Ein lernfähiges Vision-System mit KNN in der Medizintechnik

Michael Eberhardt[1], Siegfried Roth[1], and Andreas König[2]
[1]Olympus Diagnostica Labautomation GmbH, Freiburg
[2]Lehrstuhl Integrierte Sensor Systeme, TU Kaiserslautern

ITG-Fachgruppensitzung, 17.11.2006

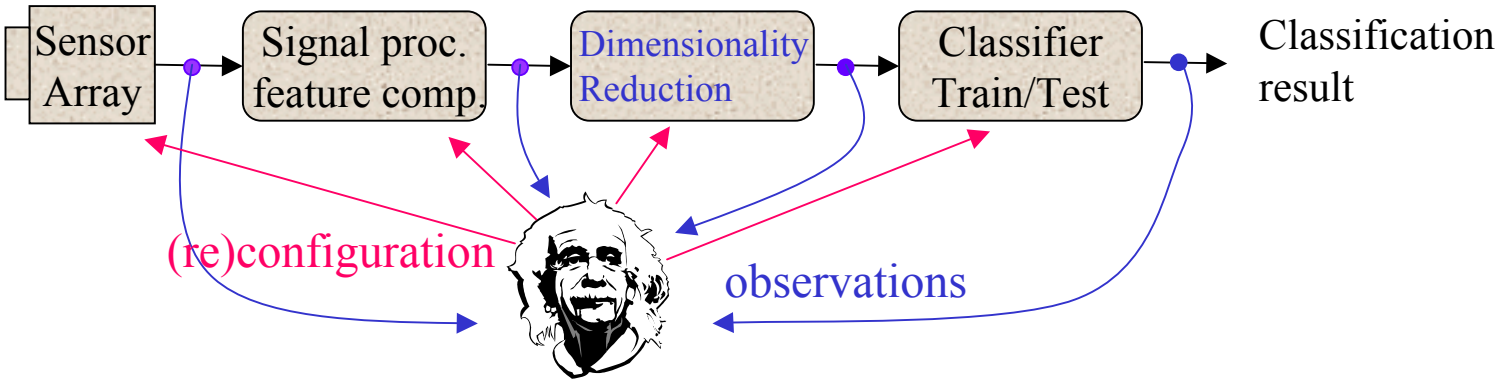
Übersicht:

- Einführung
- Erkennungsaufgabe im Laborbereich
- Vision-System und MILL-Erweiterung
- Ergebnisse einer Anwendungsstudie
- Zusammenfassung und Ausblick

