Politecnico di Torino

Department of Mechanical and Aerospace Engineering

Master's Degree in Mechanical Engineering

Sensors' Architecture Definition for Energy Consumption Reduction in Urban Battery Electric Vehicles

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CENTRO NAZIONALE PER LA MOBILITÀ SOSTENIBILE

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

Ministero dell'Università e della Ricerca

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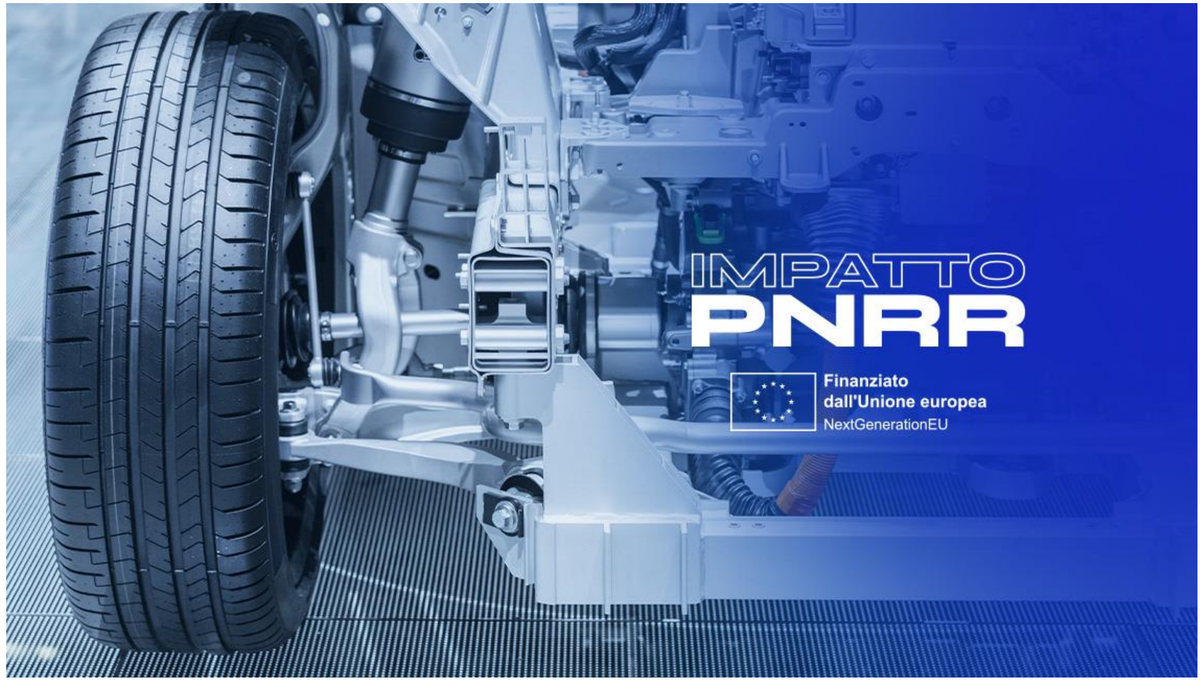
NextGenerationEU

Table of Contents

CONTEXT: ENERGY MANAGEMENT
Spoke 2: Sustainable Road Vehicle



Spoke 2 - **Sustainable Road Vehicle**, focuses on road mobility, in particular on zero emission electric and hydrogen vehicles, their interaction with charging networks and data for fuel economy, safety and reliability.

Main Objectives of the Spoke 2:

- Create a zero-emission vehicle demonstrator that uses sensors to meet energy management requirements ;
- The objective of the thesis is to define the architecture of the sensors necessary for the prototype.

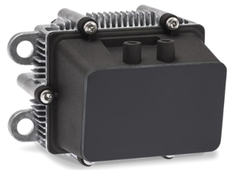
DONOR VEHICLE: ADAS EQUIPMENT
Spoke 2: Sustainable Road Vehicle

Donor Vehicle Equipments: Baseline 500e ADAS Architecture (sensors access subject to OEM agreement)

Camera: device that captures visual information from the vehicle's surroundings.

Stereoscopic camera: device equipped with two or more cameras positioned to simulate human binocular vision with the ability to perceive depth.

Radar: transmits radio waves and analyzes signals reflected from nearby objects.



LiDAR: create a three-dimensional map of the surrounding environment.

