



PASSION FOR
TECHNOLOGIES

EDGE FOR SEAMLESS AND EFFECTIVE AV TESTING

Overview of Edge in Automotive

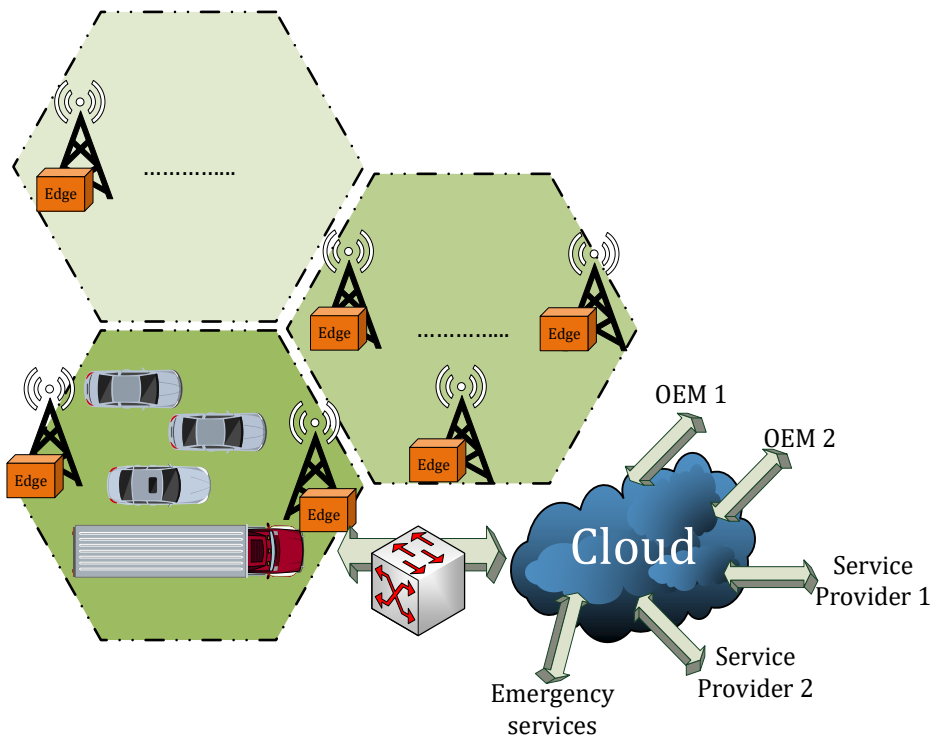
05.05.2020

Harsha Jakkanahalli Vishnukumar

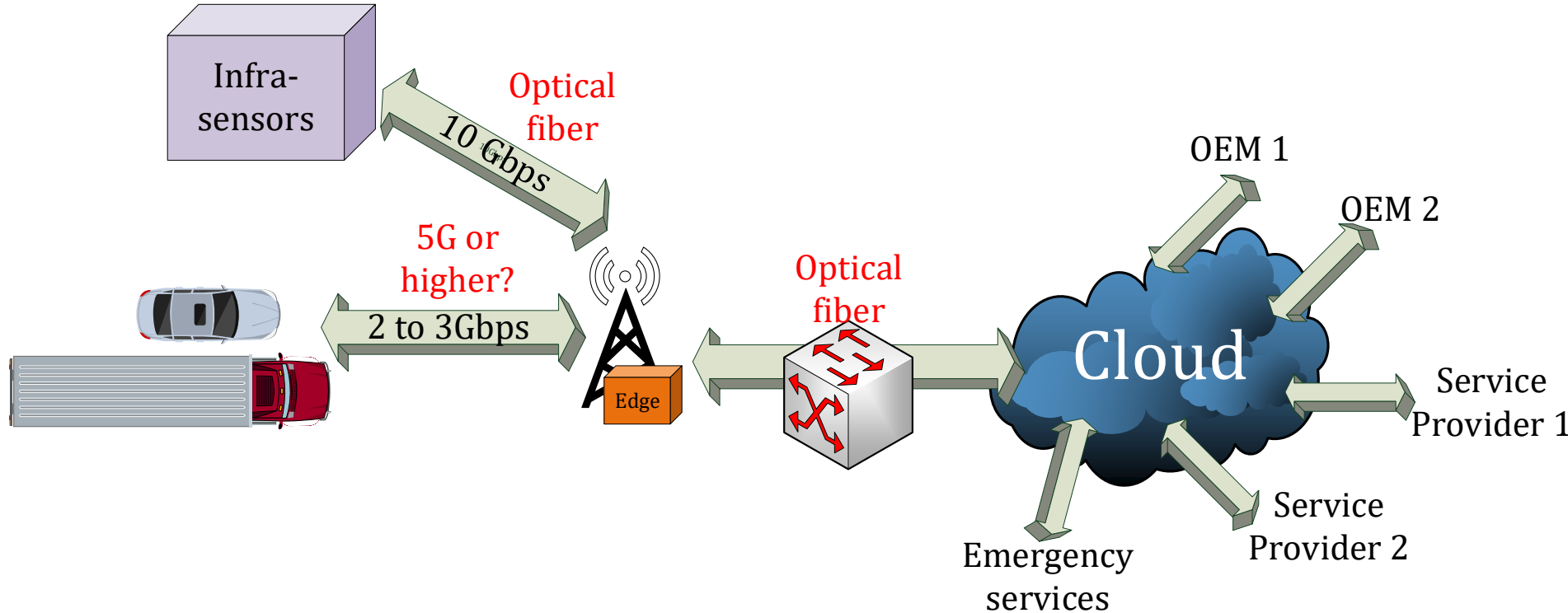


OVERVIEW OF EDGE COMPUTING IN AUTOMOTIVE DOMAIN

- Autonomous driving use case:
 - Shared vehicle sensors
 - Shared infrastructure sensors
 - Connected public mobility
 - Connected and shared logistic services
 - Shared computing
 - Shared software updates
 - Connected testing
- Advantages:
 - Up to 90% effective use of resources
 - Sensors, computing etc.
 - 70% reduction of costs in sensors
 - Saves up to 90% of time in software updates
 - Reduced total data traffic to cloud
 - Swarm autonomous modes made possible with CAR2X

