red: class 1-1, green: class 1-2, blue: background. Dashed lines: decision boundaries according the class boundaries and the rejection area.

## Experiments - Sequential Update




(a) (b) (c) (d) (e) (f) (g) (h) (i)

Figure: 2. to 4. Step. (a), (d) and (g): Results of automatically detect new instances before editing. (b), (e) and (h): Result after editing. (c), (f) and (i): Prototypes.

## References

Fidler, S. (2006). Combining Reconstructive and Discriminative Subspace Methods for Robust Classification and Regression by Subsampling. *PAMI 28*(3), 337–350.

Uray, M., D. Skočaj, P. M. Roth, H. Bischof, and A. Leonardis (2007, September). Incremental LDA Learning by Combining Reconstructive and Discriminative Approaches. In *BMVC*.

Van Gool, L., G. Zeng, F. Van den Borre, and P. Müller (2007, September 19-21). Towards mass-produced building models. In *PIA*, Volume 36, Munich, Germany, pp. 209–220.

Institute for Geodesy and Geoinformation
Department for Photogrammetry
http://www.ipb.uni-bonn.de

Nussallee 15
53115 Bonn, Germany
Tel. +49 228 73 2908

Contact:
Susanne Wenzel
susanne.wenzel@uni-bonn.de