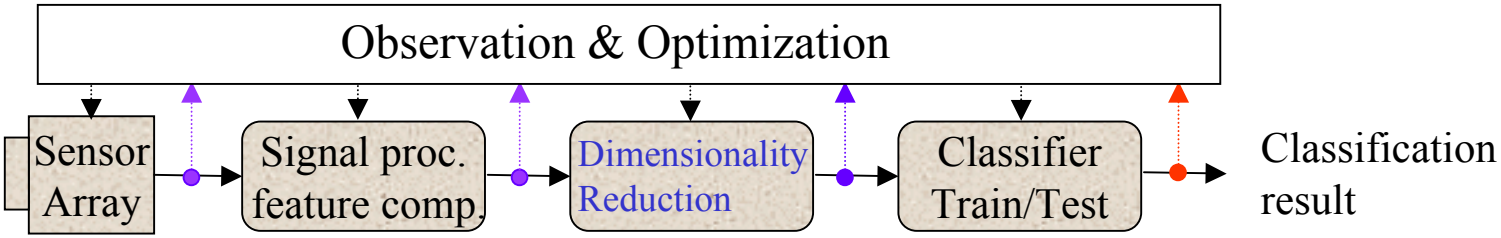
Introduction

Towards Industrial Use of (Intelligent) Sensor System Design Automation

- State of the art: expert driven design, manual, costly, slow, & tedious

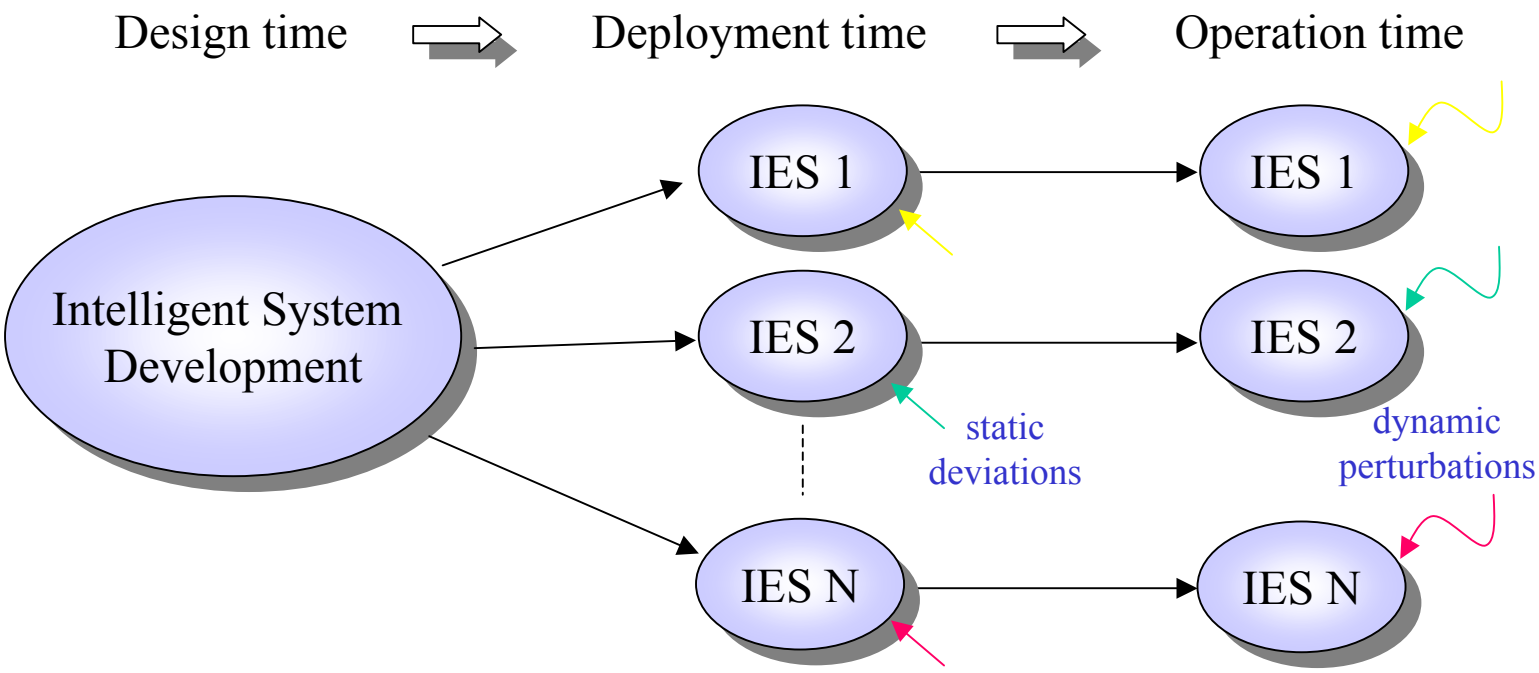


- Emerging alternative: Automated design by suitable optimzation



Introduction

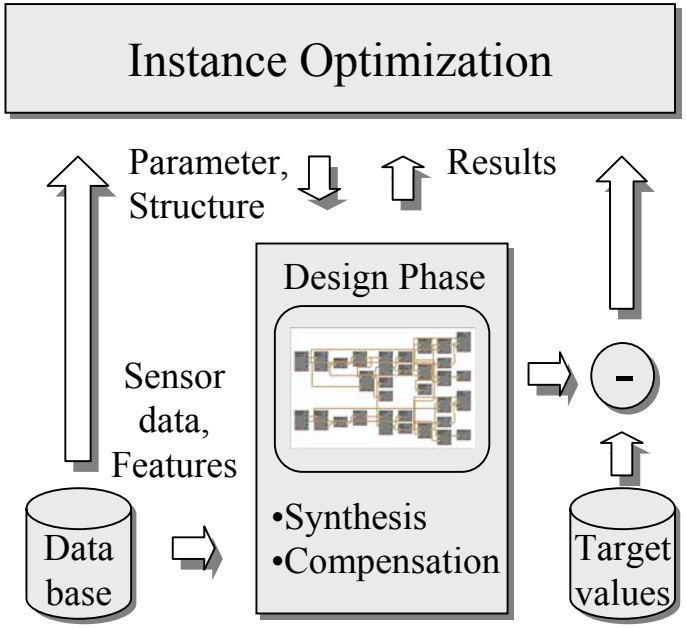
From Academic/Industrial Lab to Multiple Application Sites & Systems



- Design time solution development commonly bases on single prototype
- Deployment to multiple instances demands for static deviation compensation
- Various dynamic perturbation influences demand for dynamic compensation
- In addition, task variations can take place in the application field

Introduction

From Design to Operation Time: Instance-Specific Compensation



- Medical Laboratory Robot DAVID:
- **Task**: Tubes sorting & decapping
- Multiple installation sites in Europe

- **Machine-In-the-Loop-Learning**
- General system development
- Instance training for compensation of static non-idealities & deviations

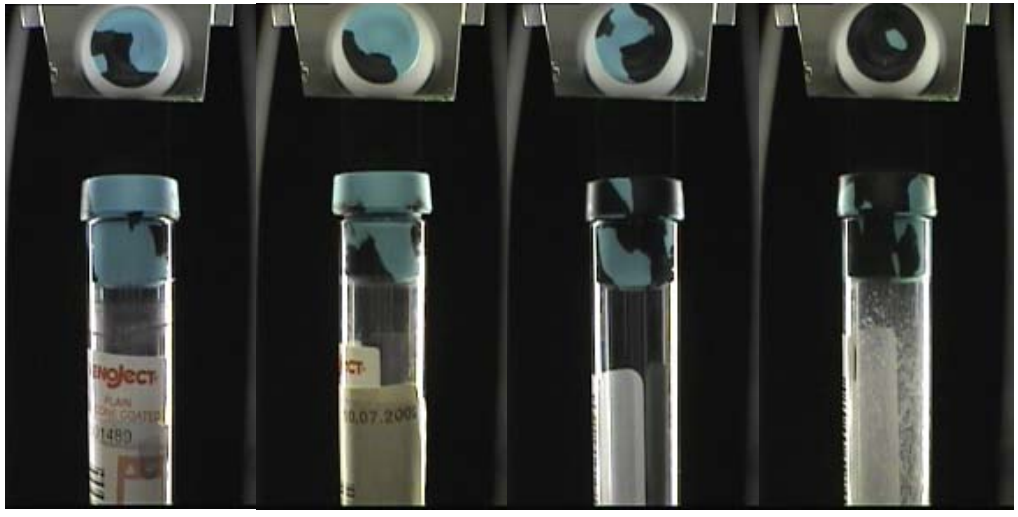
Recognition Task for Medical Laboratory

OLA2500 (top left) with Decapper unit (top right) and tube examples (bottom)

