

Interactive Online Learning for Obstacle Classification on a Mobile Robot

Viktor Losing^{1,2}, Barbara Hammer² and Heiko Wersing¹

¹University of Bielefeld
Bielefeld, Germany

²Honda Research Institute Europe GmbH
Offenbach, Germany

Online Learning

Motivation:

- ▶ Adaptation to user habits & environment
- ▶ Current methods rather simple



Benefits:

- ▶ Incremental learning
- ▶ Incorporation of new classes
- ▶ Control of model complexity
- ▶ Handling of drift

Challenges:

- ▶ Stability - Plasticity

Goals

1. Realization of a new interactive Learning Scenario on a Mobile Robot
 - Outdoor object recognition in a garden environment
 - Interaction via iPad
 - Recording of a challenging outdoor benchmark dataset for learning

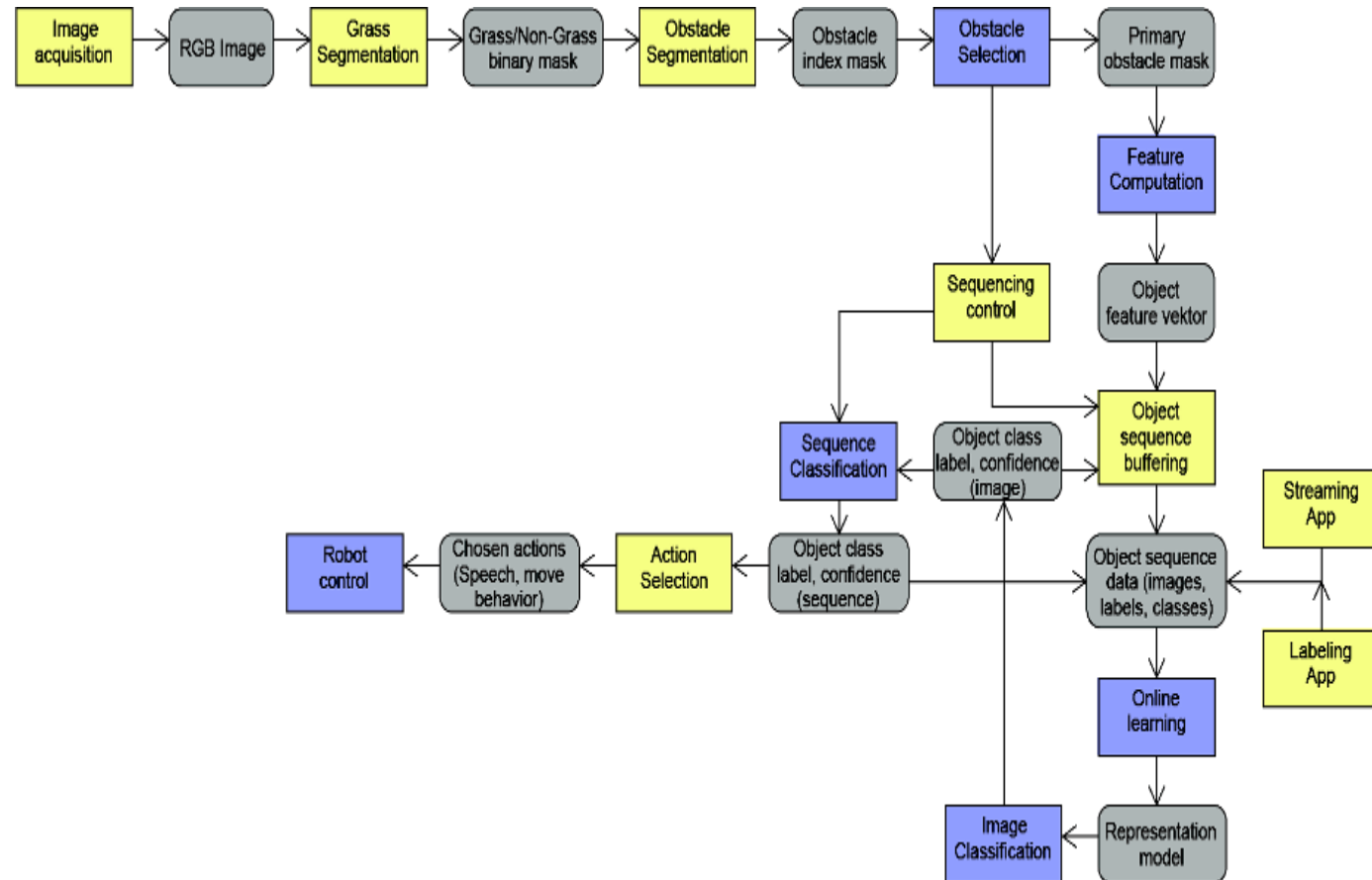
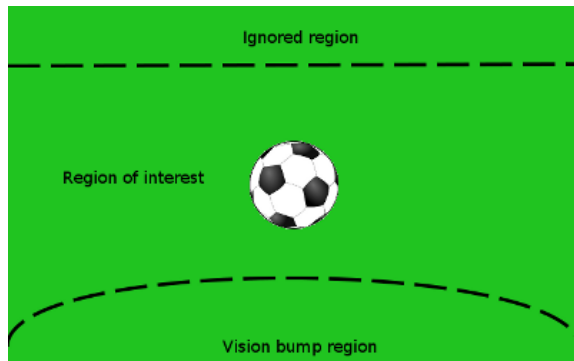
2. Improvement of incremental learning for LVQ
 - Analysis of prototype placement strategies
 - Comparison on artificial/real datasets

