Reconfigurable Embedded Systems for Autonomous Driving

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WRC'2018, HIPEAC, MANCHESTER UK

Design Tools for Reliable Transportation Systems

- By 2020: more than 80% of population will live in urban areas (Smart Cities)
  - **CO_2 emission + 33%.**
  - **Cars in traffic will increase 20%.**
  - **1.3 million people are killed on world roads** every year
    - +3,500/day, 90% in developing countries

- 94% of all accidents are caused **by human error**

Motivations:
Advanced Driver Assistant Systems (ADAS)

- **ADAS** help drivers to make quick and correct decisions in critical situations
- Embedded systems are widely used for critical & real time tasks in ITS.
  - Must be reliable and tolerant to faults.

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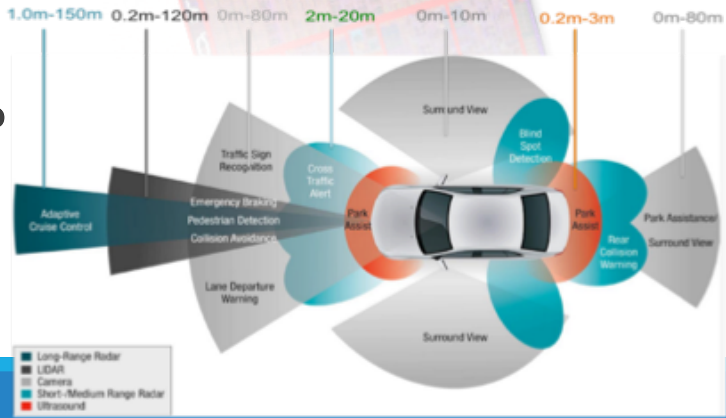
Advanced Driver Assistant Systems ADAS's

- ADAS must support complex applications:
  - Fragile road users, elderly and disabled people
  - Hard weather and lighting conditions
- Number of sensors increasing:
  - Cameras, Radars, Lidars, V2V, V2I, ..
  - V2V, V2I (Autonomous cars)
- The challenges are:
  - processes the data? Extract useful info? communicate? …



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Autonomous Driving (AD)

- Autonomous driving is part of our future:
  - Reduce the number of accidents,
  - Allow a better use of the road infrastructures and
  - Protect our environment.
- Data ++ processed from the different sensors = safer for the users

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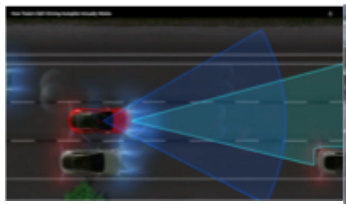
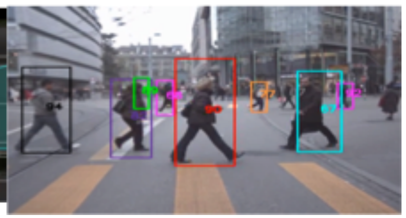
Society of Automotive Engineers (SAE) 6 levels of Autonomy

0	1	2	3	4	5
No Automation	**Driver Assistance**	**Partial Automation**	**Conditional Automation**	**High Automation**	**Full Automation**
Zero autonomy; the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.





Existing projects

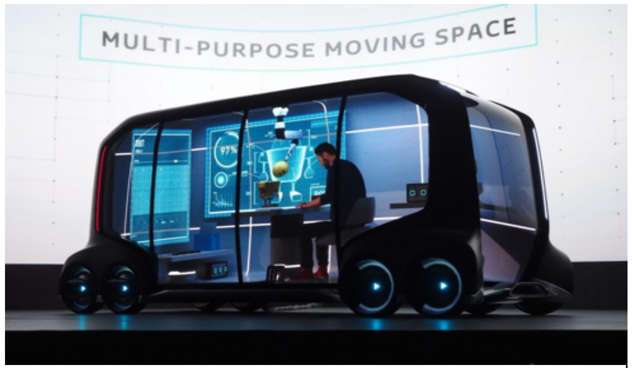
Waymo / Google Self-Driving Car

Tesla Autopilot

Navya AUTONOM SHUTTLE

Uber

nuTonomy



Toyota E-Palette

Some ADAS functionalities & SAE

Functionality	SAE Level	Sensors
Lane-departure warning	1	Camera
Drowsy-driver detection	2	Camera
Road extraction	3	Camera, Lidar
Road sign detection	3	Camera
Automated cruise control	3	Camera, Radar
forward-collision warning	3	Camera, Radar
Obstacle detection	4	Camera, Lidar, Radar
Pedestrian detection	4	Camera, Radar Lidar

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Dynamically & Partial Reconfiguration for ADAS

- Resource limitations bottleneck of ADAS
- Many features on ADAS/AD are not employed all the time
- Types of processing for ADAS change with driving conditions and environment
  - Functionality/accuracy with moving obstacles and weather changes
- DPR used to free hardware resources for other uses
  - Tracking more obstacles
  - Accelerating other computational functions
  - Reducing power consumption

