# Laser-Based Feature Extraction and Pattern Recognition in Intersection Management Systems

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Pattern Recognition, 2014

# Context

Master's Research Project:
Multisensor Architecture for a Vehicular Intersection Management System

# Transportation Systems

Issues in traditional transportation systems

- Congestion
- Traffic rules violation
- Vehicle interaction

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Intersections are critical places in transportation systems

# Intelligent Transportation Systems

Objectives of ITS

- Increase safety
- Increase efficiency
- Reduce costs

# Intersection Management Systems

Tasks

- Traffic Monitoring
- Traffic Management
- Warning Advertisement

# Intersection Scenario

- Pedestrians, Vehicles (Cars, Two-wheeled vehicles, Big vehicles)
- Recognition, Classification, Tracking
- Incident detection, Intersection Management

# Main Objective

- To develop a feature extraction and pattern recognition laser-based module for an intersection management system

# Sub-objectives

- Review of laser-based feature extraction and pattern recognition in ITS and IMS

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- Evaluate pros and cons of the reviewed methods
- Implement at least one method
- Evaluate implemented module and compare it with similar developments

# Conditions

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- [New!] Just one laser.

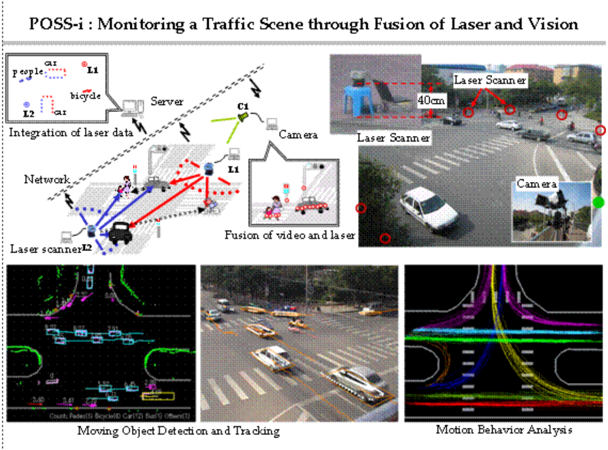
# Research Groups

- PKU Omni Smart Sensing (POSS) Research group at Peking University (POSS-i project)
- Institute of Measurement, Control and Microtechnology at Ulm University (Ko-PER program)

# PKU Omni Smart Sensing (POSS)

- POSS is leaded by Prof. Huijing Zhao, Ph.D.
- Focus on perception technologies using an intelligent vehicle, a network sensing system or a collaboration of them

# POSS-i

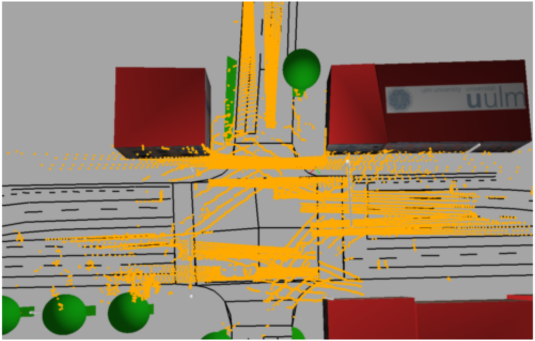



POSS-i project. [Zhao09][Zhao12][Song13b]

# Ko-PER

- Ko-PER from Cooperative Perception
- Included in Forschungsinitiative Ko-FAS from Bundesministerium für wirtschaft und Technologie (Germany)
- Cooperative and collaborative sensors system for perception and preventive road safety.
- Daniel Meissen from Ulm University as leader researcher.