Interactive Scenario

- ▶ Random exploration
- ▶ Grass-segmentation for detection
- ▶ Labeling via iPad
- ▶ Object specific actions
 - Comment
 - Drive around/over
- ▶ Confidence estimation
 - Unknown objects
 - Drive around in case of low confidence

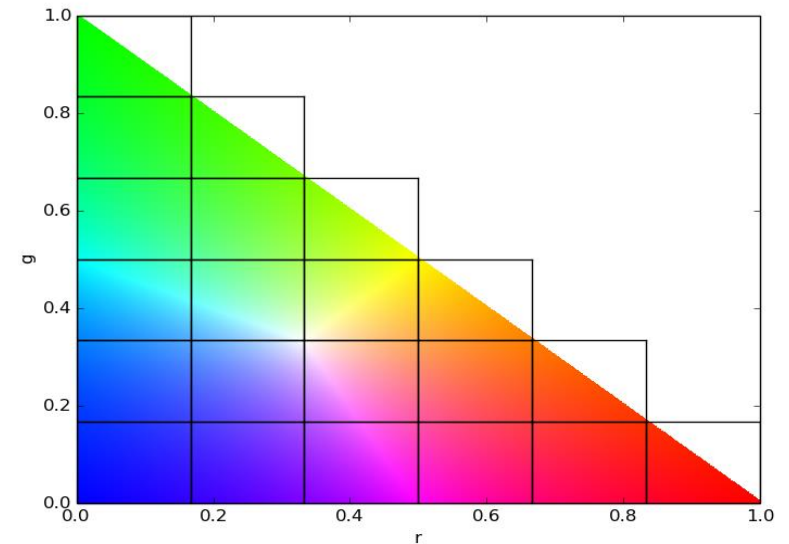


Perception and Control



Feature Representation

- ▶ Color based: simple & robust
- ▶ rg-Chromaticity histogram
- ▶ Intensity invariant
- ▶ 21 dimensions
- ▶ Hist.-normalization for size invariance