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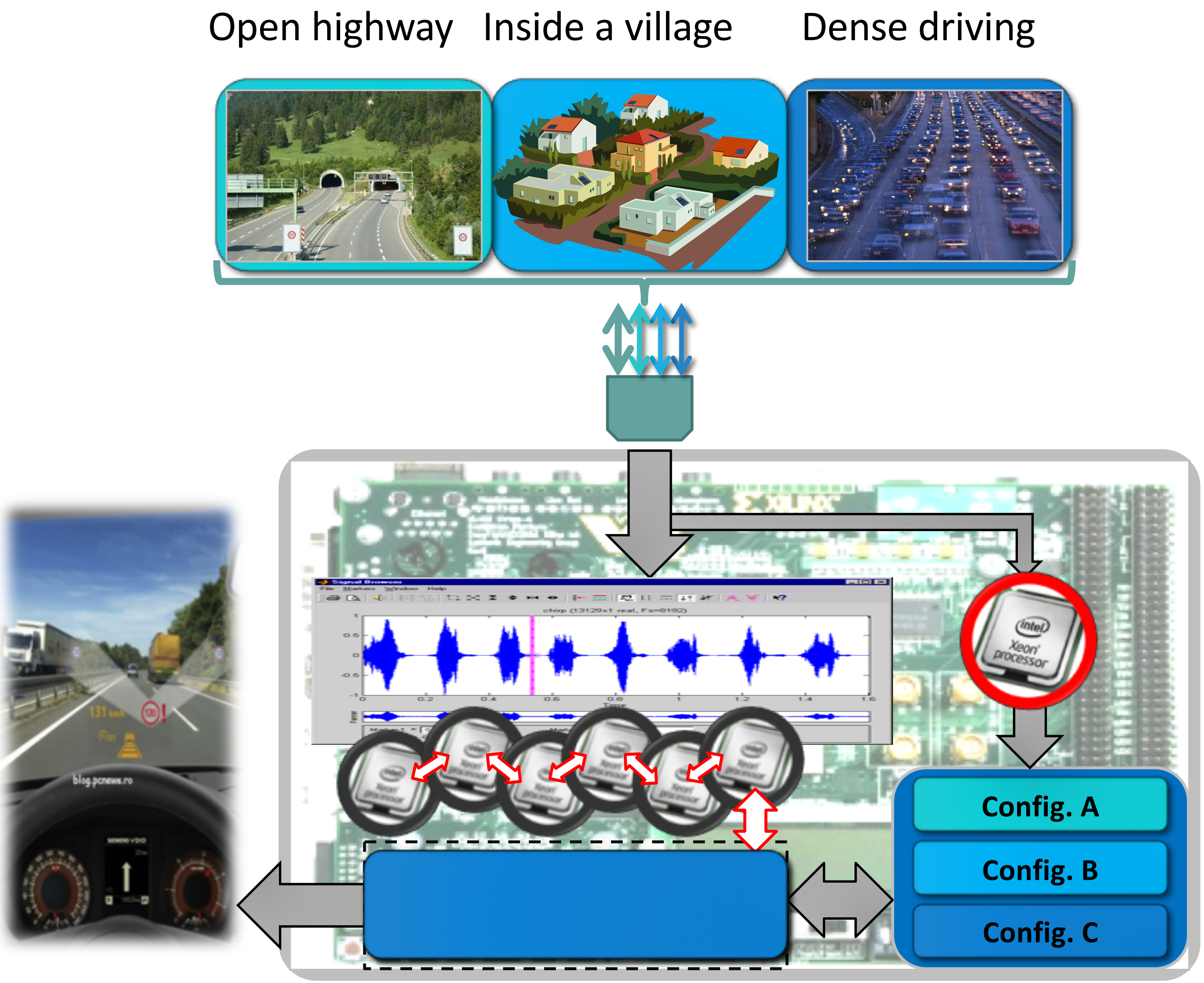
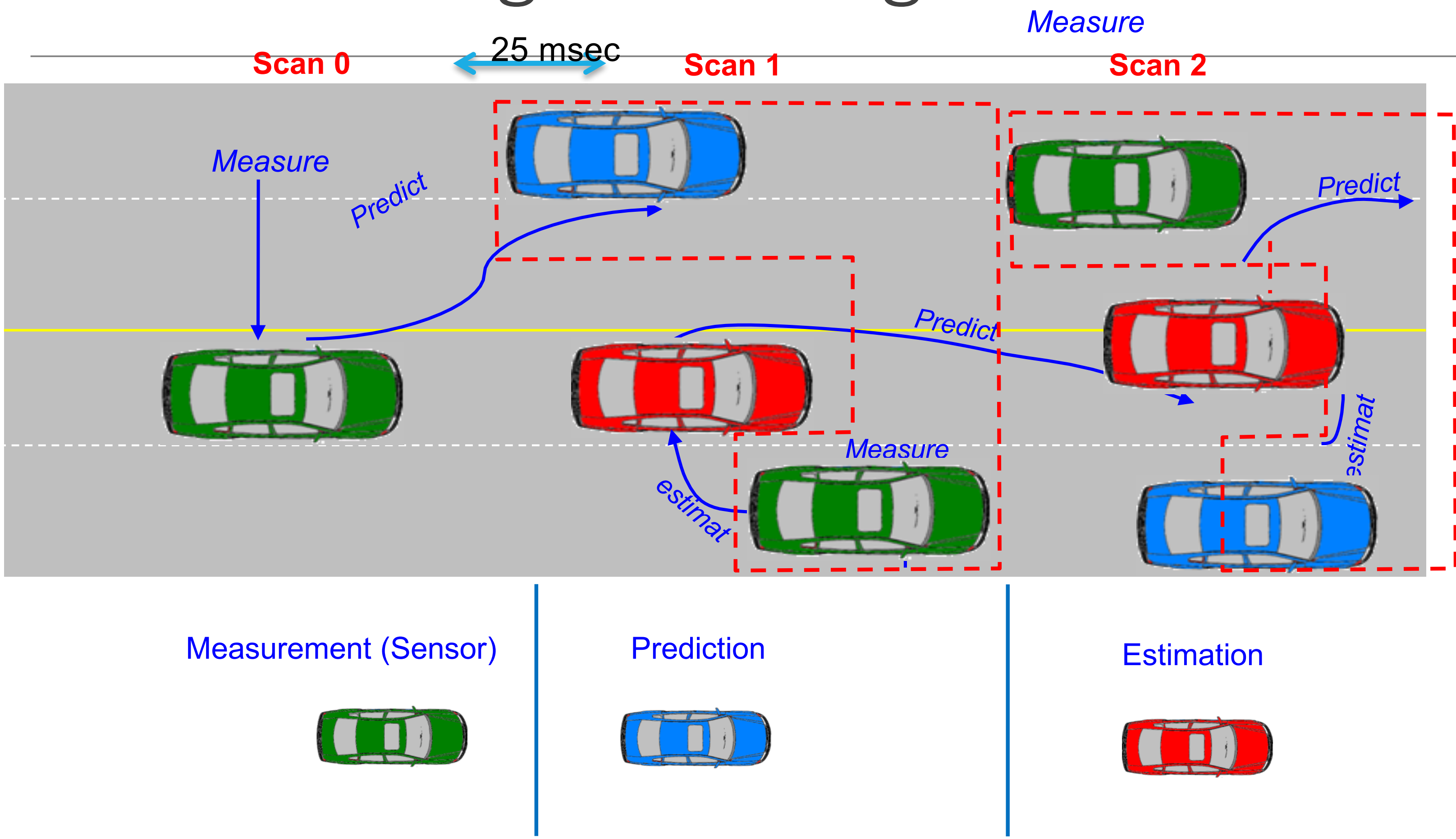
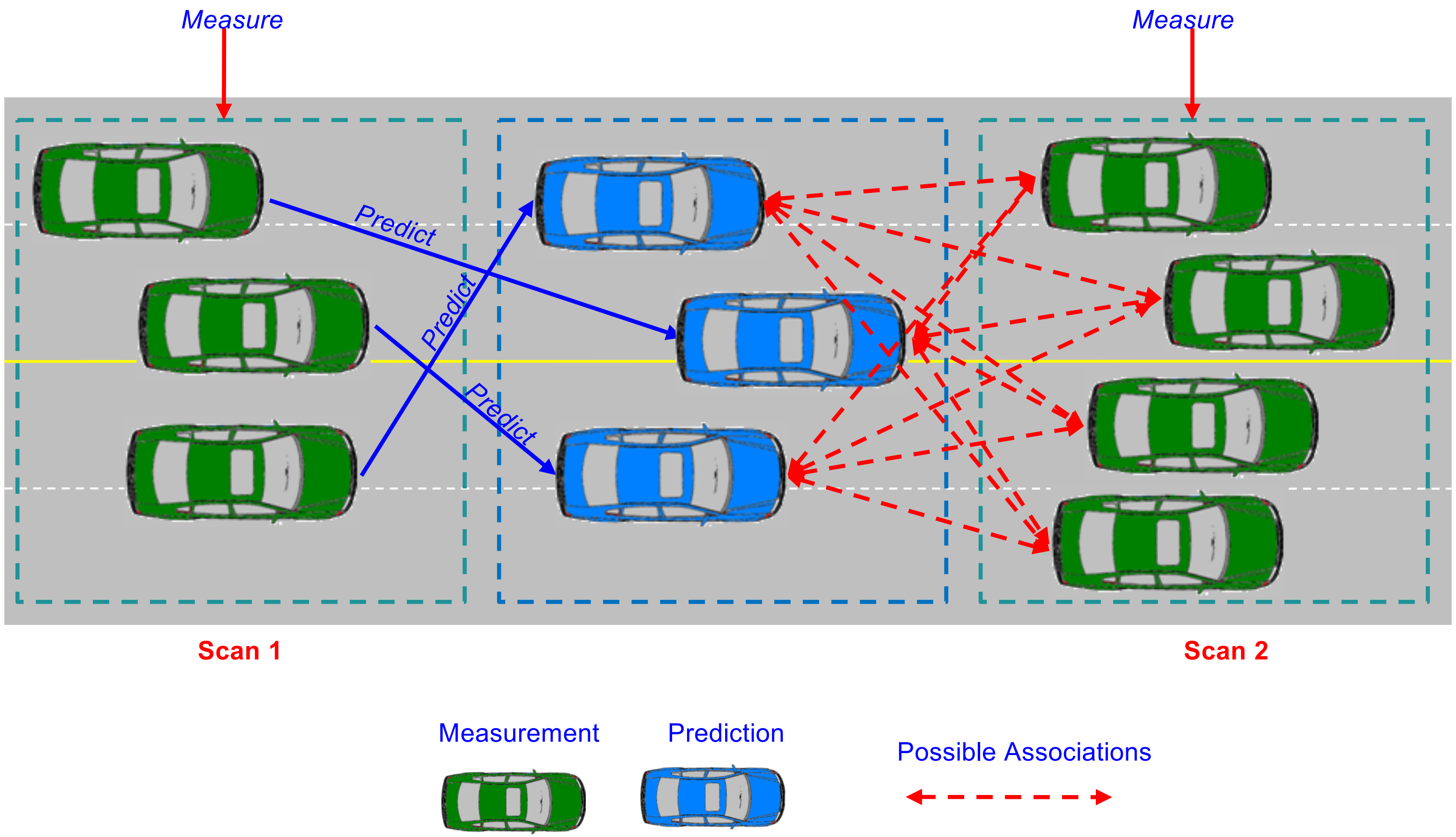