Recognition Task for Medical Laboratory

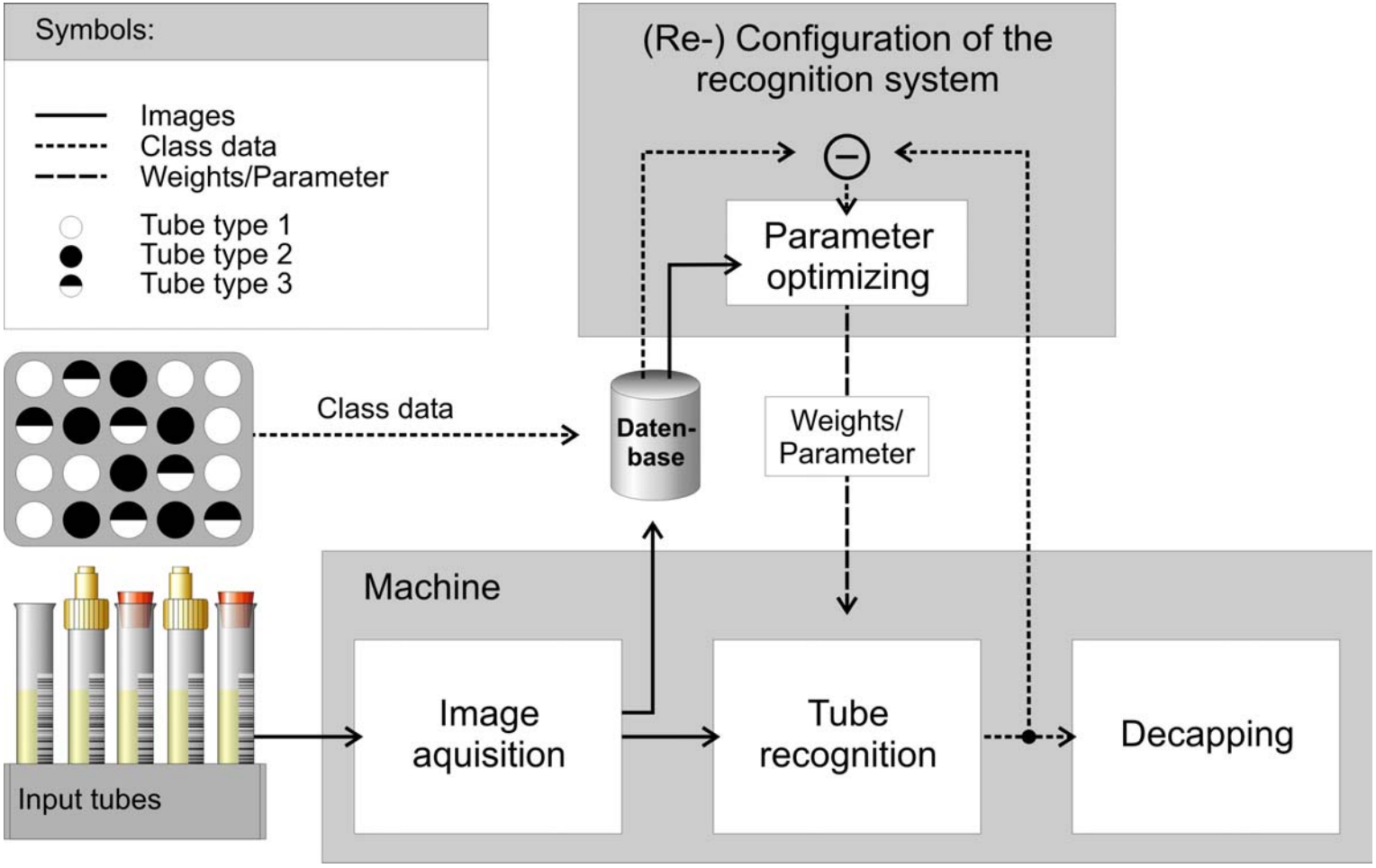
Recognition Problem

- Automated detection of cap type for decapping unit critical
- Misclassification can lead to sample contamination & desctruction
- New challenge by multiple coloured caps (Tiger caps) with blob like colour appearance, with obvious large variety of different colour segment sizes, representing the same type



Recognition Task for Medical Laboratory

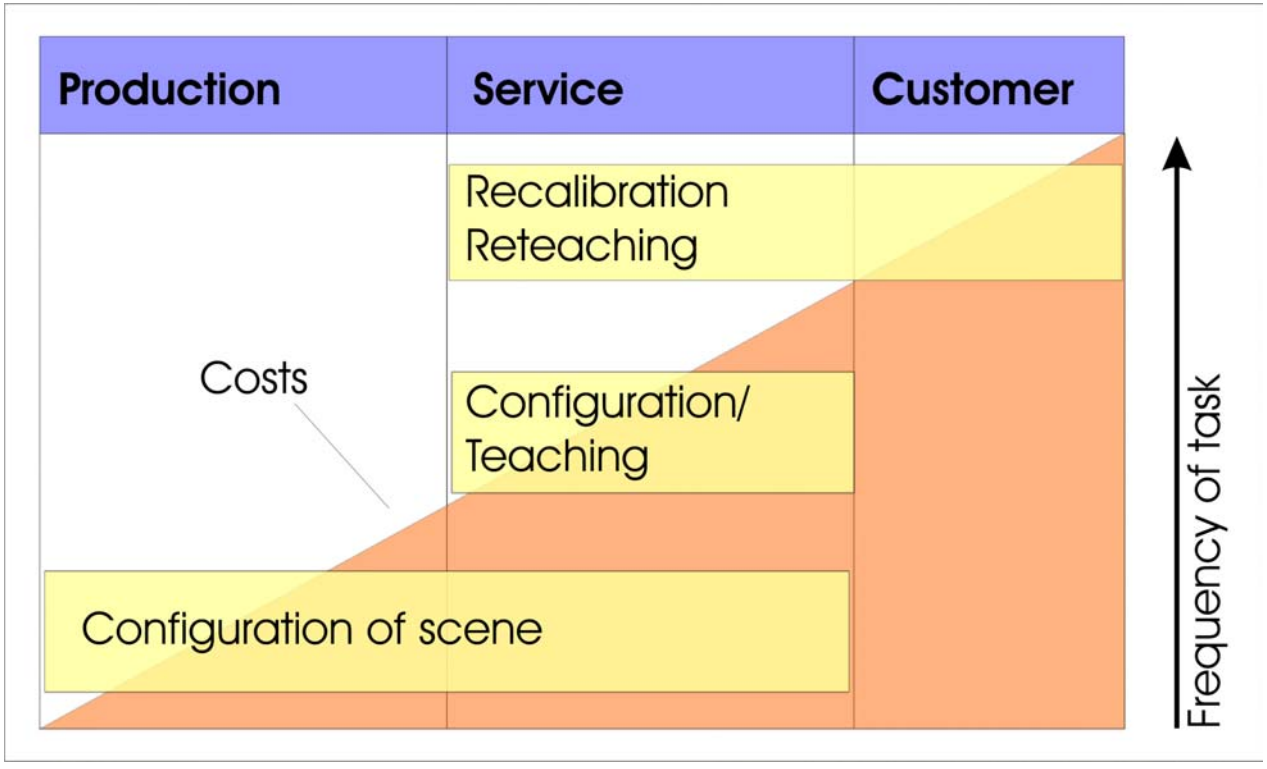
Block diagram of the basic robot system with the vision unit & reconfiguration