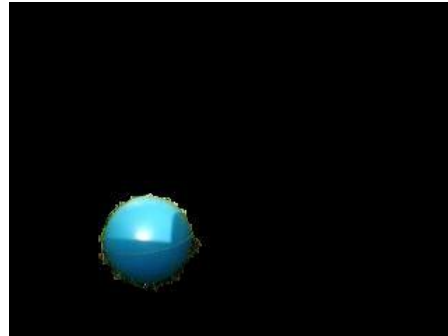


Processing pipeline

Input



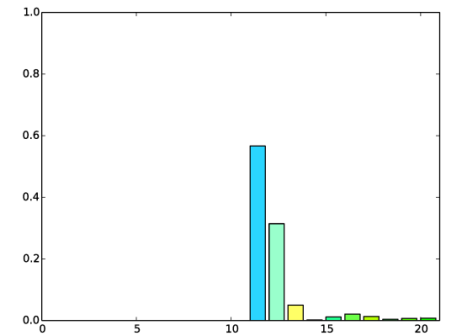
Segmentation



rg-Chromaticity



Histogram

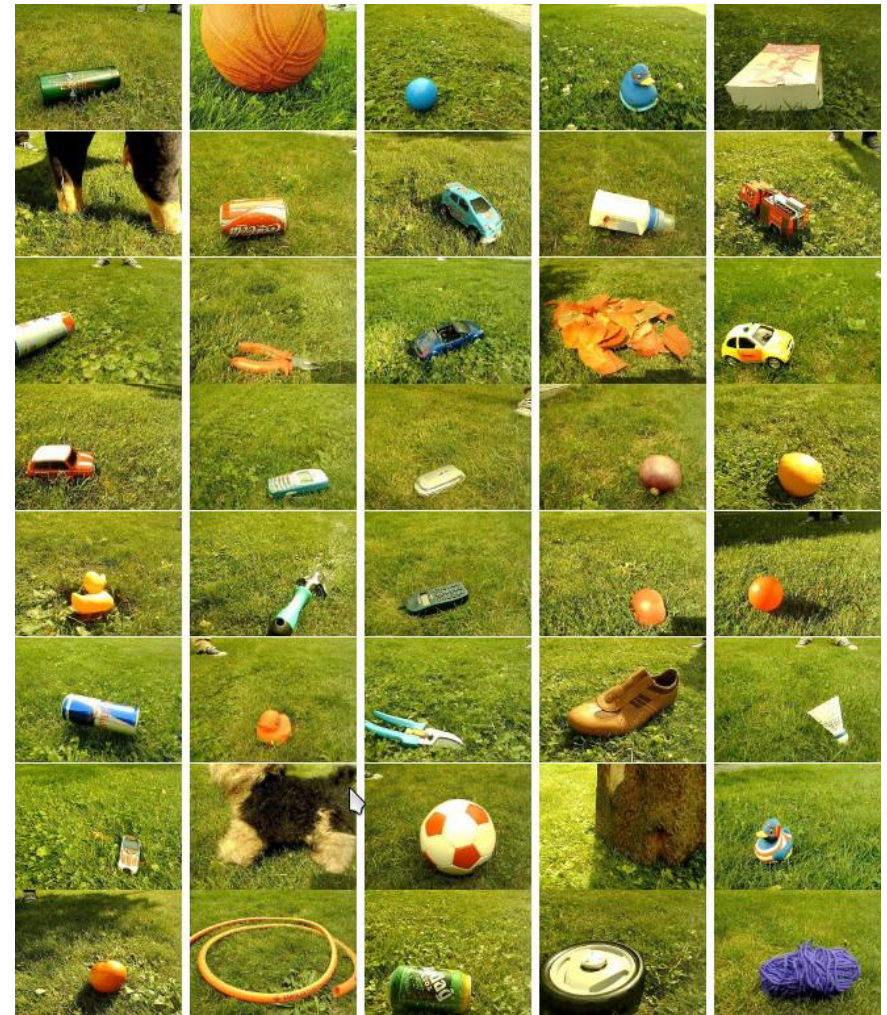


Outdoor benchmark dataset

- ▶ 40 objects
- ▶ 5 sequences in cloudy/sunny conditions
- ▶ 10 images per sequence