Open highway
Inside a village
Dense driving
Config. A
Config. B
Config. C

What is Target Tracking ?

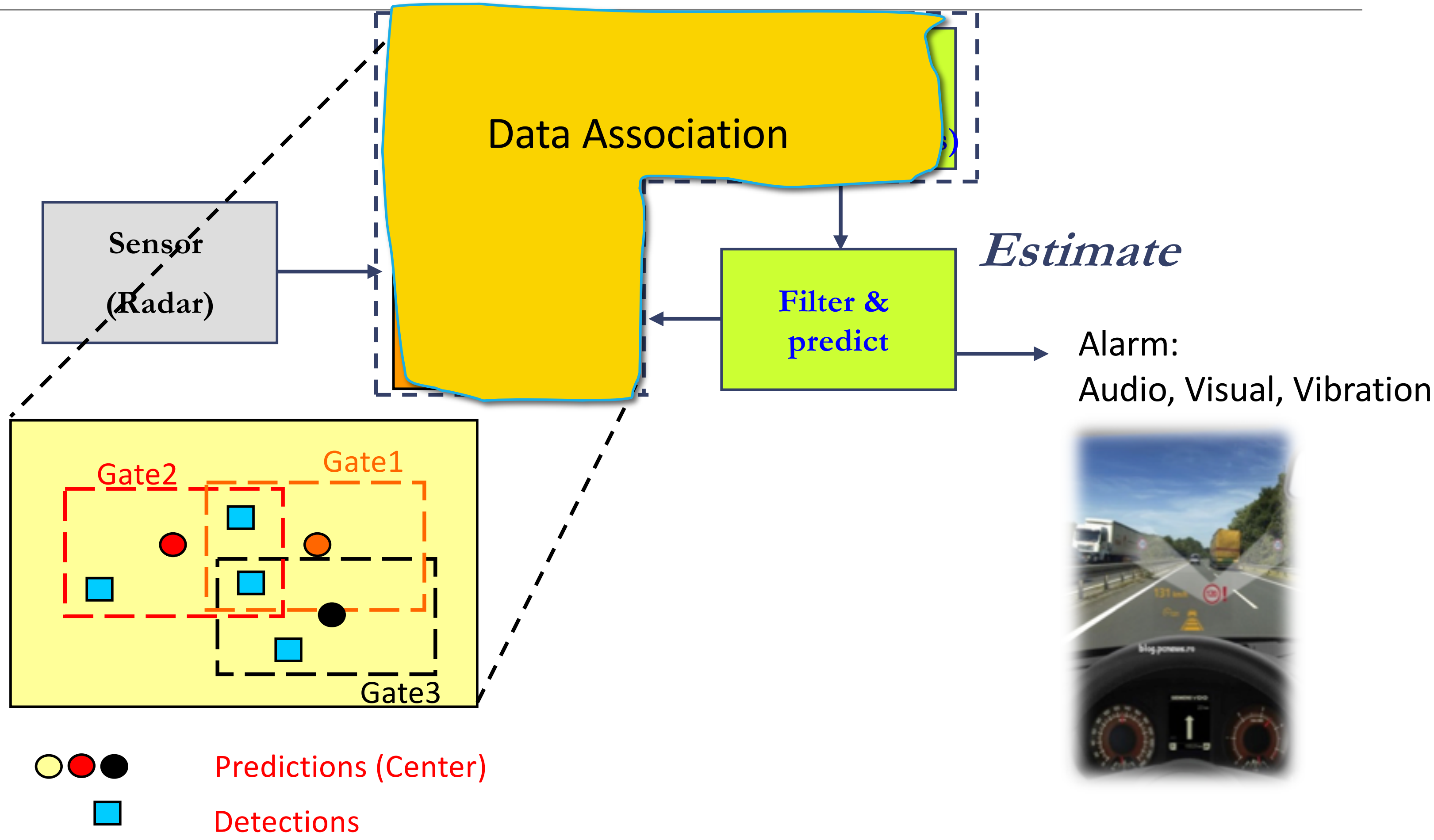


J.Khan, S.Niar, M. Saghir, Y. El-Hillali, A. Rivenq, “Trade-off Exploration for Target Tracking Application in a Customized Multiprocessor Architecture”, EURASIP Journal on Embedded Systems 2009.

Multiple Target Tracking (MTT)



Internal Structure MTT



Use case 1: DPR Based on Obstacle Density

- The computational needs of a MTT system increase with the number of targets
- Environment changes: open highway to narrow city street,
  - Higher levels of accuracy: track multiple, potentially closer targets.
- Environment changes from dense to sparse, the accuracy reduced
  - Minimize resource utilization and energy consumption.

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N. Harb, S. Niar, R. Ben-Atitallah, M. Saghir, "A Dynamically Reconfigurable Kalman Filtering Block for an Automotive Multiple Target Tracking System", Workshop on Reconfigurable Computing, 2012.