Recognition Task for Medical Laboratory

Analysis of Configuration Activities

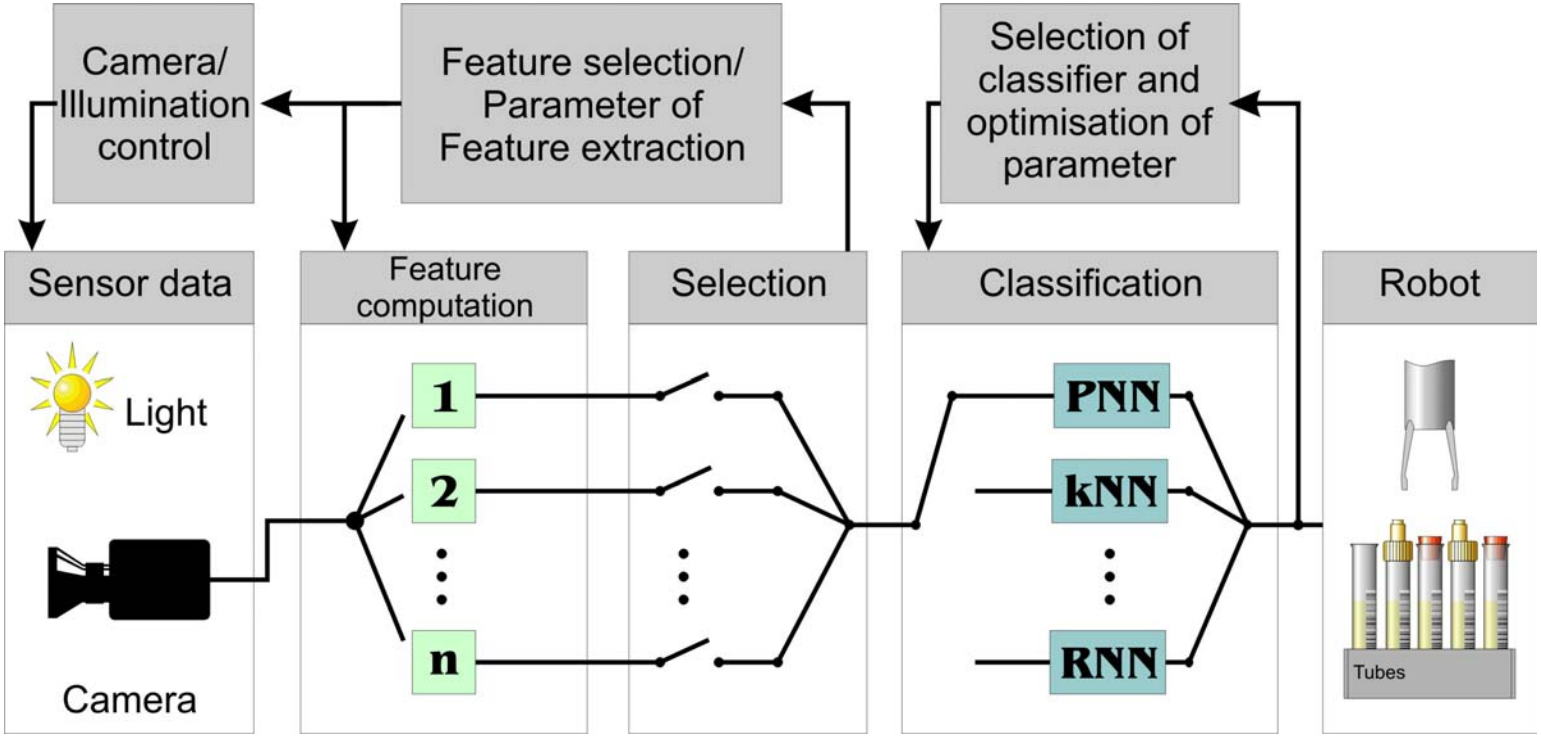
- Cost structure in different phases of the product life time