# Projects




3D-recreated intersection scene with laser beams depicted [Meissner12, 13a, 13b, 13c, 14][Striegel13]

# Applications, Methods and Techniques

| Project | POSSi | Ko-PER |
|---|---|---|
| Applications | Recognition, Classification and Tracking of Vehicles and Pedestrians | |
| Methods and Techniques | - Clustering<br>- KL Transform<br>- Markov Chains<br>- Kalman Filtering<br>- AdaBoost | - DBSCAN<br>- Multi-object Bayes Filter<br>- Sequential Monte Carlo Methods<br>- Dempster-Shafer Theory<br>- Multiple-Model Probability Hypothesis Density Filter (in Gaussian Mixture representation) |

POSSi and PKU projects comparison

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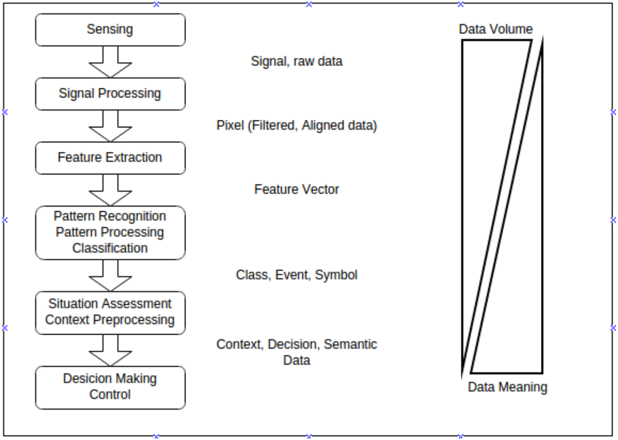
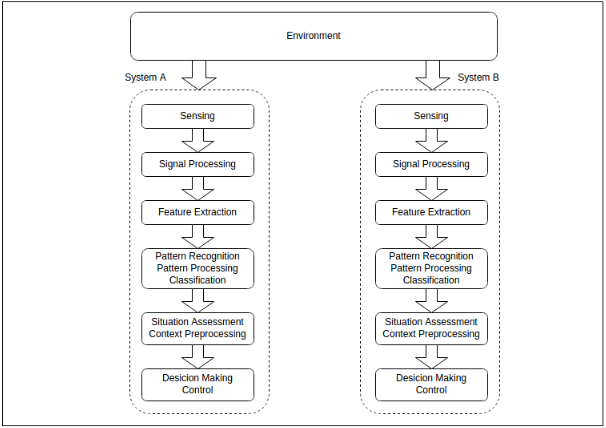
# Typical System for one source of data



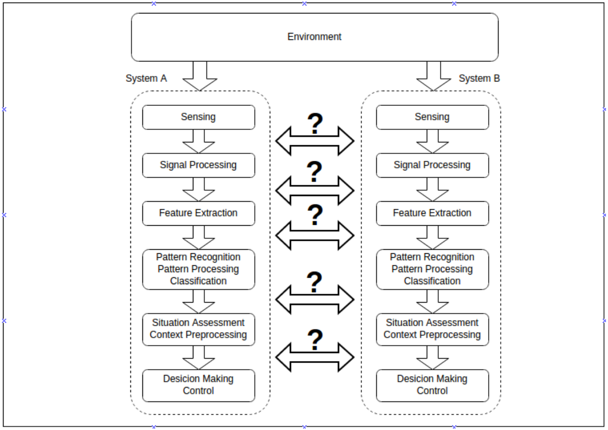

Single source system block diagram

# Multisensor Data System



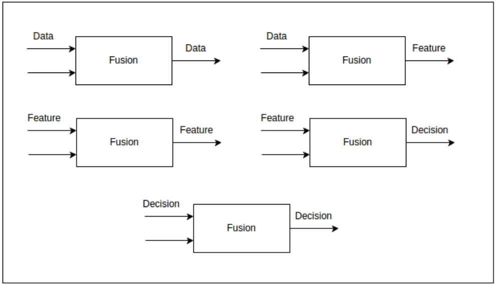

Multisensor system block diagram

# How to fuse information?




Multisensor system block diagram

# Fusion Levels



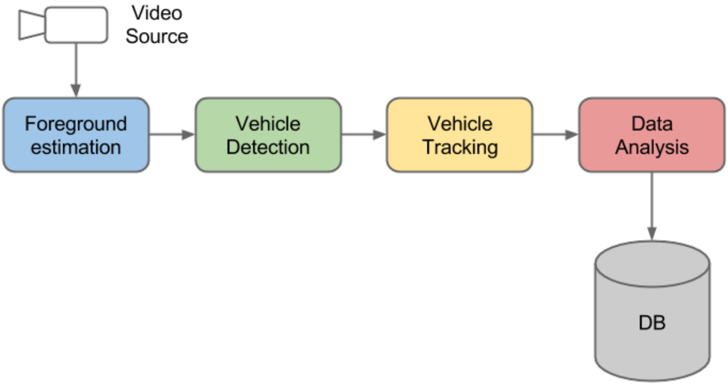

Fusion Levels [Luo11]