Use Case 2 : DPR Based on Obstacle Position

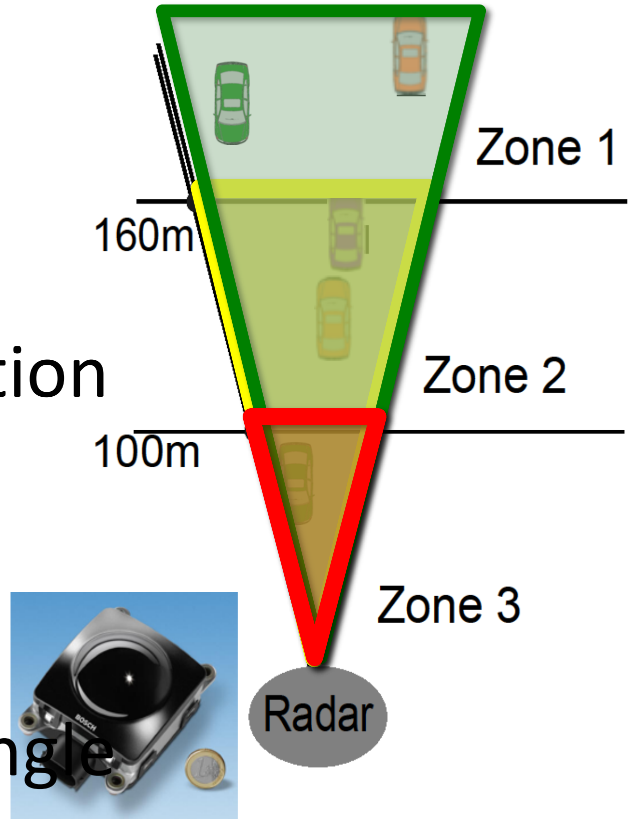
- Accuracy of an MTT automatically tuned to match the dynamics of moving obstacles
  - When targets move *closer to the radar:* more hazardous -> tracked at higher accuracy
  - When targets move further away, less accurate tracking (filters) can be used.

3 Filters for Filtering & Prediction Unit

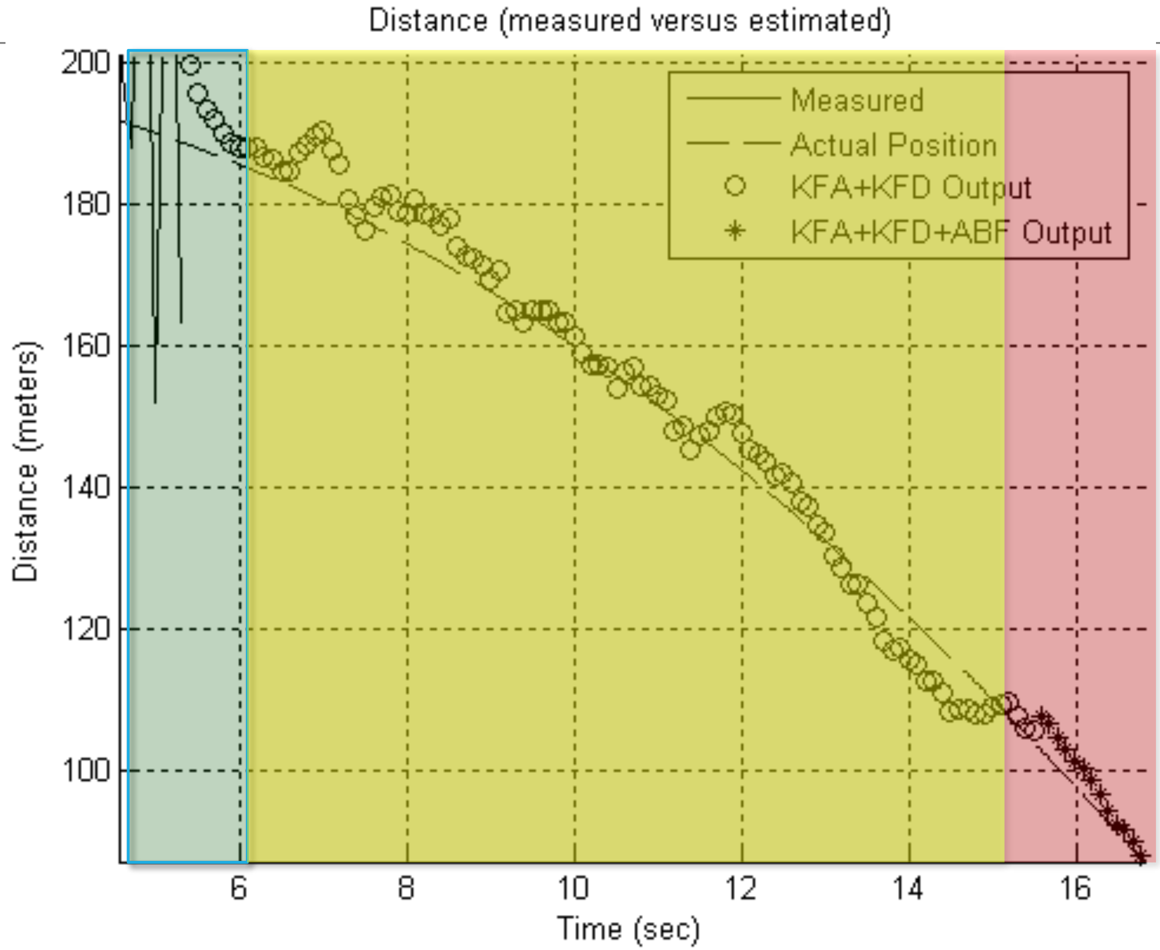
3 filters for 3 different scenarios

Far, Medium and Close

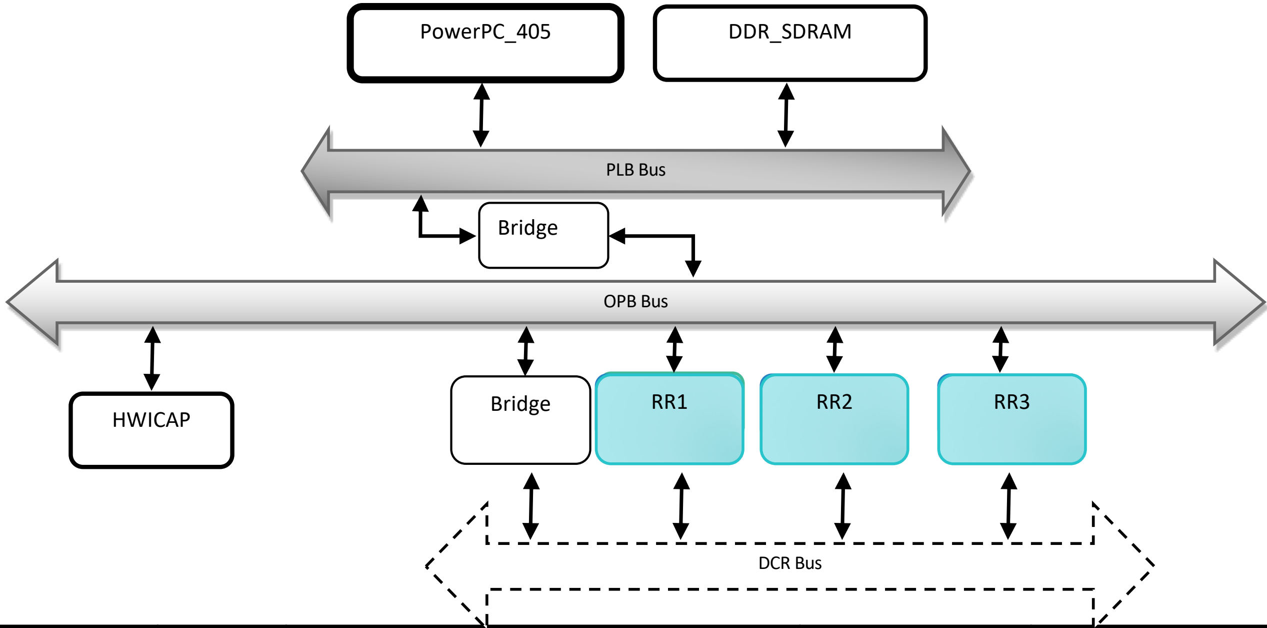
- Kalman filter for angle estimation (KFA),
- Kalman Filter for distance estimation (KFD)
- Extended α-β filter.
  - used over KFA and KFD
  - provides better distance and angle estimation.