- Trade-off of manual/interactive vs. automated (re)configuration tasks

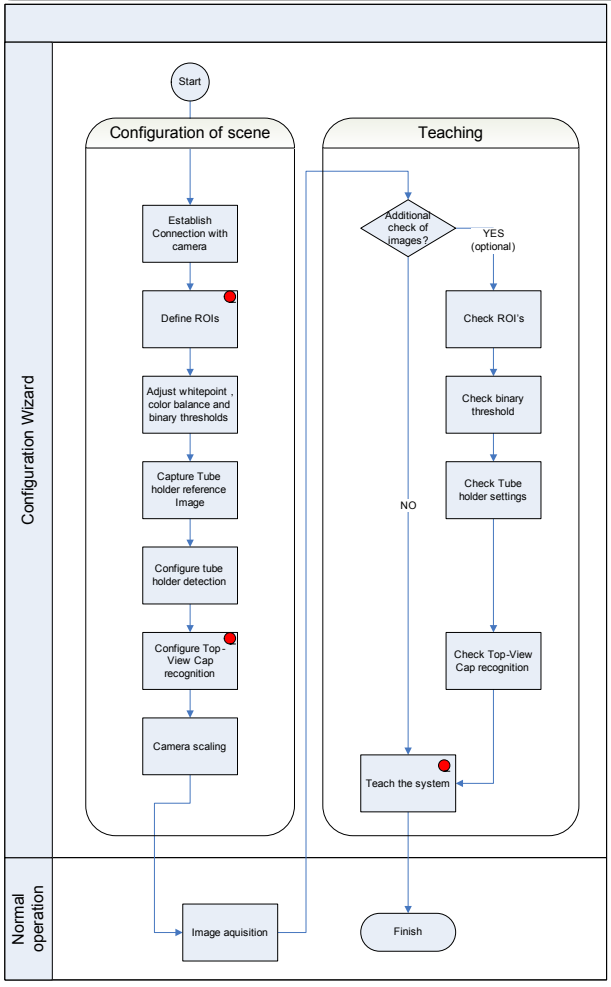
Vision System with MILL-Extension

Block diagram with design time options

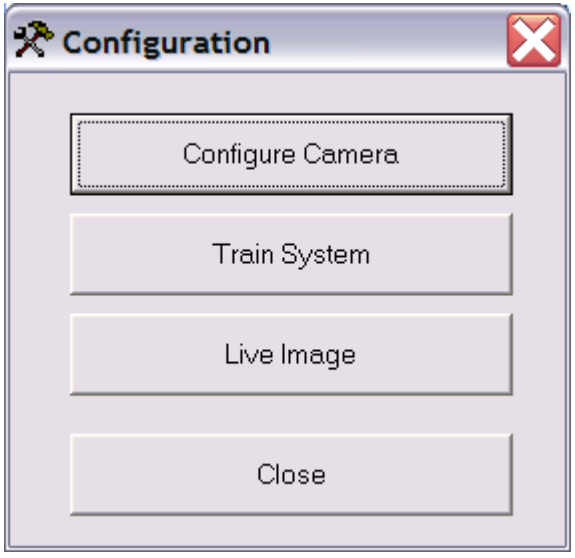


Vision System with MILL-Extension

Phases and steps of configuring the vision system



- Start dialog for configuration of the vision system



Vision System with MILL-Extension

- Step 2 of the scene configuration: ROI definition

Camera Settings

Step 2: Bounds

Help

Common Information

The Bounds dialog is used to check the mechanical adjustment of the tube inspection unit and to adjust the image regions required for the tube detection. Depending on the program context different sections of this documentation apply:

- Mechanical adjustment
- Adjustment of region of interest
- Adjustment of regions for tube detection

The parameter groups "Basic Settings" and "Region of Interest" are available only in the camera configuration mode since the camera hardware is required to change the parameters for Rotation and Offset X; in parameter setting mode the dialog controls for these parameters are disabled.

Protocol

Basic Settings
Rotation: 90

Region of Interest
Offset X: 0

Mirror area
Top: 1 Bottom: 48
Left: 40 Right: 111

Area of side view
Top: 86 Bottom: 274
Left: 22 Right: 114

Show Areas

Ini Run Loop Stop

Previous Next >> Close

Vision System with MILL-Extension

- Step 6 of the scene configuration: Configure the Cap Region

Camera Settings

Step 6: CapRegion Configuration

Help

Overview

Note: If no cap colors are used where color detecion is enabled in top view (ColorsFromTop>0 in Tubes.INI), this dialog may be skipped - the parameter settings adjusted with this dialog are relevant only if color detection from top is enabled for at least one cap color in use.

Note: The tube holder detection parameters (previous dialog) must be properly adjusted to get good results for the cap region detection. If no suitable setting for proper cap region detection can be found, please re-check the tube holder detection parameters.

For cap color recognition in top view the program needs to find the exact position of the tube's cap in the mirror image. This is a more complex task

Protocol

Thresholds

Saturation 40

Gradient Red 40

Gradient Green 40

Gradient Blue 40

Tube Cap Radius

Minimum Radius 16

Maximum Radius 22

Ini Run Loop Stop

Previous Next >> Close

Vision System with MILL-Extension

- Training of the vision system

Training of the vision system

Configure Database with tube information :
- Name
- Number of colors to detect from side and top
- Cap type (ID only, no additionally information in Data base)

For each tube type (cap, cap color):
- pre-sort tube into racks
- pre-select the cap type and color
- Process the tubes in normal operation in the machine

Start the training process :
- Press the „Training“ -Button
- Check the result in the confusion matrix

Vision System with MILL-Extension

- Step 5 of the teaching: Training of the vision system

Camera Settings

Step 5: Teach

Help

Teaching - Available Help topics:

Teaching Procedure
contains a short description on the teaching procedure

Analysis of the Teaching Result
describes how the teaching result is to be interpreted

Tube Detection Summary description
describes the structure of the tube detection summary diagnosis messages

Tube Detection Result details
describes the tube detection summary diagnosis messages in detail, including hints on possible reasons for detection problems

Teaching Procedure

- Depending on the type of tube all **pictures** are **pre-sorted** in **single** directories. These directories have been automatically generated during the pre-teach step as sub-directories of the directory displayed in the training picture directory field (See set-up manual for detailed information). It is **strongly recommended** to check whether these directories do contain exclusively tube images of the correct tube type and cap color before the teach

Protocol

Training picture directory (for each tube type one subdirectory):

E:\TubeSamples\60_Demo\Learn\ ...

Teach

Training: Max. samples per class: 100

Stop

Cap detection rate:

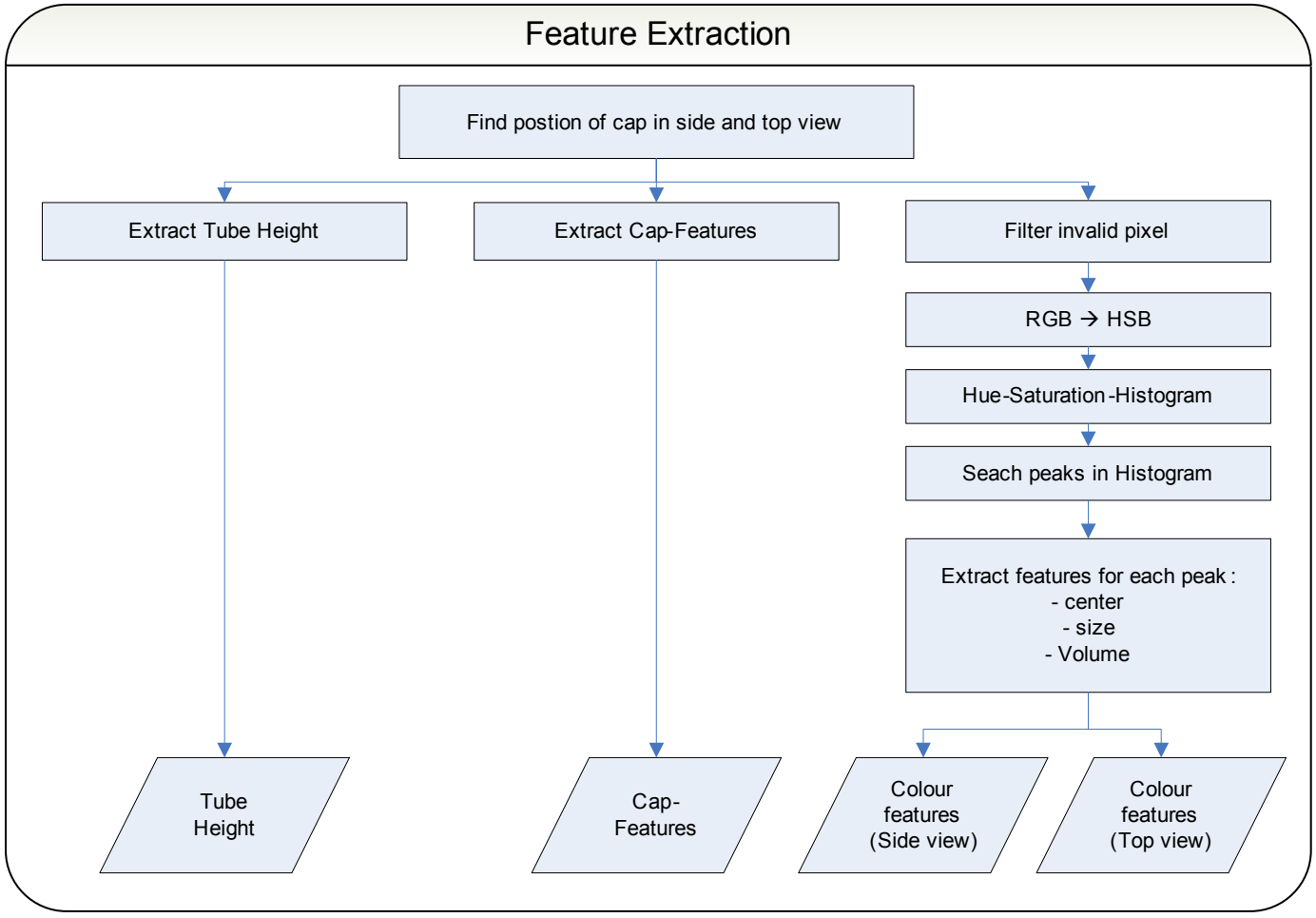
	Rejection	BD Vacutainer 100x12H	BD Vacutainer 75x12H	Vacuette 75x12	Terumo VS 100x15	Terumo VJ 100x15	Secondary Tube	open tubes 100x12
BD Vacutainer 100x12H	0,00	100,00	0,00	0,00	0,00	0,00	0,00	0,00
BD Vacutainer 75x12H	0,00	0,00	100,00	0,00	0,00	0,00	0,00	0,00
Vacuette 75x12	0,00	0,00	0,00	100,00	0,00	0,00	0,00	0,00
Terumo VS 100x15	0,00	0,00	0,00	0,00	100,00	0,00	0,00	0,00
Terumo VJ 100x15	0,00	0,00	0,00	0,00	0,00	100,00	0,00	0,00
Secondary Tube	0,00	0,00	0,00	0,00	0,00	0,00	100,00	0,00
open tubes 100x12	0,00	0,00	0,00	0,00	0,00	0,00	0,00	100,00

	Rejection	BD H red	BD H light green	BD H yellow	BD H violet	BD H green	BD H beige	Vac grey	Vac light blue	Terumo VS red	Terumo VJ cherry-red
BD H red	0,00	100,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
BD H light green	0,00	0,00	100,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
BD H yellow	0,00	0,00	0,00	100,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
BD H violet	0,00	0,00	0,00	0,00	100,00	0,00	0,00	0,00	0,00	0,00	0,00
BD H green	0,00	0,00	0,00	0,00	0,00	100,00	0,00	0,00	0,00	0,00	0,00
BD H beige	0,00	0,00	0,00	0,00	0,00	0,00	100,00	0,00	0,00	0,00	0,00
Vac grey	0,00	0,00	0,00	0,00	0,00	0,00	0,00	100,00	0,00	0,00	0,00
Vac light blue	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	100,00	0,00	0,00
Terumo VS red	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	100,00	0,00
Terumo VJ cherry-red	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	100,00