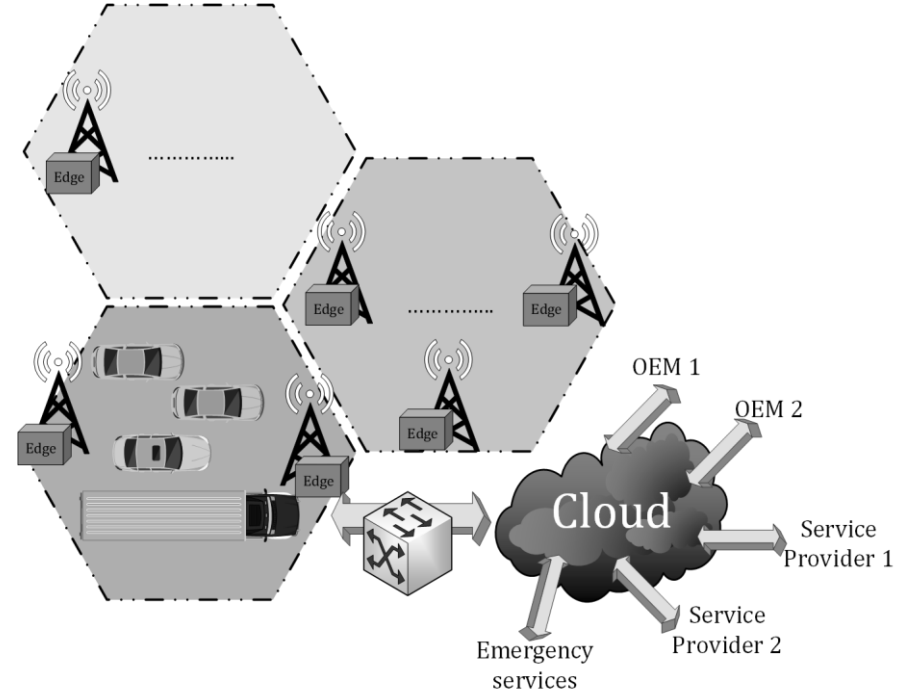
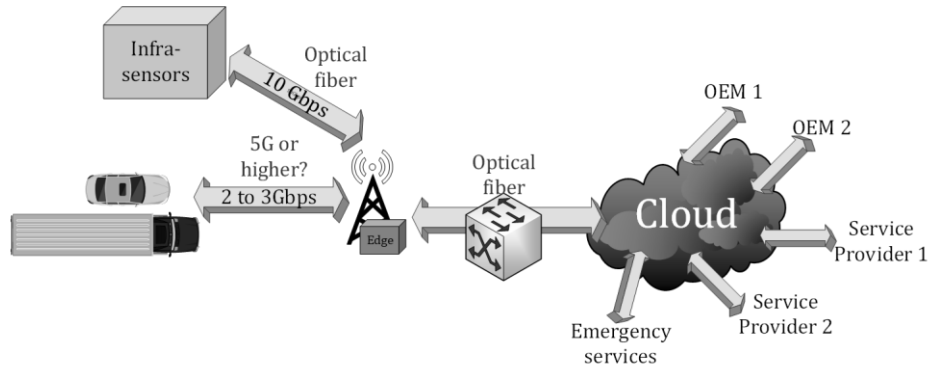