Results

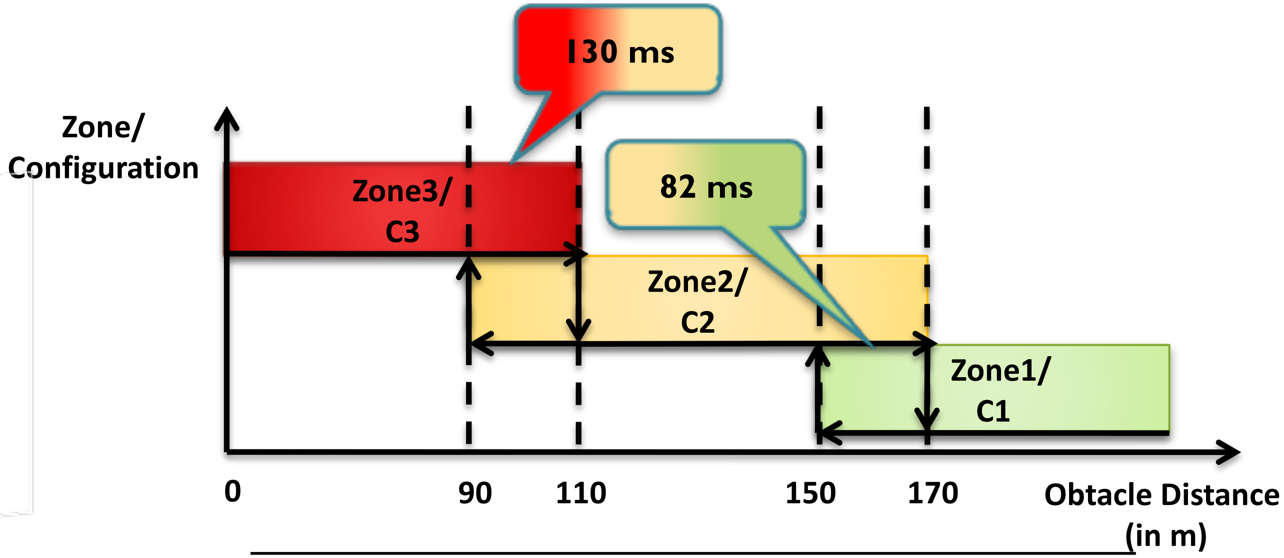


- Free RR used as an enhancement block (DUE)
- DUE is only implemented when in Zone 1 or 2



Used Filters	Name	Utilization	Reconf Region	Accuracy
KF for Angle	KFA	Used alone; D>160m	R1	A:15%; D:20%
KF for Distance	KFD	Used with KFA, 100<D<160m	R1+R2	A:15%, D:4%
ABF for A&D	ABF	Used with KFA and KFB, D<100m	R1+R2+R3	A:7%, D:2%

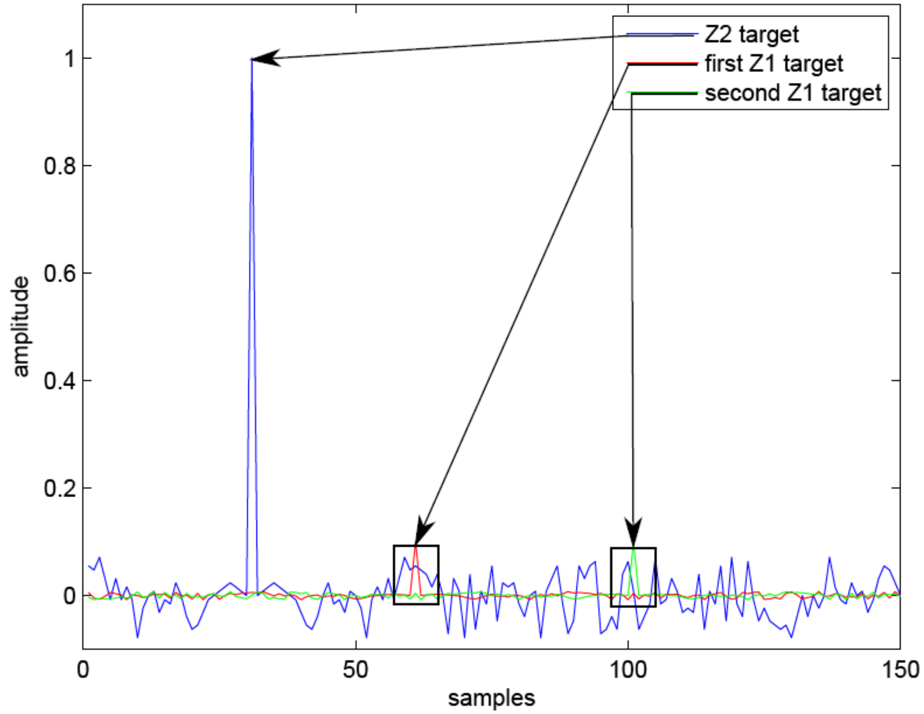
Reconfiguration Heuristics and Overhead



	Reconfiguration time
0-C1 / C1-0	87.3 msec
C1-C2 / C2-C1	82.8 msec
C2-C3 / C3-C2	130.1 msec

Detection Unit Enhancement (DUE)

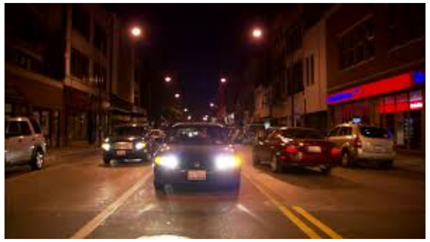
- Signals detected from two targets in Zone 1 hidden by side lobes from signal in Zone 2.
- In Zone 2 and Zone 1, implementing the Detection Unit Enhancement
- DUE improves weak target signals detection



Use case 3 : Camera-Based Car Detection

- Object appearance changes in different conditions,

Updating the detection method dynamically



- Light (Day Time): visual appearance
- Dusk : Visual appearance changes but shape features done by classification stage.
  - Edge and shape boundaries + lights
- Dark: Set of convolutional filters to detect the tail lights of vehicles

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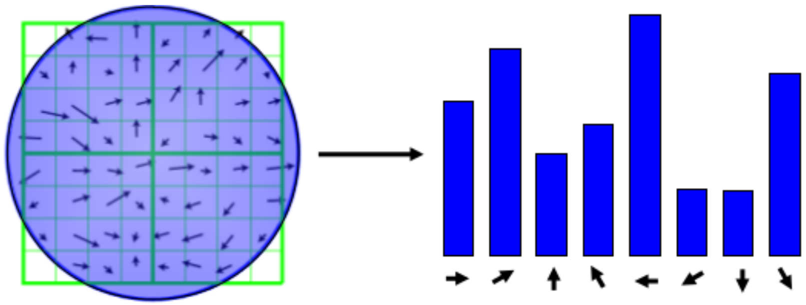
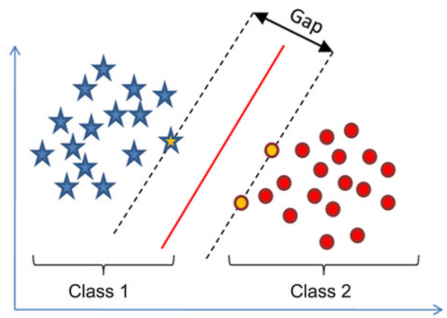
Filters in Ligth, Dusk, Dark