Previous Done Close

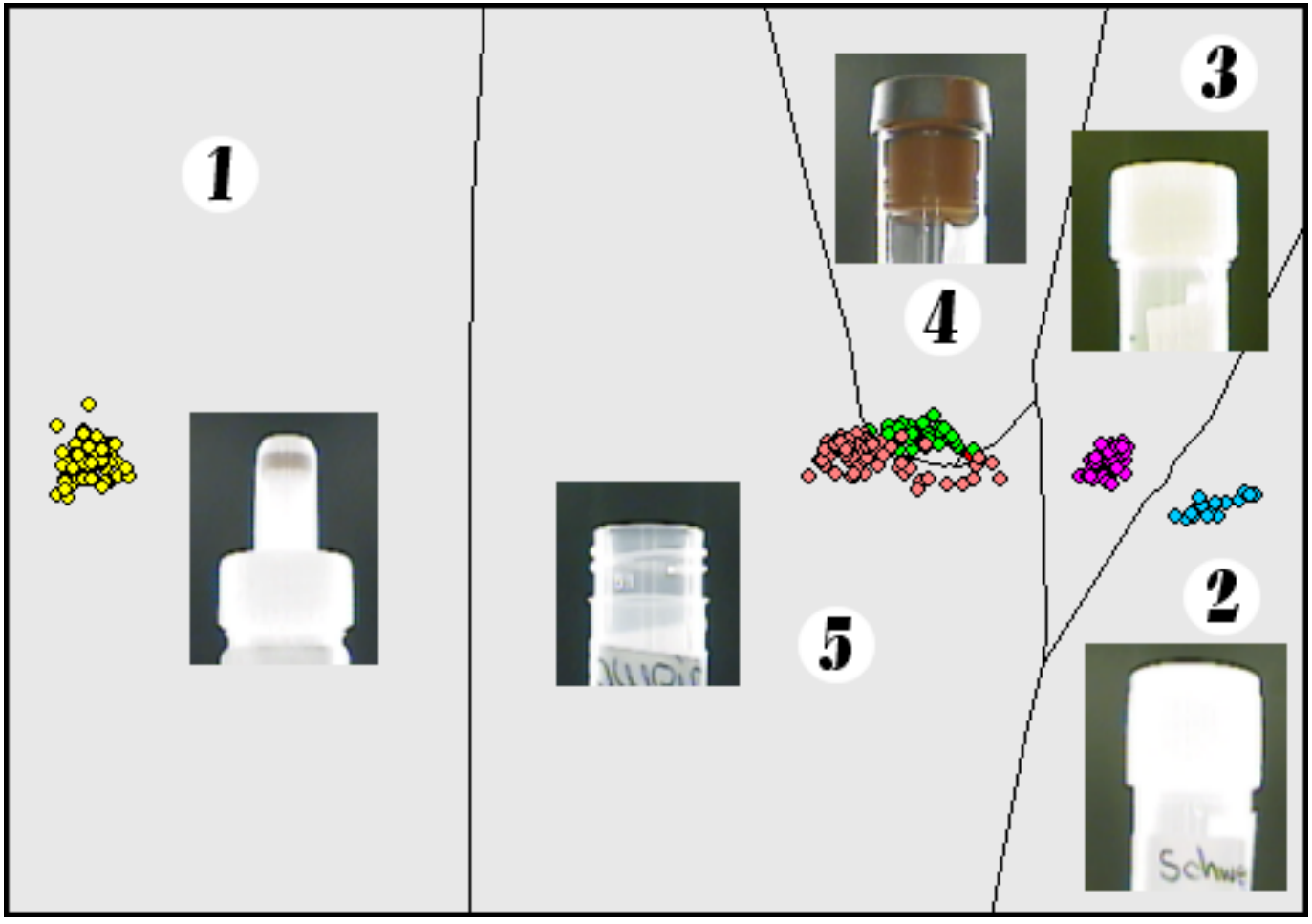
Vision System with MILL-Extension

Flow of feature extraction process



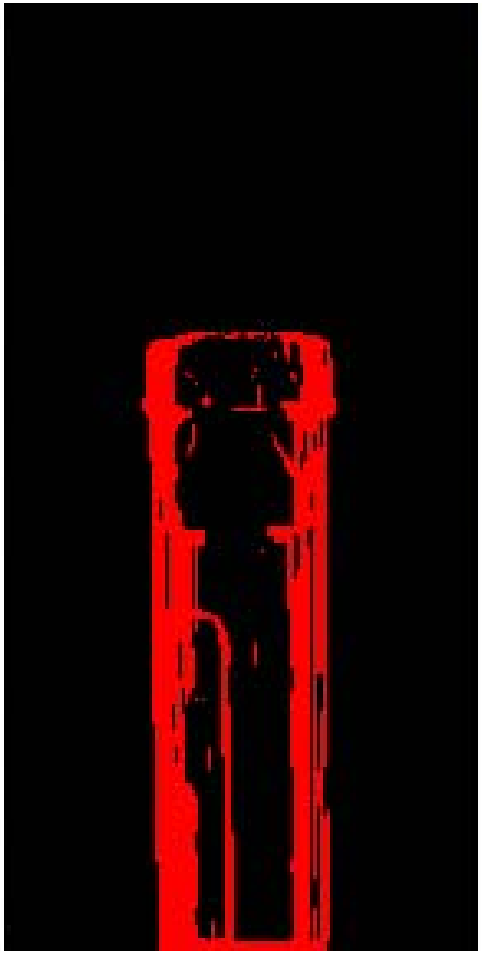
Vision System with MILL-Extension

Example of feature space from contour information for five tube types



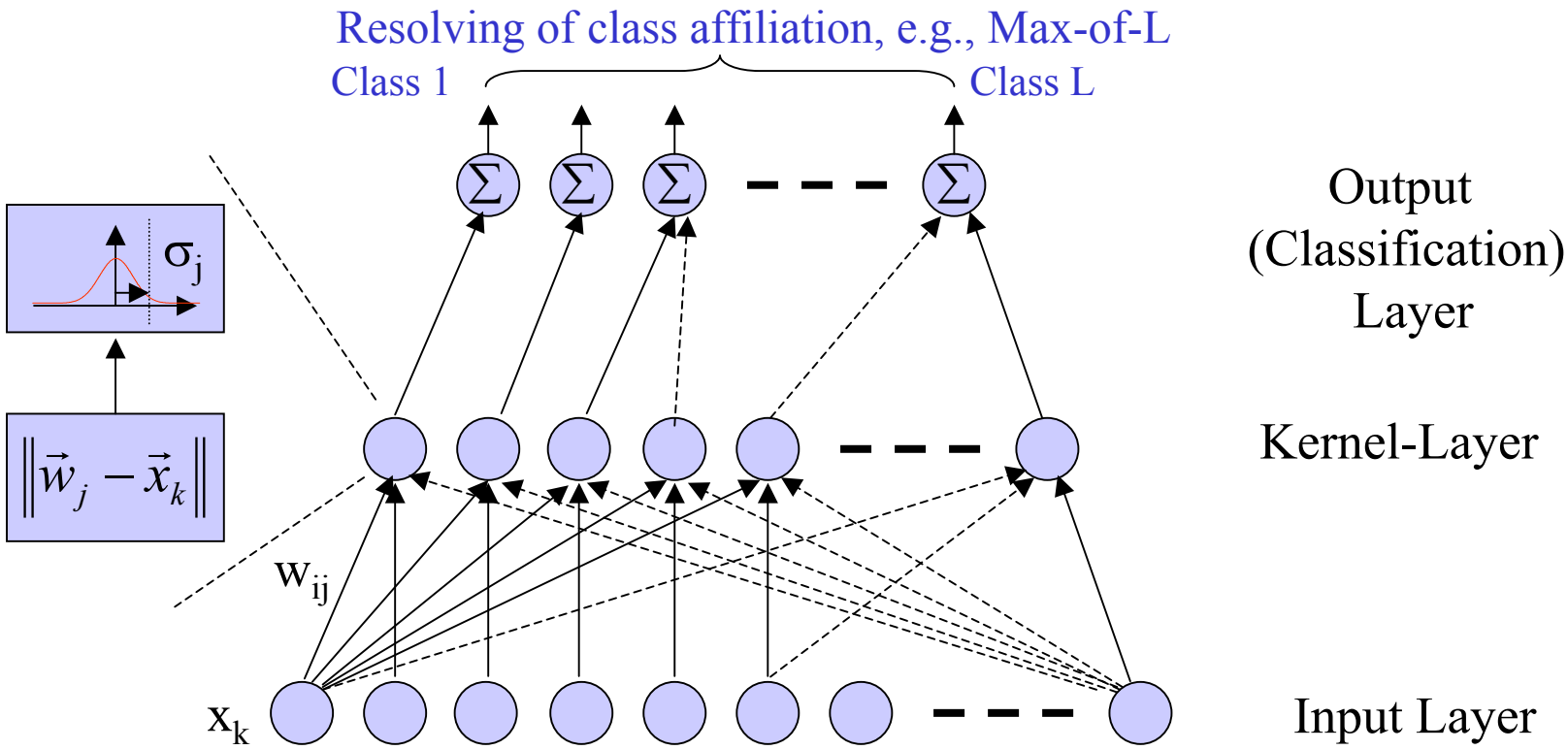
Vision System with MILL-Extension

Tube with tiger cap and corresponding color blob segmentation



Vision System with MILL-Extension

Probabilistic-Neural Network (PNN) of Specht

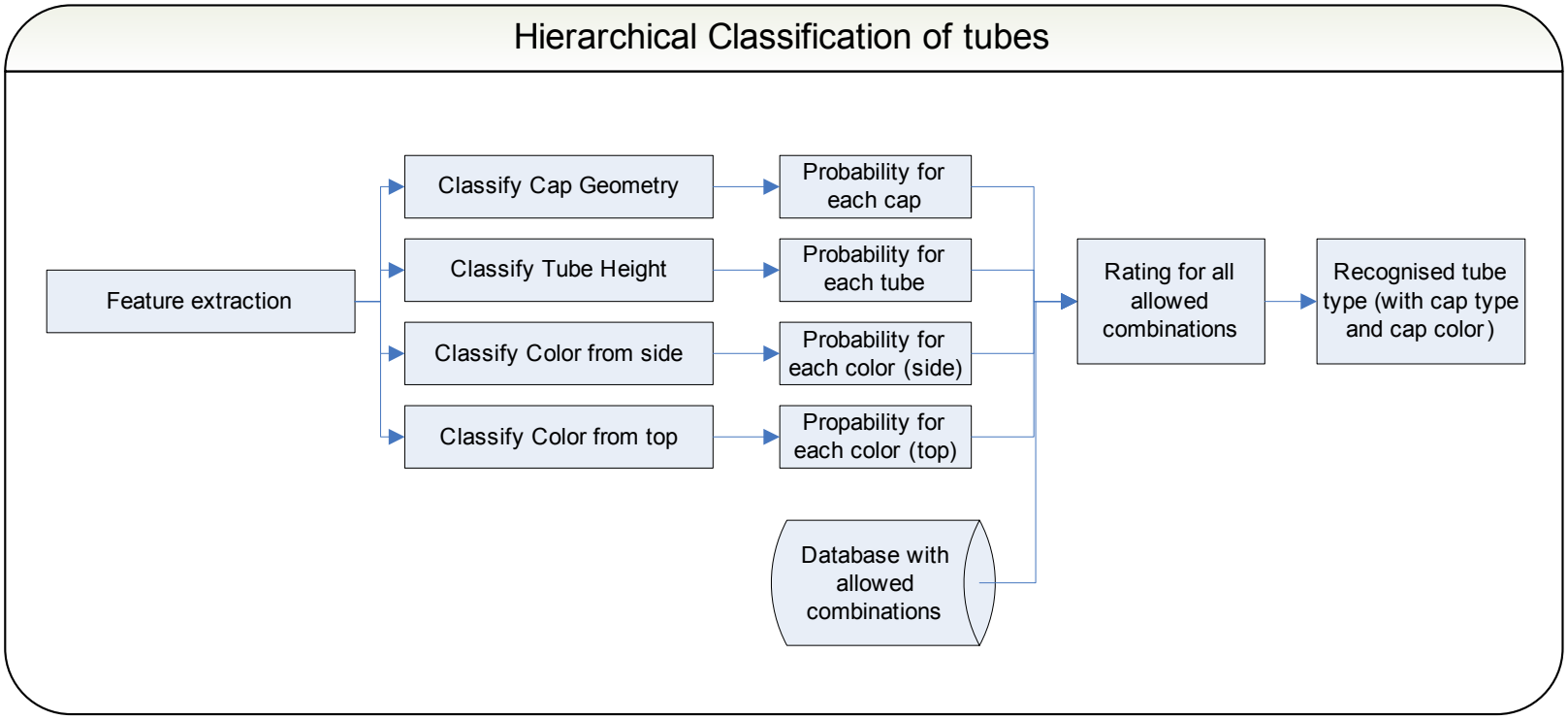


- Each training data vector is stored as Gaussian kernel with fixed global σ
- According to class labels, kernel are wired to pdf summation nodes
- Explicit cost or a priori weighting can be employed before pdf max-of-L

Vision System with MILL-Extension

Decision-Level Fusion Architecture

- Hierarchical classification of tubes with two-level rejection mechanism



Results of Large-Scale Application Study

Motivation of Classifier Choice

- Results of classifier selection (Parameters: m = dimension of feature vector, s = width of gaussian kernel of the PNN classifier, k = number of considered nearest neighbours of the kNN classifier)
- Data from one installation, 27,744 tubes, six different cap geometries

Classifier	*parameters*	*Recognition Rate*
PNN	*$\sigma = 2$ m = 80*	*99,1 %*
PNN	*$\sigma = 2$ m = 5*	*94,4 %*
PNN	*$\sigma = 10$ m = 80*	*98,8 %*
PNN	*$\sigma = 10$ m = 5*	*98,4 %*