Sequences



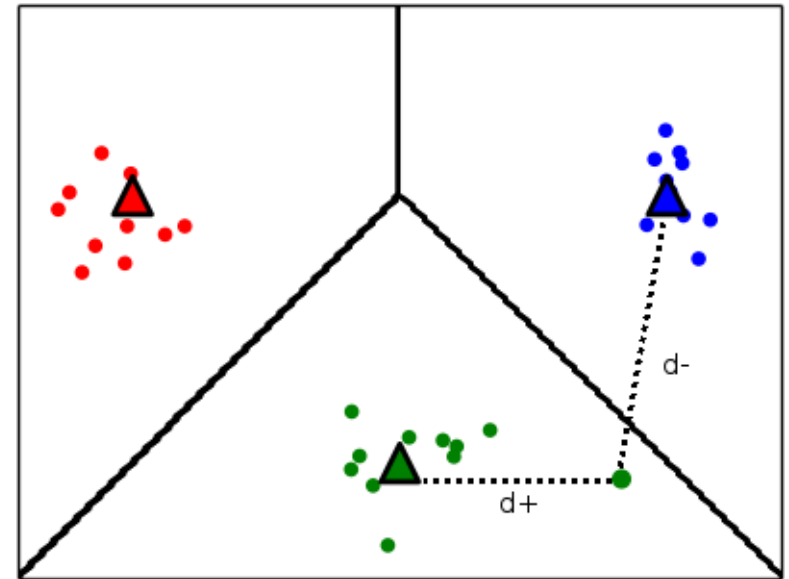
All objects

Challenges



GLVQ¹

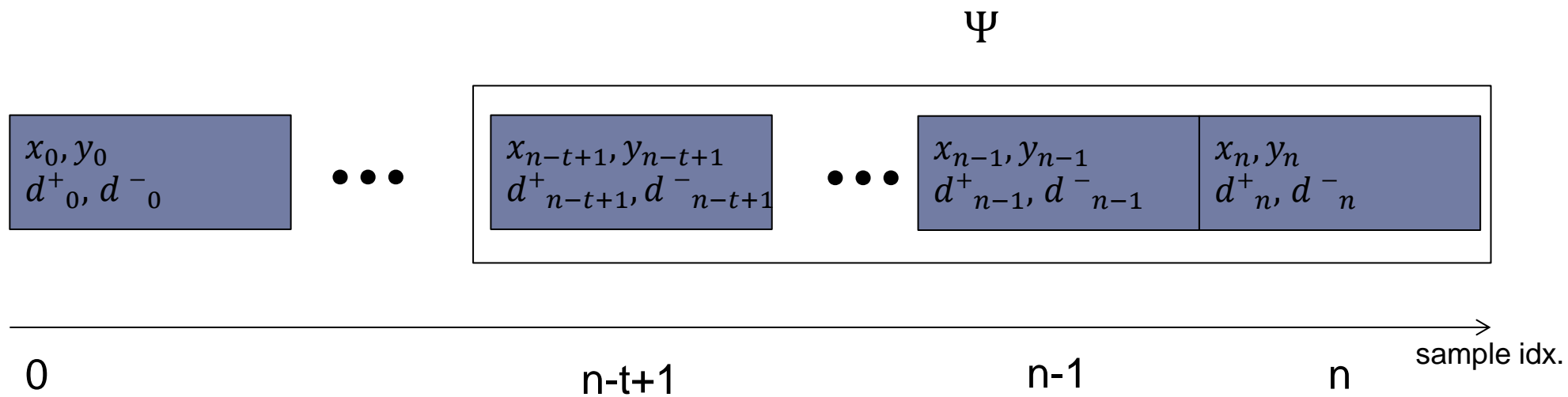
- ▶ Supervised, prototype-based
- ▶ $E(X) = \sum_{i=1}^n \Phi[(d^+_i - d^-_i)/(d^+_i + d^-_i)]$
- ▶ $w^\pm := w^\pm - \lambda \frac{\partial E(X)}{\partial w^\pm}$
- ▶ Minimized in stochastic gradient descent scheme



¹ A.Sato, K.Yamada "Generalized Learning Vector Quantization", 1995

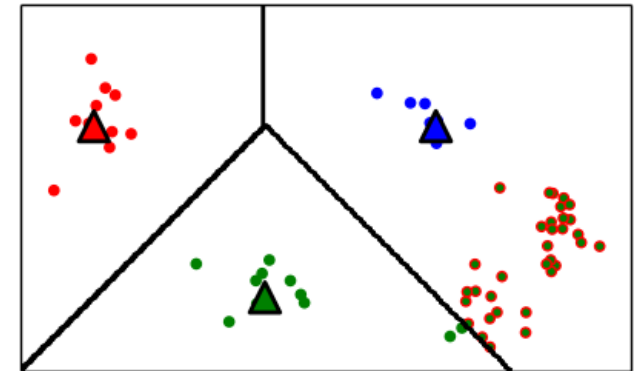
Short term memory

$\Psi := \langle (x_i, y_i, d^+_i, d^-_i) \mid i \in 1, \dots, t \rangle$, window of recent t samples