- Light and Dusk: Similar classifiers but different pre-trained models:
  - Histogram of oriented gradients (HOG) + Support Machine Vectors (SVM)
- Dark: A novel algorithm (set of convolutional filters) to detect the tail lights of vehicles
  - Convolutional kernels to detect size and appearance tail lights

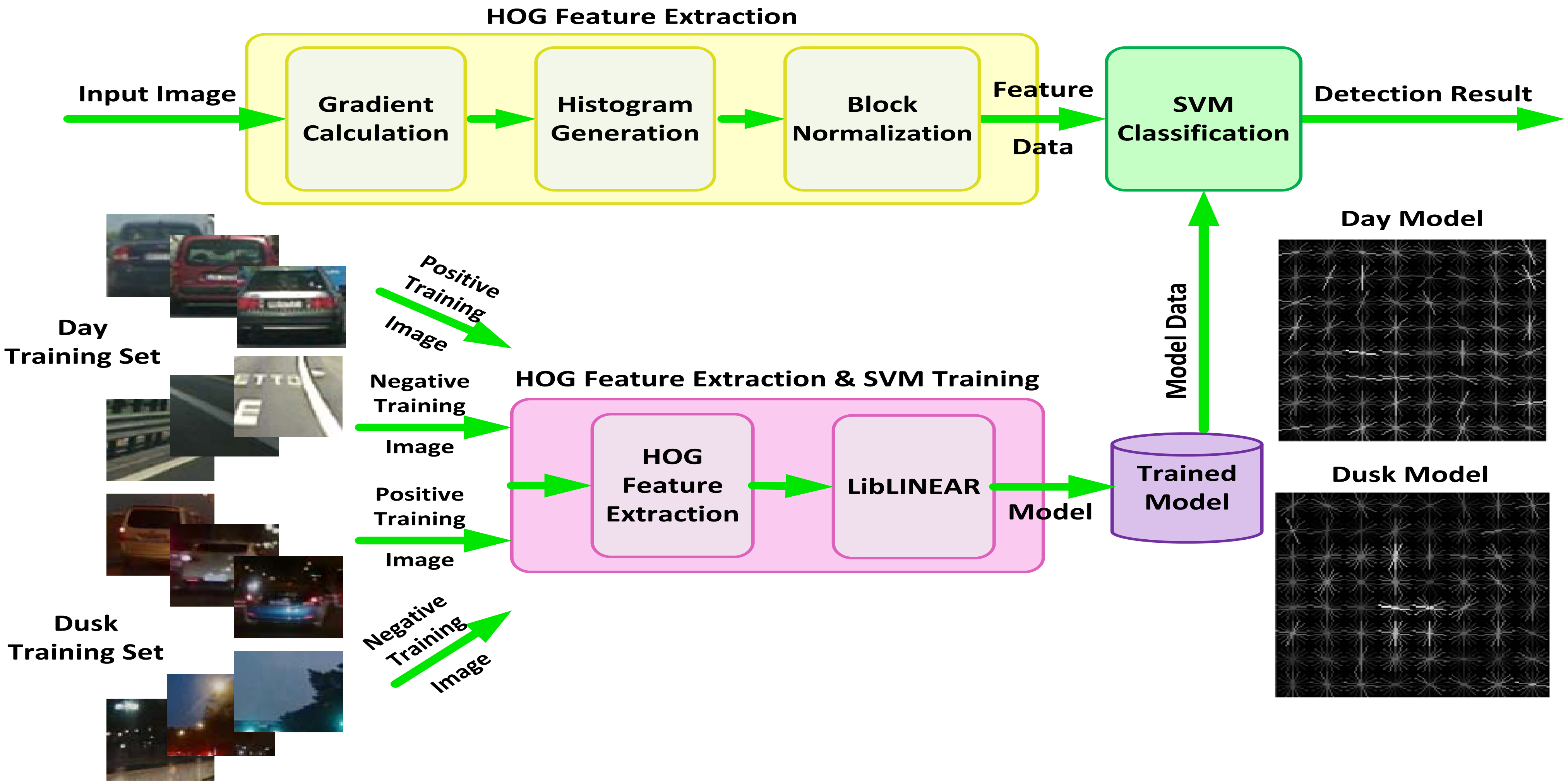


HOG: gradient orientations+histogram



SVM : Max gap btw classes

Training and Inference Phases : Day & Dusk



Static and Reconfigurable Parts

- Static part : data capture and pedestrian detection continues its operation during the reconfig.
  - Guarantees the **real-time and safe behavior**
- Reconfiguration part is designed to detect the vehicle with the choice of three different algorithms (particular environmental lighting conditions)

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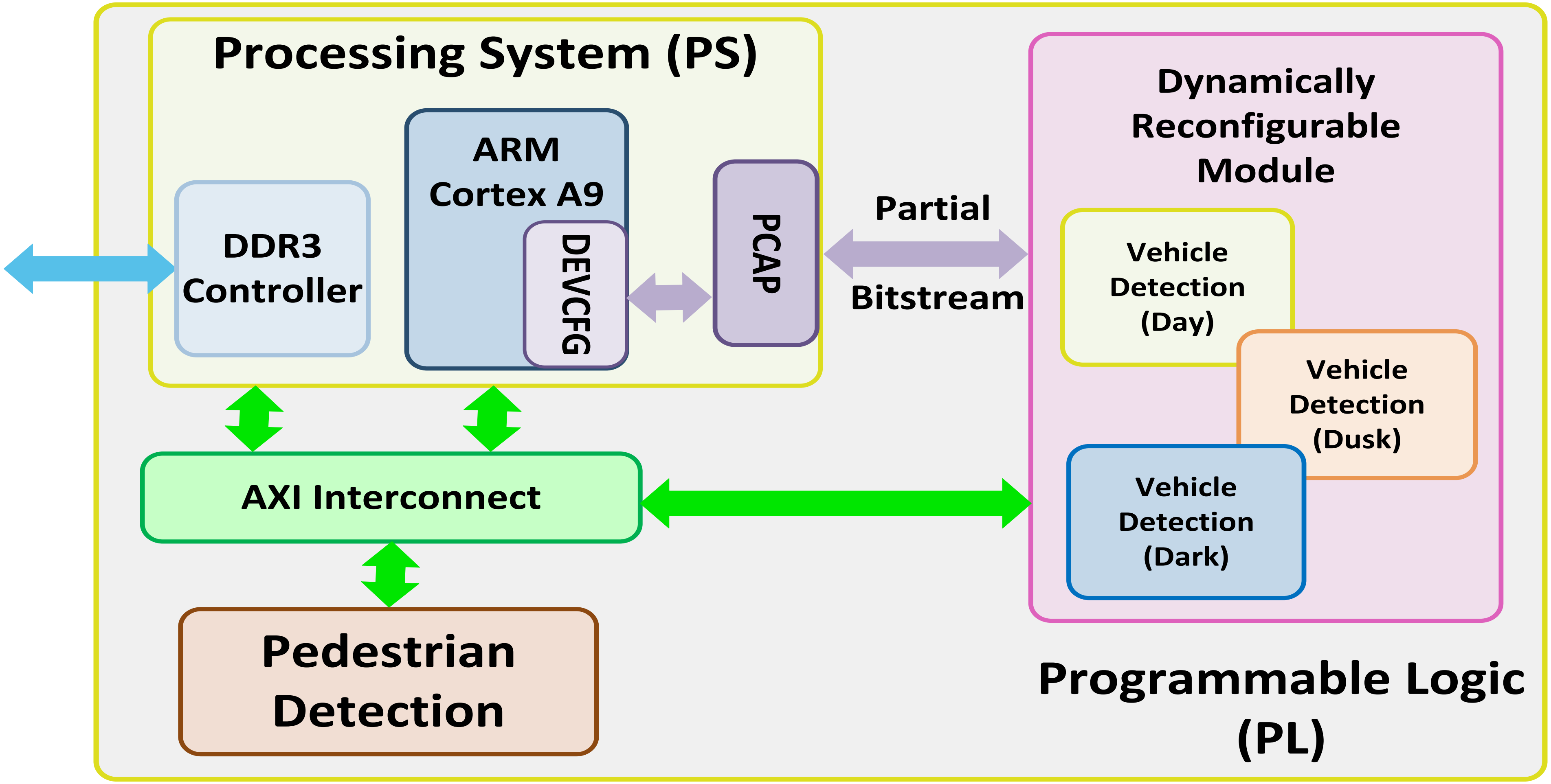
Adaptive Driver Assistance System