kNN	*k = 10 m = 80*	*98,4 %*
kNN	*k = 10 m = 5*	*90,9 %*

Results of Large-Scale Application Study

Selected Date from Multiple Relevant Installations

- Summary of the investigated data:

Total Analysed tubes in test sets:	19.993
Number of sample sets:	17
Number of different machines:	16
Size of sample sets:	168-3856
Number of samples per class in training sets	20 - 100
Number of Cap-Types per sample set:	5-18
Number of combinations of Cap and Colour:	7-37

Results of Large-Scale Application Study

Selected Date from Multiple Relevant Installations

- Overall classification results for the sample sets mentioned on previous slide

	Correct Percent	Wrong Percent	Rejected Percent	Correct Total	Wrong Total	Rejected Total
Tube types	98.97	0.03	1.00	19'993	6	202
CapsColors	98.78	0.06	1.16	19'955	12	234

Conclusions and Outlook

- The system in its state of evolution until recent updates has been field application on more than 250 installations all over the world !
- The subjective user satisfaction was high in the majority of cases
- Several pathological cases could be identified and led to the recent system state summarized in this contribution
- The remaining error rate is so small, that it is absolutely sufficient for the requirement of this application and the satisfaction of users
- Currently, the potential of computational intelligence methods and the basic learning architecture has only be fractionally exploited, more to come ....