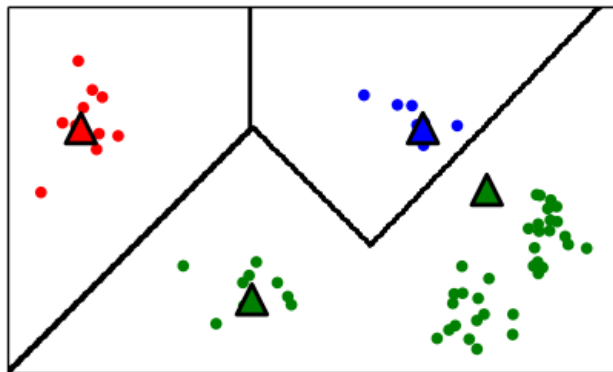


Current Placement Strategies

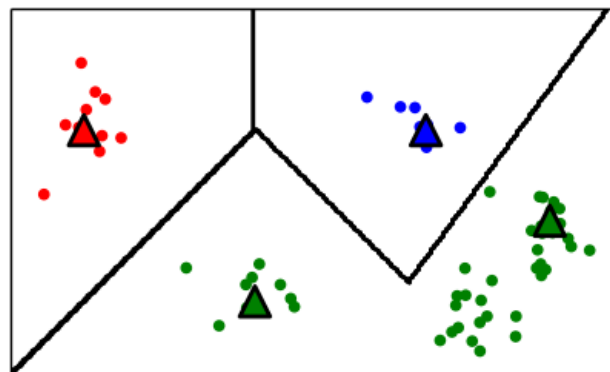
- ▶ Based on class-local heuristics
- ▶ Use misclassifications only



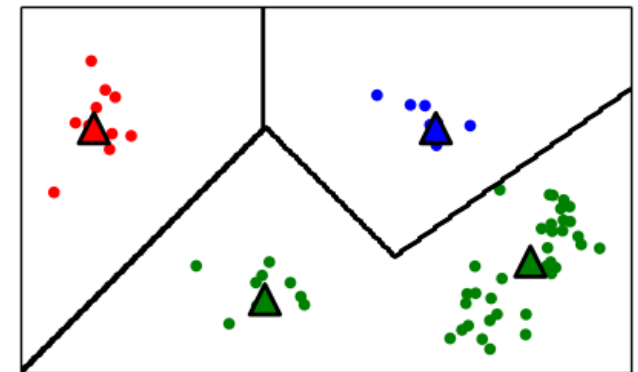
Closest¹



Cluster²



Voronoi³



¹ S.Kirstein, H.Wersing "Rapid Online Learning of objects in a biologically motivated architecture", 2005

² M.Grbovic, S. Vucetic "Learning Vector Quantization with adaptive prototype addition and removal", 2009

³ S. Bermejo, J. Cabestany "A new dynamic lvq-based classifier and its application to handwritten digits", 1998

Proposed Strategy - SamplingCost

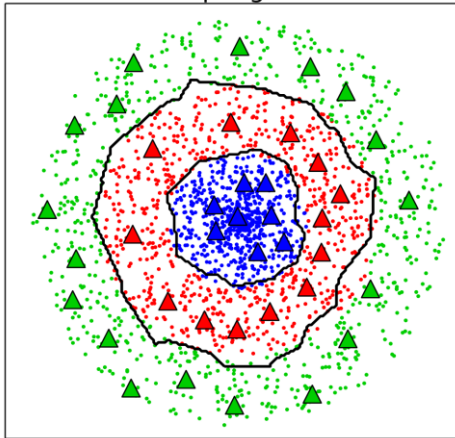
- $\hat{\Psi} \subseteq \Psi, |\hat{\Psi}| = \hat{t}$
- $\forall (x_i, y_i) \in \hat{\Psi}$:
 - $\widehat{W}_i := \{W \cup (x_i, y_i)\}$
 - $\dot{\Psi}_i = \text{update } \Psi$
 - Calculate cost-function value $E(\dot{\Psi}_i, \widehat{W}_i)$
- Choose \widehat{W}_i s.t. $E(\dot{\Psi}_i, \widehat{W}_i)$ is minimized