M. Hemmati, M. Biglari-Abhari, S. Niar, and S. Berber. Real-Time Multi-Scale Pedestrian Detection for Driver Assistance Systems. (DAC ’17).

Experimental Results

Feature	Value
Platform	Zynq-7000 AP SoC Mini-ITX
Bitstream downloaded	145 MB/sec
Bitstreams size	8.2 MB
Reconfiguration Delay	56 ms (@200 Km/h, ==3m)
Speed (execution time)	@ 125MHz , 50 fps (20msec/frame)

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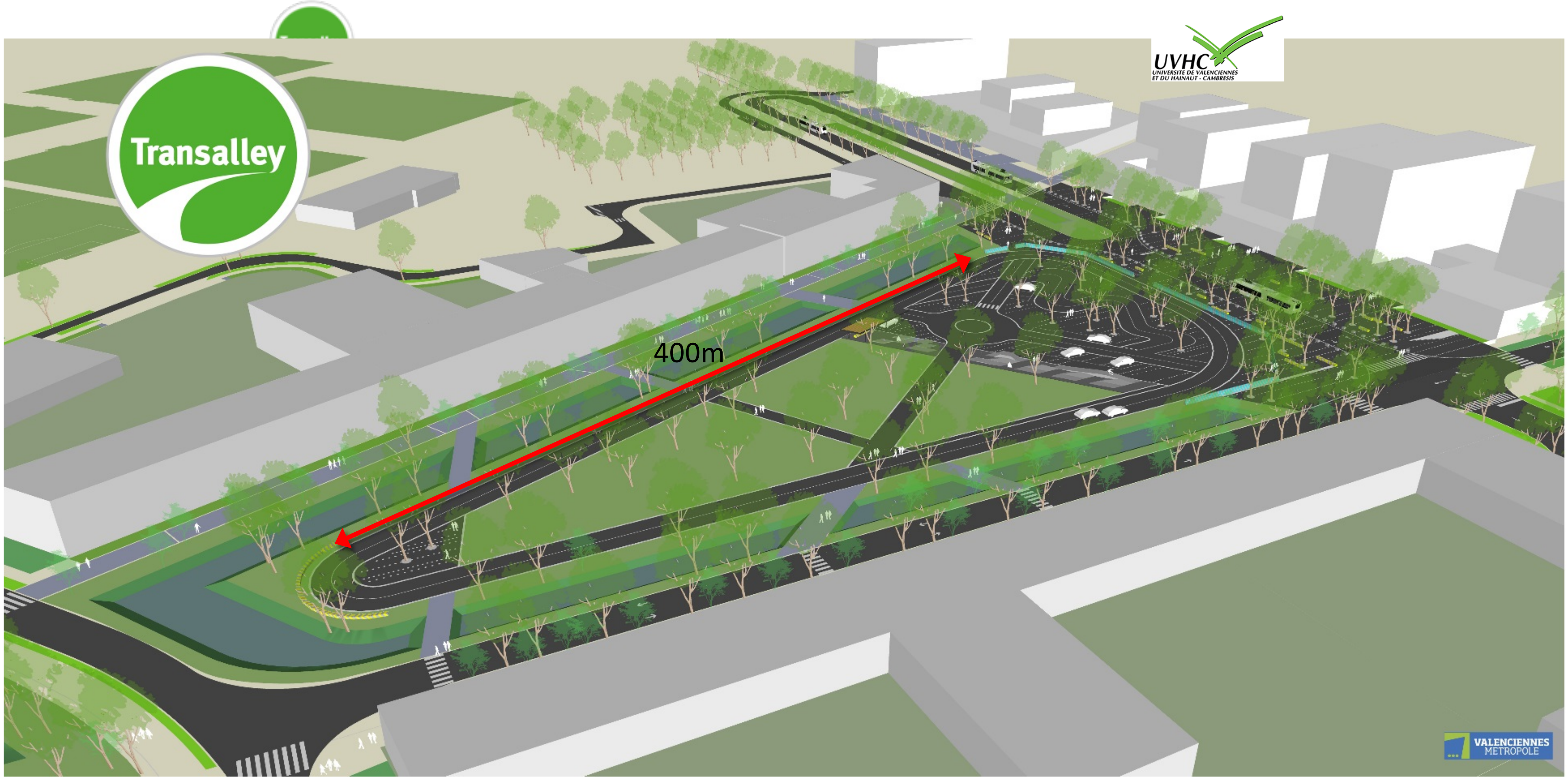
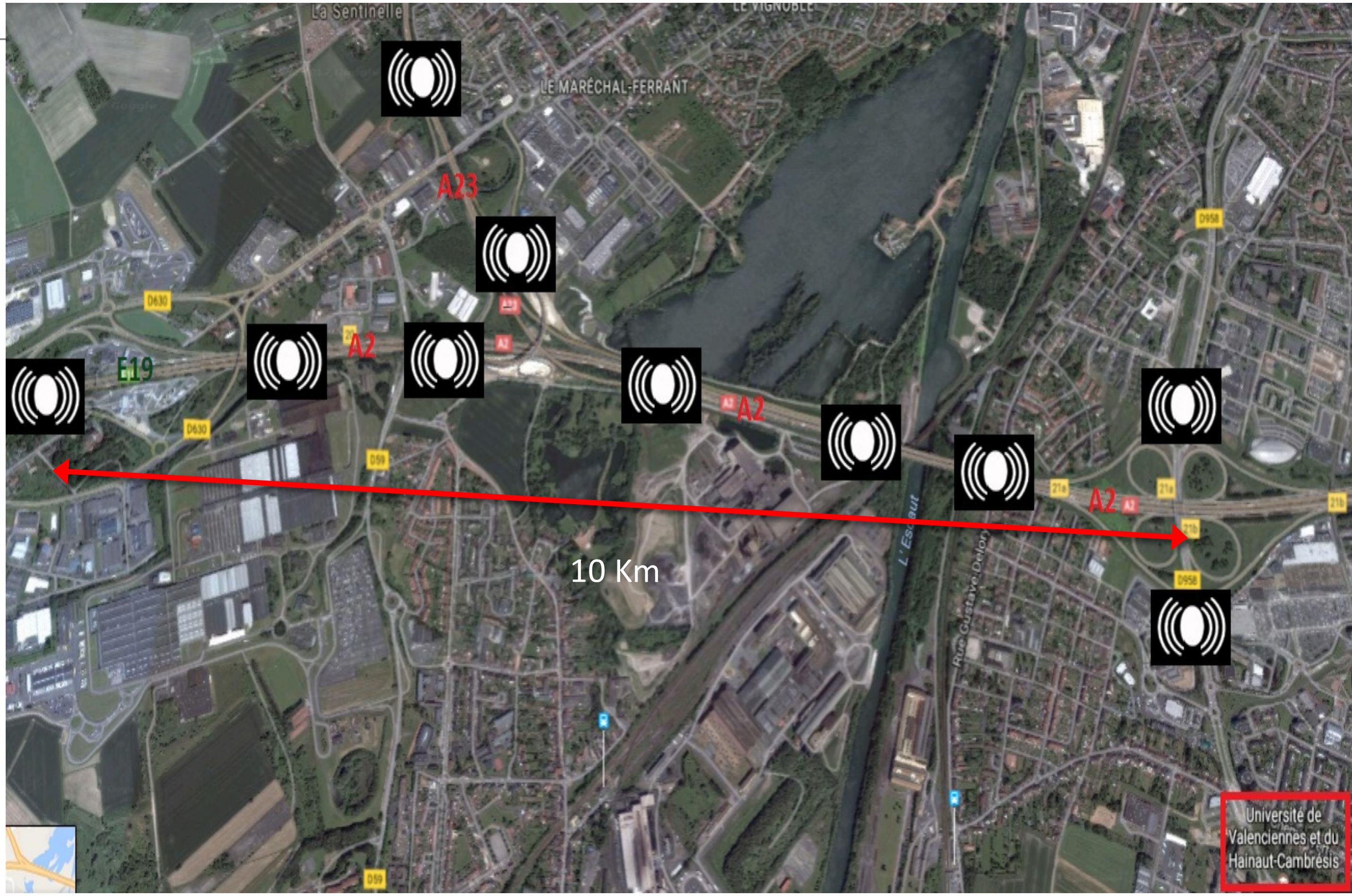
Track for Experimenting ADAS/AD in the Campus of Valenciennes