NEW ADAS Architecture Requirements

Case Study: 500e with NEW ADAS sensors and features (additional to OEM)

ADAS SENSORS

Sensors' Features	*Interfaces / Communication*	*Additional Features*
Range 0 – 200 [m]	**CAN / ETH**	Automotive-grade
Resolution – depends on functions	ROS Integration is a plus	Functional Safety compliance (opt)

INTERFACE

Operating System	*Interfaces / Communication*	*Additional Features*
Linux – ROS / ROS2	**CAN / ETH**	Automotive-grade
Autoware integration is a plus	USB	Functional Safety compliance (opt)

CONTROL

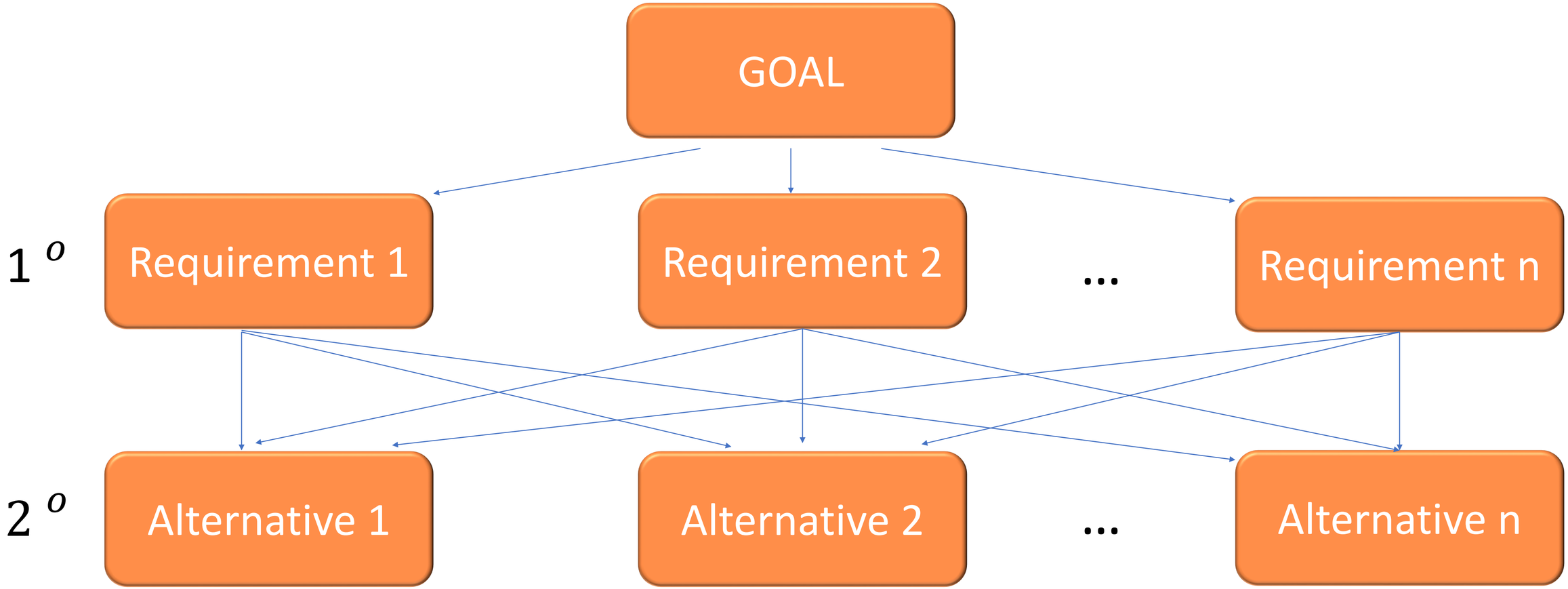
Standard Functions	*Detection Functions*		*Semi - Autonomous Functions*
Adaptive Cruise Control (ACC)	Lane - Change - Assist	Lane - Support - Functions	**Traffic-Jam-Assist**
Lane Keeping Assist Systems (LKAS)	Speed-Limit-Assist		**Highway Assist**

Analysis Performed

- Market Analysis
- Sensors’ Benchmark
- Analytic Hierarchy Process (AHP)
- Selection of most performing
- Sensors’ Hardware Architecture

AHP OVERVIEW:

Analytic Hierarchy Process: Method of decision-makings



Key performance indicators (KPI) of the analisys are:

$$\lambda = \frac{\text{Weighted } Sum\ Value}{Criteria\ Weights} \qquad \lambda_{max} = \frac{\lambda_1 + \cdots + \lambda_n}{n} \qquad C.I. = \frac{\lambda_{max} - n}{n-1} \qquad C.R. = \frac{C.I.}{R.I.}$$

AHP Method for Solid State Lidar: Robosense RS M1

1^{st} Level

	Range	Range Accuracy	Field Of View	Resolution	Cost	Weather Robustness	Urban ADAS	Highway ADAS	Innovation
Range	1	1	5	3	7	5	5	3	9
Range Accuracy	1	1	7	3	7	3	5	3	9
Field Of View	1/5	1/7	1	1/5	3	1/5	1/3	1/3	1
Resolution	1/3	1/3	5	1	3	1	5	3	5
Cost	1/7	1/7	1/3	1/3	1	1/5	1	1/3	1/3
Weather Robustness	1/5	1/3	5	1	5	1	3	1	3
Urban ADAS	1/5	1/5	3	1/5	1	1/3	1	1/3	5
Highway ADAS	1/3	1/3	3	1/3	3	1	3	1	5
Innovation	1/9	1/9	1	1/5	3	1/3	1/5	1/5	1

λmax	C.I.	$\frac{C.I.}{R.I.}$
10,0	0,13	0,09

Consistency check [%]

9

Extremely less important	1/9
	1/8
Very strongly less important	1/7
	1/6
Strongly less important	1/5
	1/4
Moderately less important	1/3
	1/2
Equal Importance	**1**
	2
Moderately more important	3
	4
Strongly more important	5
	6
Very strongly more important	7
	8
Extremely more important	9