Cross-class optimization

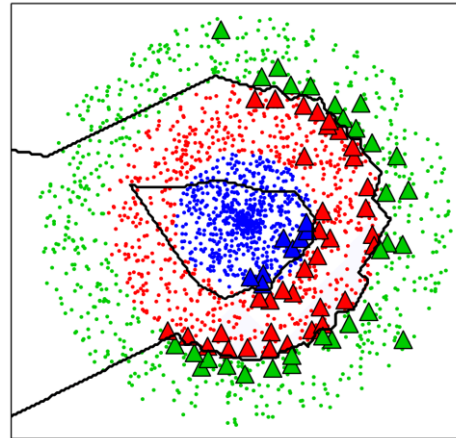
Artificial dataset Border

<i>Border-DS</i>	Acc.	Nodes
SamplingCost	93.51	38.2
Closest	90.17	58.2
Cluster	91.93	42.9
Voronoi	91.71	46.4

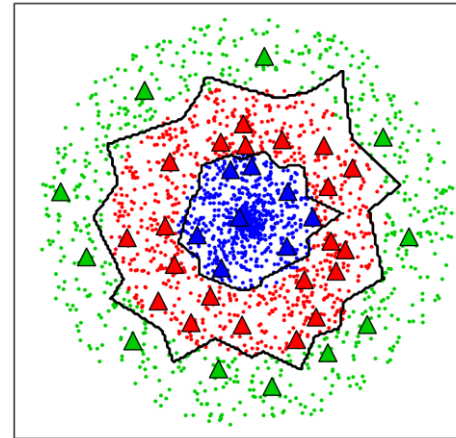
SamplingCost



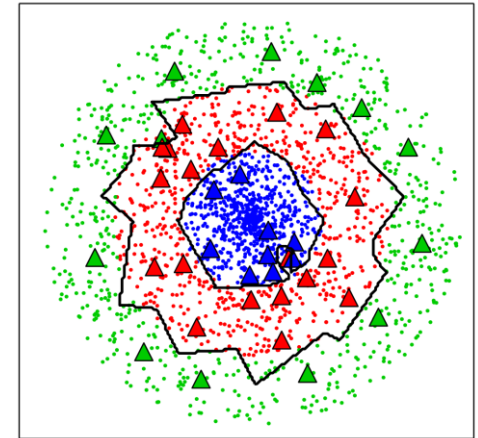
Closest



Cluster

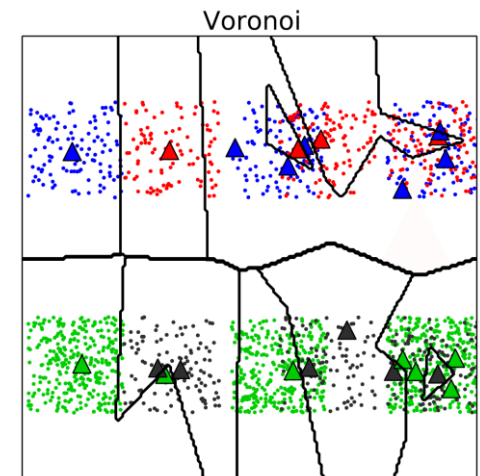
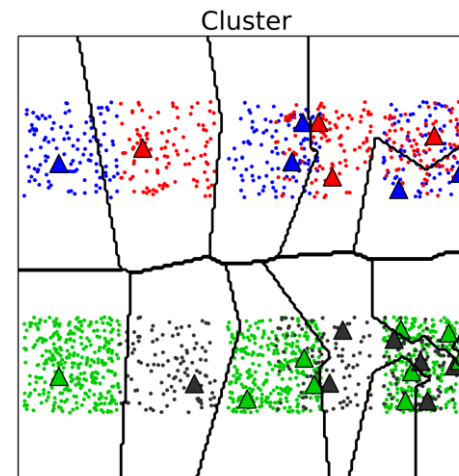
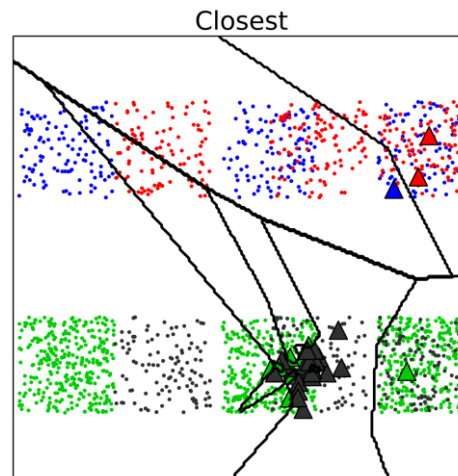
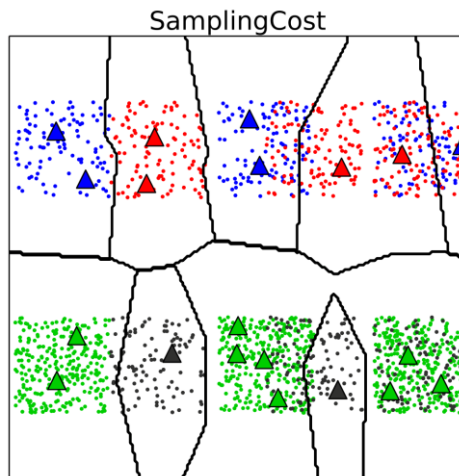