EDGE COMPUTING IN AUTOMOTIVE DOMAIN – REQUIREMENTS

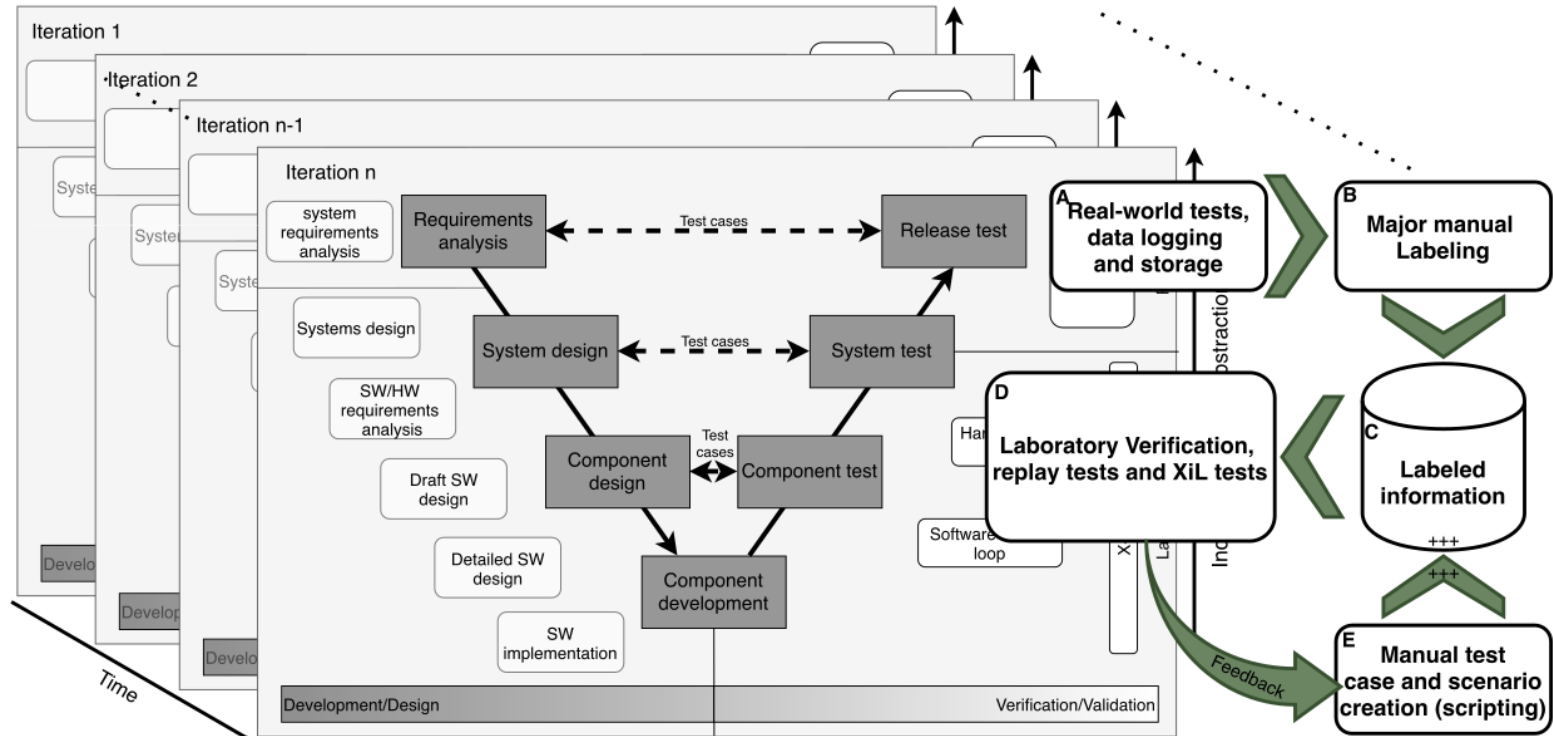


EDGE COMPUTING IN TESTING AUTONOMOUS VEHICLES

- How can Edge computing help in testing?
- What are the current challenges?
- What is the proposed concept?
- What are the advantages?



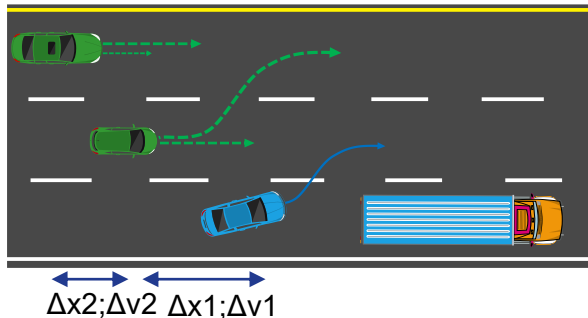
STATE-OF-THE-ART IN ADAS & AV TESTING



Goal of AVs: Each function or feature in the vehicle has to work without failure and finally translate into no accidents until the end of life of the vehicle

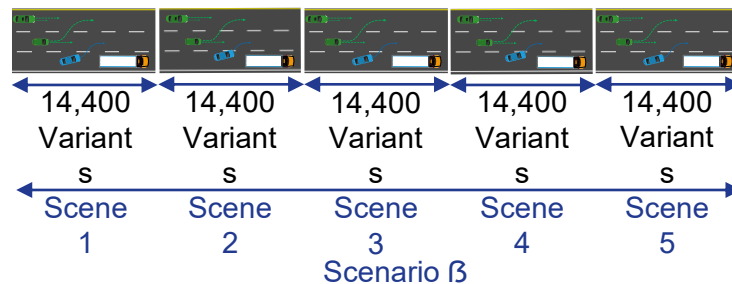
It requires **6.62 Billion test kilometers** to be driven for the release approval of a highway pilot system [8]

- Scene [9]: ‘scene as a snapshot in time’