Transalley
Sustainable and Innovative Mobility Technopole
Valenciennes
Development
main caracteristics
45 ha
campus
34 ha
technopole
Tramway
Technopôle Transalley
Université de Valenciennes - Campus du Mont Houy
Tramway
Transalley
: RSU
: RSU
: RSU
: RSU
P
P
P
Université de Valenciennes et du Hainaut-Cambrésis
2 Km
802.11p Radio ITS-G5 / WAVE
DYNAC
TCP/IP
ITS-G5
5.9GHz
C-ITS-S
R-ITS-S
V-ITS-S

PHASE II: Deployment on the A2 and A23 highways (Paris-Brussels)



To Paris

To Brussels

Equipements/Sensors

Equipement	Features	Price
Velodyn Lidar PUCK™ VLP-16	830 gr, 100m Range, 300K Points per Second, 360° Horizontal FOV, ± 15° Vertical FOV	15K€
Continental Short Range Radar	Distance 50m, Angle [-20°, +20°] up to –[75°...+75°], 4.5W	3K€
Continental ARS 408-21 Premium Long Range Radar	Distance 250m, Angle [-9°, +9°], Cycle time 70msec, up to 8 obstacles, 12W.	3K€
Camera AXIS Q6055-E PTZ	Weight 3.7Kg, Horizontal field 62.8° Vertical field 36.8°, resolution HDTV 1920x1080, 60 fps.	3K€



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Many Challenges Facing Us for AD

- Managing ambiguous situations
  - A police officer waving through a red light or Stopping at a green light.
  - AD have to understand human sign language

- AD is a multitasking activity: uses HL cognitive human capacity
  - Anticipation, guess using experience, decision, etc...

- Sensors plays an important role
  - Maintained clean
  - Snow: lose of markers
    - Use a smaller number of sensors to move

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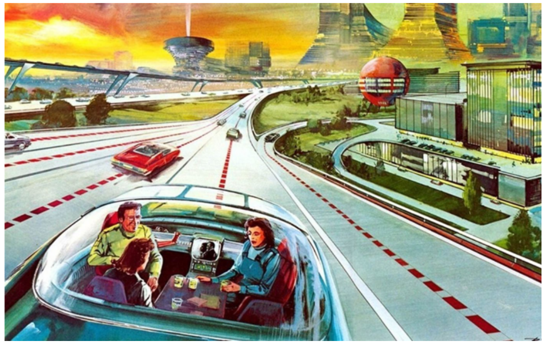
Many Challenges Facing Us for AD….

- 54% of U.S. drivers feel less safe sharing the road with a self-driving vehicle,
- 78% of Americans afraid to ride in AD
  - Women (85%) likely to be afraid than men (69%)



- Can Traditional and AD Coexist?
  - Autonomous Navya shuttle bus collided with a truck few hours after Las Vegas celebrate its first day city-wide test (2017).

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Conclusion

- ADAS/AD in the roadmap of car makers : Embedded HPC
- RC/DPR may help to design efficient embedded systems
- DPR on FPGA:
  - Radar-based MTT : Obstacle Density & Distance
  - Camera-based for car detection using ML
- AD: Several challenges to overcome
- Functional Safety (ISO 26262) Automotive Safety Integrity Level ASIL (A to D)
  - Any Component (SW or HW) in the car must be certified
- Security: Confidentiality of data

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13th International Symposium on Reconfigurable Communication-centric Systems-on-Chip

ReCoSoC

www.recosoc.org

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During the past decade, **ReCoSoC** has established itself as a reference international event for researchers in the areas of reconfigurable and communication-centric systems-on-chip. Its informal and dynamic philosophy encourages the technical and scientific interactions between senior academics and young researchers.

All accepted papers will be published in **IEEE Xplore**. The authors of the best papers will be invited to submit an extended version of their contribution to the **journal Microprocessors and Microsystems**: Embedded Hardware Design (MICPRO, Elsevier).

Topics of interest:

The areas of interest include (but are not limited to) :

- New paradigms for reconfigurable and communication-centric computing
- Reconfigurable and adaptive embedded SoCs
- Communication-centric design techniques at different abstraction levels
- On-chip communication architectures
- Low power design of reconfigurable and multiprocessor SoCs
- Communication-aware multiprocessor embedded systems
- OS and middleware for reconfigurable and multicore SoCs
- Specification languages and design methodologies
- Verification and evaluation techniques
- Industrial case studies: HPC, Routers, Mobile systems, Transportation syst. Etc.

Submission:

Authors are invited to submit contributions as maximum 8 page papers in IEEE conference format. Contribution(s) have to be submitted electronically through the EasyChair portal of the conference:
https://easychair.org/conferences/?conf=recosoc2018

Important Dates:

Abstract submission deadline :	9th April 2018
Full paper submission deadline :	16th April 2018
Notification of acceptance :	21st May 2018
Camera-ready due :	11th June 2018

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