Voronoi



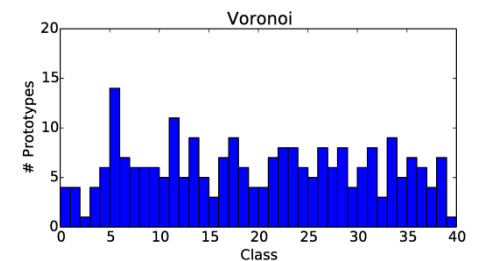
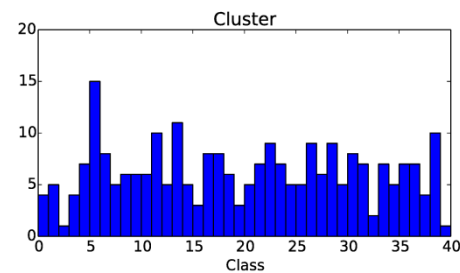
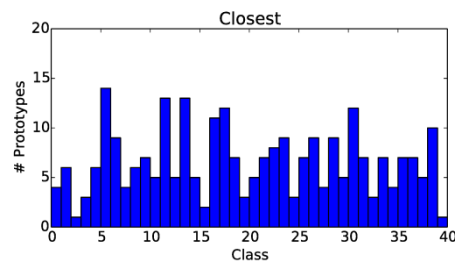
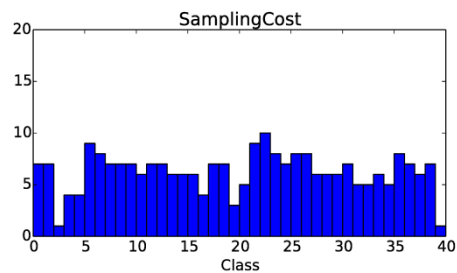
Artificial Dataset Overlap

<i>Overlap-DS</i>	Acc.	Nodes
SamplingCost	78.74	21.3
Closest	65.76	29.8
Cluster	74.85	25.6
Voronoi	74.08	26.4



Outdoor Dataset

<i>Random-order</i>	Test acc.	Train acc.	Nodes	<i>Sequence-order</i>	Test acc.	Train acc.	Nodes
SamplingCost	81.58	85.94	234.8	SamplingCost	61.38	91.04	232.0
Closest	78.03	83.23	253.4	Closest	59.58	88.04	245.8
Cluster	78.55	83.06	247.0	Cluster	59.18	88.96	235.6
Voronoi	81.18	85.62	236.6	Voronoi	58.81	89.22	231.3



<i>Sequence-order</i>	Acc. / Nodes 500 samples	Acc. / Nodes 1500 samples	Acc. / Nodes 2800 samples
SamplingCost-GLVQ	42.9 / 116.4	58.6 / 446.2	64.3 / 948.8
SamplingCost-GMLVQ	44.1 / 100.4	59.3 / 376.6	67.1 / 773.5
iSVM	40.6 / 363.3	57.5 / 777.0	65.2 / 1347

Easy/Difficult Objects

Easy



Difficult

Object	Mostly confused with		
			
			
			
			

Video



Summary

- ▶ New interactive real-time learning scenario
- ▶ Outdoor benchmark dataset for learning
- ▶ Proposal of cost-function based placement strategy
- ▶ Comparison to current strategies on artificial and real datasets
- ▶ SamplingCost performs superior, especially for Overlaps
- ▶ Representation not robust enough, could be extended by shape based features

Thank you for your attention!