AHP Method for Solid State Lidar: Robosense RS M1

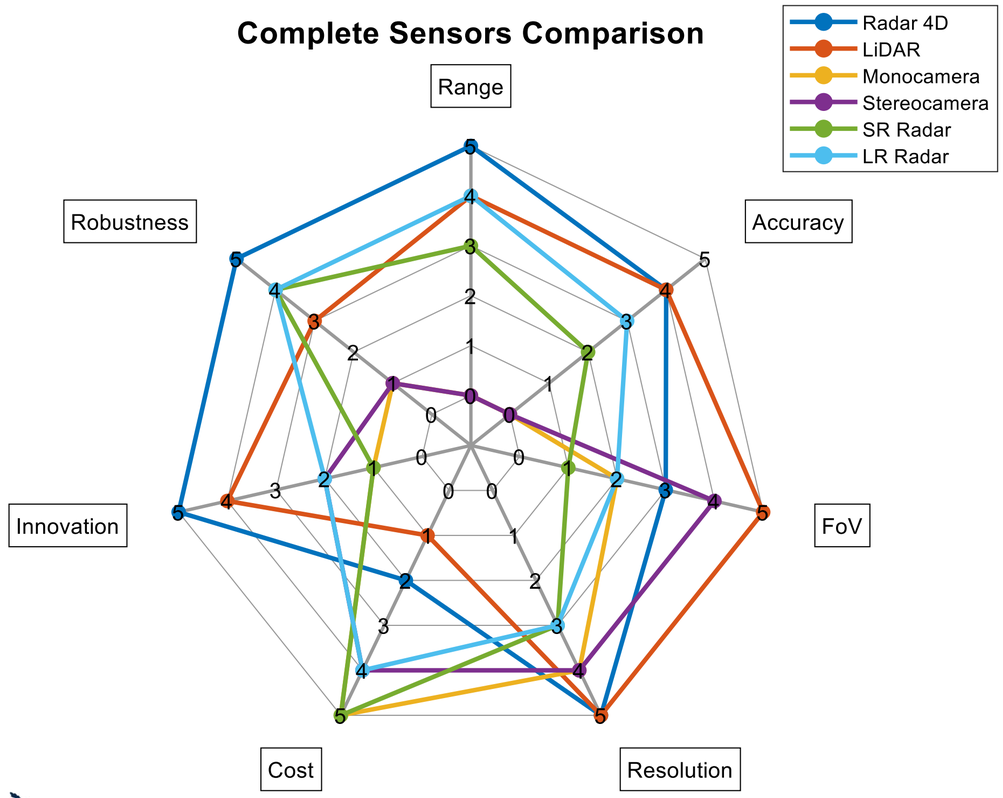
2^{nd} Level

LiDAR i	LiDAR j	Range 200m		Ranking		Value
Robosense RS M1	Hesai AT 128	200	200	A	1	1
Robosense RS M1	Blickfeld Cube 1	200	250	B	0,8	5
Robosense RS M1	Velodyne Velarray	200	200	A	1	1
Robosense RS M1	Livox Horizon	200	260	B	0,77	5
Robosense RS M1	Innoviz PRO	200	135	A	1,48	7
Hesai AT 128	Blickfeld Cube 1	200	250	B	0,8	5
Hesai AT 128	Velodyne Velarray	200	200	A	1	1
Hesai AT 128	Livox Horizon	200	260	B	0,77	5
Hesai AT 128	Innoviz PRO	200	135	A	1,48	7
Blickfeld Cube 1	Velodyne Velarray	250	200	A	1,25	5
Blickfeld Cube 1	Livox Horizon	250	260	B	0,96	1
Blickfeld Cube 1	Innoviz PRO	250	135	A	1,85	9
Velodyne Velarray	Livox Horizon	200	260	B	0,77	5
Velodyne Velarray	Innoviz PRO	200	135	A	1,48	7
Livox Horizon	Innoviz PRO	260	135	A	1,93	9

GLOBAL PRIORITY SOLID STATE LiDAR			
	Robosense RS M1	Velodyne Velarray	InnovizPRO
Range	0,026	0,026	0,0064
Range Accuracy	0,035	0,035	0,0351
Field of View	0,012	0,0031	0,0009
Resolution	0,017	0,0097	0,024
Cost	0,0009	0,0125	0,0062
Weather Robustness	0,011	0,011	0,011
Urban ADAS	0,0027	0,0024	0,0025
Highway ADAS	0,0081	0,0075	0,0077
Innovation	0,029	0,0009	0,0014
	0,14	0,11	0,096

Best Performing ADAS Sensors

From the requirements defined with the project team, the Sensors chosen after market analysis are:



Robosense RS M1

Continental ARS 548 RDI

NileCAM25 CUOAGX GMLS2

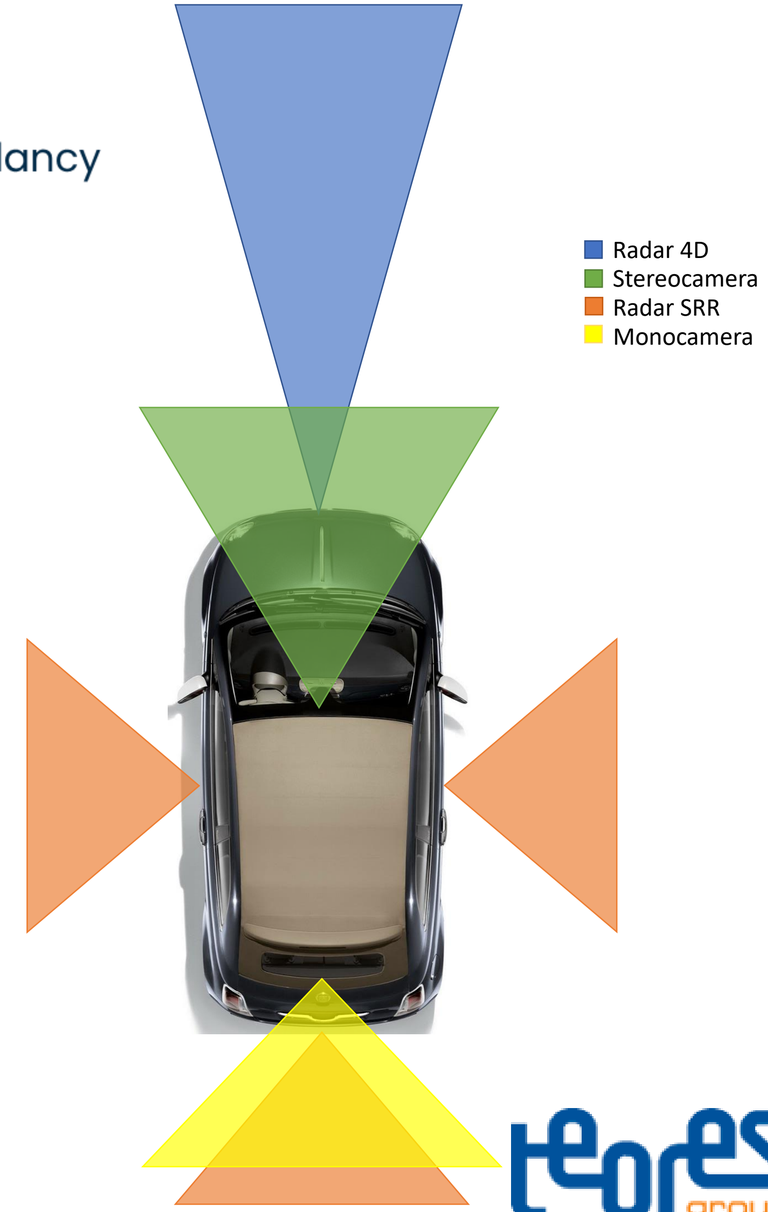
ZED X

Continental SRR 520

RESULTS:
NEW ADAS Architecture – Solution 1

Solution 1: Kit composed by 4D Radar, SR Radars and mono/stereo camera redundancy

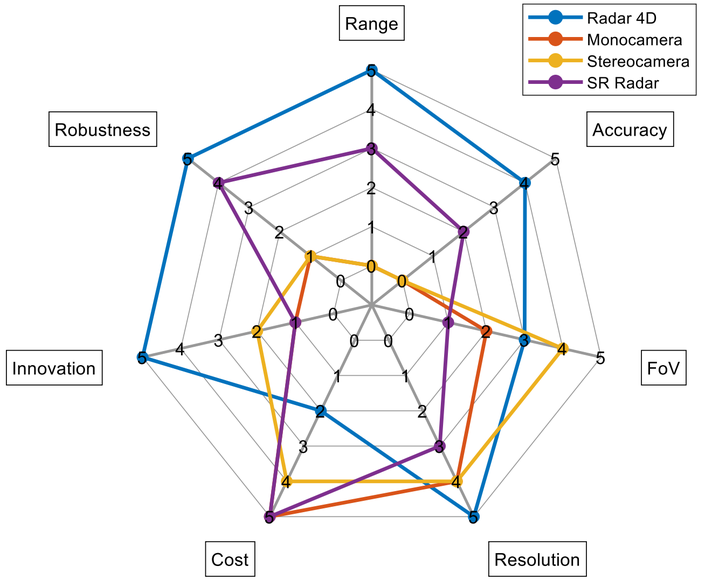
SENSOR	Type	Max Range	Range Accuracy	FoV	Resolution	Cost	Quantity
CONTINENTAL ARS 548 RDI	Radar 4D	300 m	± 0.15 m	± 60°	0.10 m/s	4000 €	1
ZED X / Leopard AR0234CS	Smart Stereo / Stereocamera	20 m / 8 m	-	110°H/80°V 121.5°H/73.5°V	1920Hx1200V	550 € / 370 €	1
CONTINENTAL SRR520	Radar SRR	100 m	± 0.22 m ± 0.5 m	± 90°	0.35 m/s	50 €	3
NileCam25 CUOAGX GMLS2 / CONTINENTAL MFC527	Monocamera / Smart Mono	-	-	104.6°H/61.6°V 110°H/70°V	1920Hx1200V 1280Hx960V	505 € / 550 €	1

