Challenges and Approaches for Development and Evaluation of Automated Vehicle Systems

Ibeo Automotive Systems

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Dr.-Ing. Ulrich Lages, MBA
Mario Brumm, MBA
Ibeo’s Vision since 1998

We are the world’s technological leader in laserscanner based driver support systems. We will equip every car in this world with laserscanners and reliable safety applications.

Our contribution to the society will be the saving of a huge number of lives by doing so. Our children will grow up in a safer world, where the car really is our partner.
Ibeo’s Timeline (Company Perspective)

- **1998**: Foundation of Ibeo Company
- **2000**: SICK AG becomes parent company
- **2001**: Start of Production (SOP) ScaLa
- **2006**: SAE Tech-Award: “The most Innovative Product of the Year”
- **2007-2008**: Management Buy Out: Ibeo becomes independent from SICK
- **2009**: Federal President Award: “Smart Eyes for Vehicles – Country of Innovations”
- **2009**: SAЕ Tech-Award: “The most Innovative Product of the Year”
- **2008**: Frost & Sullivan Award: “European Automotive Safety Systems Entrepreneurial Company Award”
- **2007**: Team LUX @ DARPA Urban Challenge
- **2010**: Cooperation Contract with Valeo
- **201x**: Start of Production (SOP) ScaLa
Ibeo Automotive

AUTONOMOUS DRIVING PROJECTS
1999 First project about Autonomous Driving

Video: Autonomes_Fahren VW 1999.MPG
Ibeo got the official permission to drive autonomously in public traffic from German TÜV in 2007 (3 years before Google)

Video: Darpa_4way_stop_uturn_einparken.avi
2016 Intuitive Driving

Intuitive Driving

- Adaptation of vehicle behavior to driver capabilities and mood
- Seamless cooperation between driver and vehicle
- Driver can shift driving responsibility at any time & any level
- Predictive and focused information by HMI
- Vehicle acts also as electronic copilot in critical situations
2016 Robot Taxi to start testing in Japan

Mr. Shinjirō Koizumi, Parliamentary State Secretary, et al. (second from left)

http://jp.reuters.com/article/2015/10/01/auto-driving-car-test-japan-idJPKCN0RV4LW20151001
2020 Robot Taxi to operate in Japan

Project Presentation by ZMP on 26 August 2015 in Tokyo

Ibeo is responsible for:
- Map making for Autonomous Driving
- 360 deg object tracking and classification
- Ego-Positioning of the vehicle
State of the Art ADAS applications

My Lane Keeping System and my ACC system work perfectly, today...

This MUST NOT happen with Autonomous Vehicles!
AUTOMATIC SENSOR / SENSORFUSION SYSTEM EVALUATION IN PUBLIC TRAFFIC
Challenge for System Suppliers

How can we do the testing of sensors and sensor fusion system efficiently and reliably?
Reference Data is generated by manual labelling of the recorded DUT data using cameras.
Traditional Sensor Evaluation by Manual Object Labeling

Reference Data is generated by manual labelling of the recorded DUT data using cameras.

Manual Labelling

- Offline MANUAL
  - Ground Truth Data Generation
  - time consuming
  - cost intensive
  - changing performance

Device Under Test (DUT)

Customer Sensor (e.g. stereo camera)

Real time Object Tracking & Classification

Offline DUT Data Evaluation
Ibeo’s Solution for Sensor Evaluation by Automatic Object Labeling

A reference system must be "BETTER" than the DUT!