# Fusion Algorithms

| Low level fusion | | Medium level fusion | High level fusion |
|---|---|---|---|
| Estimation methods | | Classification methods | Inference methods |
| Recursive:<br>• Kalman filter<br>• Extended Kalman filter<br>Non-recursive:<br>• Weighted average<br>• Least squares | Covariance-based:<br>• Cross covariance<br>• Covariance intersection<br>• Covariance union | • Parametric templates<br>• Cluster analysis<br>• K-means clustering<br>• Learning vector quantization<br>• Kohonen feature map<br>• Artificial neural network<br>• Support vector machines | • Bayesian inference<br>• Particle filters<br>• Dempster-Shafer theory<br>• Expert system<br>• Fuzzy logic |

Classification of Fusion Algorithms [Luo11]

# Video-Based System Block Diagram



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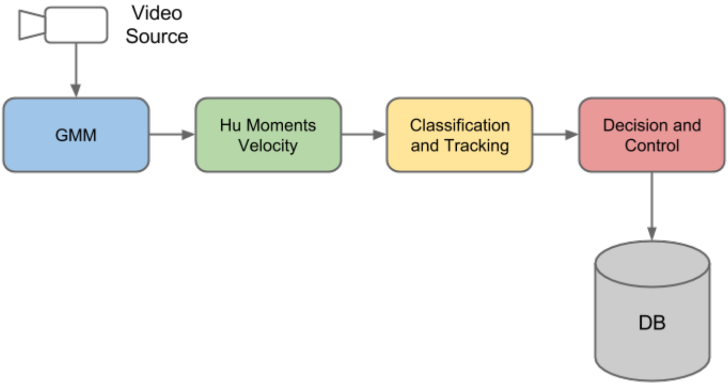
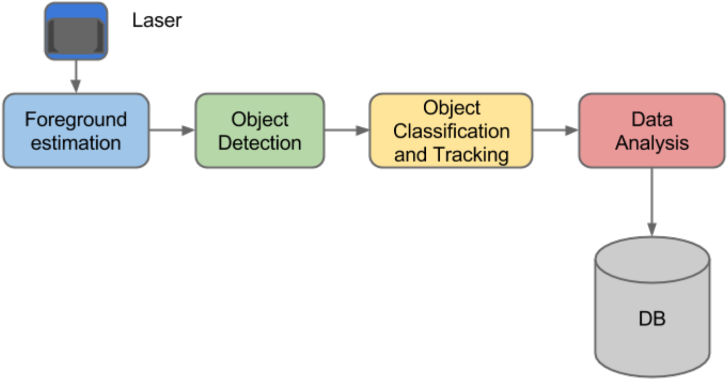


# Laser-Based System Block Diagram



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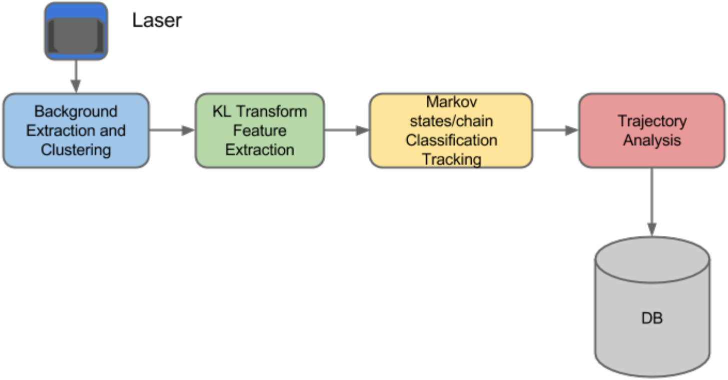


Based on [Zhao06]

# Dataset

- Although datasets for both projects are available, POSS-i dataset was choosen.
- It includes laser readings from 6 laser-scanner located in different corners in an intersection.
- The duration of scanning is approximately 10 minutes.