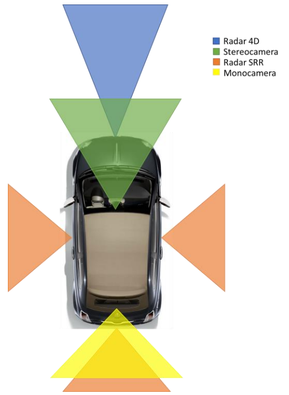


RESULTS:
NEW ADAS Architecture – Comparison

Comparison: Sensors' Kits characteristics comparison for BOM definition

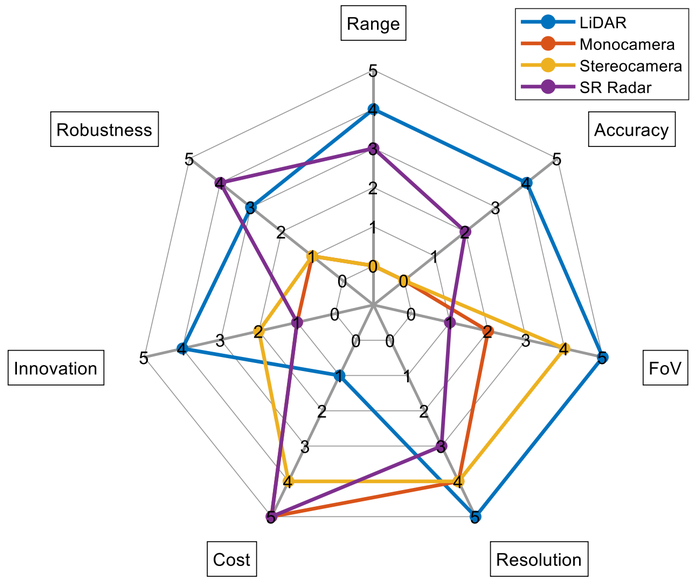
Solution 1

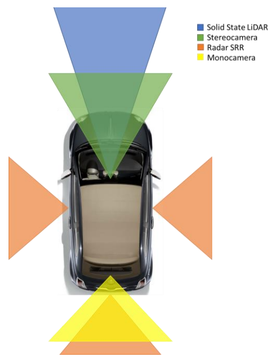




Range = 4
Accuracy = 3
FoV = 2.5
Resolution = 4
Cost = 4
Innovation = 2.25
Robustness = 2.75

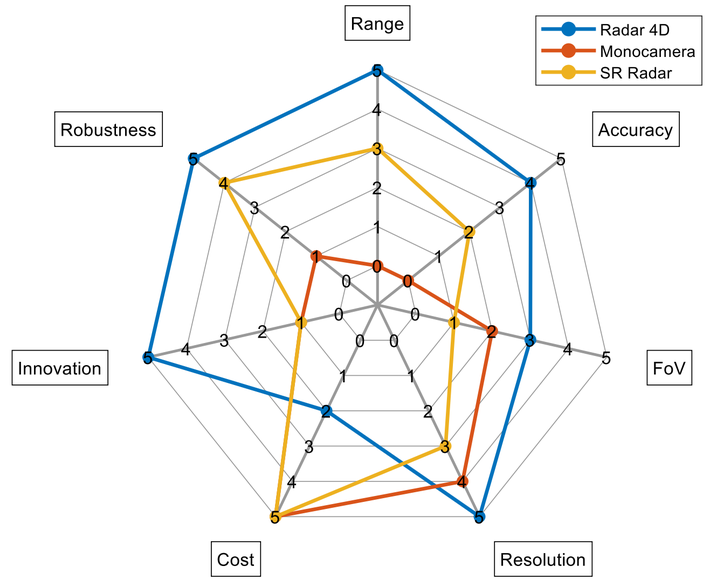
Solution 2

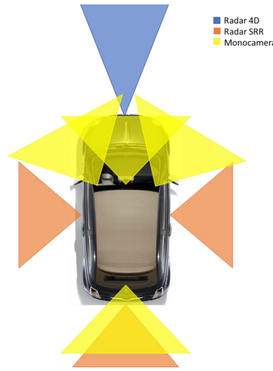




Range = 3.5
Accuracy = 3
FoV = 3
Resolution = 4
Cost = 3.75
Innovation = 2
Robustness = 2.25

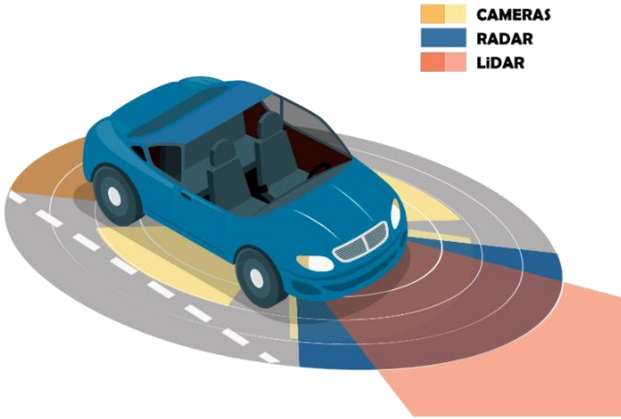
Solution 3





Range = 4
Accuracy = 3
FoV = 2
Resolution = 4
Cost = 4
Innovation = 2.33
Robustness = 3.33

Conclusions and Future Works



MOST
CENTRO NAZIONALE PER LA MOBILITÀ SOSTENIBILE

Politecnico di Torino

«Passion, obsession, car addiction;
beyond the bounds of reason
Madness»

Thank you for the attention!

teoresi group

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