Ibeo can assure this request by the Ibeo Evaluation Suite, which is an offline post-processing software with automatic object labelling mainly based on forward-backward-tracking.
Extended Range of Reference System

MR = Maximum Range (very first measurement)
Extended Range of Reference System

**MR** = Maximum Range
"very first measurement"

**DR** = Detection Range
"valid object"
Extended Range of Reference System

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Confidential
Extended Range of Reference System

MR = Maximum Range
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BSCR = Best Situation Classification Range
"perfect object shape"
Extended Range of Reference System

- **MR** = Maximum Range
  - "very first measurement"

- **DR** = Detection Range
  - "valid object"

- **CR** = Classification Range
  - "classified object"

- **BSCR** = Best Situation Classification Range
  - "perfect object shape"

Forward-Backward-Tracking

All Object Information is available at maximum range of the Ibeo Reference Sensor System, which is BETTER than the Range of any DUT
**Extended Range of Reference System**

- **MR** = Maximum Range
  - "very first measurement"

- **DR** = Detection Range
  - "valid object"

- **CR** = Classification Range
  - "classified object"

- **BSCR** = Best Situation Classification Range
  - "perfect object shape"

**After Ibeo-PostProcessing all Object Information from BSCR is available at Maximum Range of the Ibeo Reference System (IRS), which is BETTER than the DUT-Data at DR or CR.**

**Rule for any DUT:**

\[ MR > DR > CR > BSCR \]

**Rule for Ibeo Reference:**

\[ MR = DR = CR = BSCR \]

**Reference Comparison:**

\[ \text{DR}_{\text{DUT}} \text{ or CR}_{\text{DUT}} \leftrightarrow \text{BSCR}_{\text{IRS}} \]

- Stored Information
- Post-processed Information

**Object Trajectory**
Real-Time: Object Recognition Challenge

Typical real-time sensor problems: false tracks, false classifications on higher range

Video: 130902_01_IBEO_Real_Time
Advantages of Post-Processing: no false tracks, classified objects on max. range

Video: 130902_02_IBEO_Post_Processing
Reconstruction of Lane Markings

Extracted Scan Points for Visualisation of the Road including Lane Markings including Tracked & Classified Objects displayed in the Map

Video: 5_CombinedMap-OfflineObjects.mp4
Objects to Ego-Lane Association (OELA*)

Post-Processed by Ibeo Evaluation Suite:

Recognition of Ego Lane and Association of Objects to Center of Ego Lane

* OELA is currently available for highways and country roads

Video: Oela_highway.mov
AUTOMATIC SYSTEM EVALUATION ON APPLICATION LEVEL IN PUBLIC TRAFFIC
Lane Change Assist (LCA)

appr. 80 m

1 Ego-lane

2

3
Car on Left-Lane overtakes Ego-Vehicle with **HIGHER** speed; consequently Ibeo REF-PP can provide **LCA-Alert** for left side automatically.
Automatic Evaluation of LCA:
Relevant Object recognised on Right-Lane

Ego-Vehicle overtakes Truck with **LOWER** speed on Right-Lane;
consequently Ibeo REF-PP can provide **LCA-Warning** for right side automatically.
Automatic Evaluation of LCA: 
Ibeo Automatic Generation of Ground Truth

Ibeo Reference Sensing System in cooperation with Ibeo Evaluation Suite (for Post-Processing) can automatically provide **Ground Truth Scenario Information**
Automatic Evaluation of LCA: Reported Objects of Customer-LCA (real-time)

Ibeo Reference System can store all the object-information provided by Customer-LCA during the real-time test drive.
Automatic Evaluation of LCA: Ibeo-Reference compared with Customer-LCA

Ibeo Evaluation Suite can compare Ground Truth Scenario Information with object information provided by Customer-LCA after the test drive by post-processing.
Ibeo: The benchmark for automotive Laserscanners

- Ibeo Laserscanner Lane Marking Detection and Curbstone Detection
- Verification of Road Users (pedestrian is either located on pavement or on road)
- Provision of Integrated Maps, meaning that all Traffic Participants are positioned and tracked with respect to lane markings and road edges
Your contact at Ibeo Automotive

Dr.-Ing. Ulrich Lages, MBA
CEO
Ibeo Automotive Systems GmbH
Merkurring 60-62
D-22143 Hamburg

Tel: +49-40-298 676-120
Fax: +49-40-298 676-10
Mob: +49-172-417 3855

Email: Ulrich.Lages@ibeo-as.com