# Dataset


Capture of dataset viewer application [Zhao06]

# Background Extraction

- Histogram-based background extraction
- Done for each angle
- When a pick value is detected, tells that an object is detected

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- Histogram-based background extraction
- Done for each angle
- When a pick value is detected, tells that an object is detected
- Dataset already includes a background model for each laser scanner

# Clustering

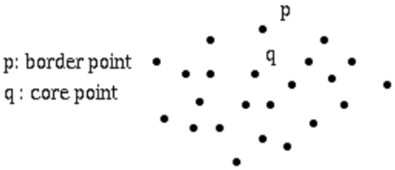
- In [Zhao06] it is not detailed how clustering was done, so DBSCAN is proposed to identify clusters in laser-data points

# DBSCAN - Introduction

- Density-Based Spatial Clustering for Applications with Noise
- Proposed by Ester et al in 1996 in KDD conference [Ester96].

# DBSCAN - Explanation

- The algorithm needs two parameters: *Eps*($\epsilon$) and *minPts*
- Also are defined two types of points: Core points and border points
- *p* is a core point if in its *Eps-Neighborhood* are at least *minPts* points.




Types of points [Ester96]

# DBSCAN - Algorithm

- DBSCAN starts at an arbitrary point *p*, then evaluate if point's *Eps-Neighnorhood* contains at least *minPts* points
- If *True*, *p* is a core point (Is in a cluster)
  - Assign *clusterId* to p and its neighbour, and neighbours of its neighbours and so on.
  - Increase *clusterId*.
- If *False*, *p* is labelled as Noise
- Continue with an unlabelled point, until all points in dataset are labelled.

# Clustering

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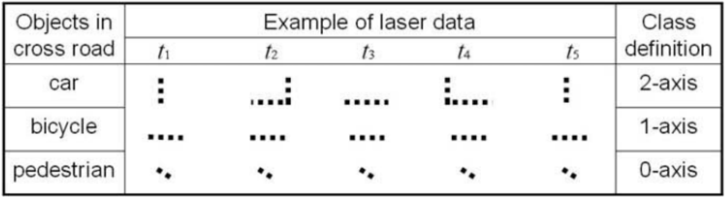
More on clustering in ...
UNSUPERVISED
LEARNING
COMING SOON
2014.11.28

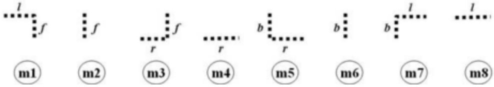
# Definitions

- Classes are proposed based on distribution of points in clusters
- Karhunen-Loeve Transform to detect number of axis

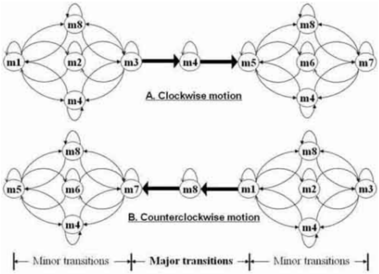


| Objects in cross road | Example of laser data | | | | | Class definition |
|---|---|---|---|---|---|---|
| | $t_1$ | $t_2$ | $t_3$ | $t_4$ | $t_5$ | |
| car | | | | | | 2-axis |
| bicycle | | | | | | 1-axis |
| pedestrian | | | | | | 0-axis |

# Markov States




There are 8 patterns that can happen




Possible transitions

# Features

- Normal Vectors
- Number of axis
- Axis lengths
- Directional vector, Motion speed
- Markov States

# Classification and Tracking

- Classification and tracking stages are under review

# Next Steps

- Implement Dataset handler
- Implement Clustering and KL Transform to classify in 0, 1 or 2 axis object
- Get features from objects and obtain trajectory

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