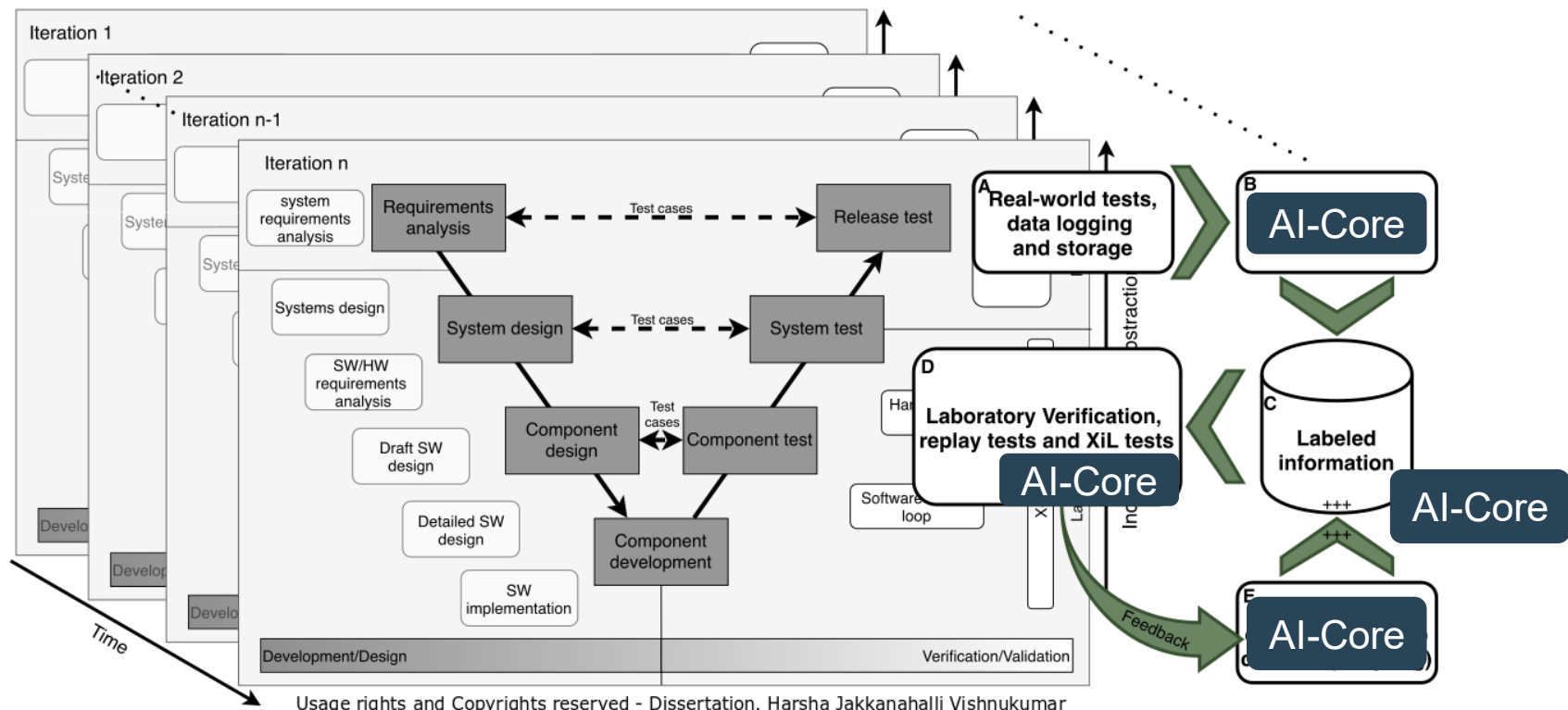
- Example Scene: The blue car overtakes the truck as shown
- Δv from 0 km/h - 120 km/h in 10 km/h steps \rightarrow 12 variants and Δx from 0 m to 100 m in 10 m steps \rightarrow 10 variants
- Two pairs $\rightarrow 12 \cdot 12 \cdot 10 \cdot 10 = 14,400$ variants for initial situation

- Scenario [9]: ‘Combination of scenes’

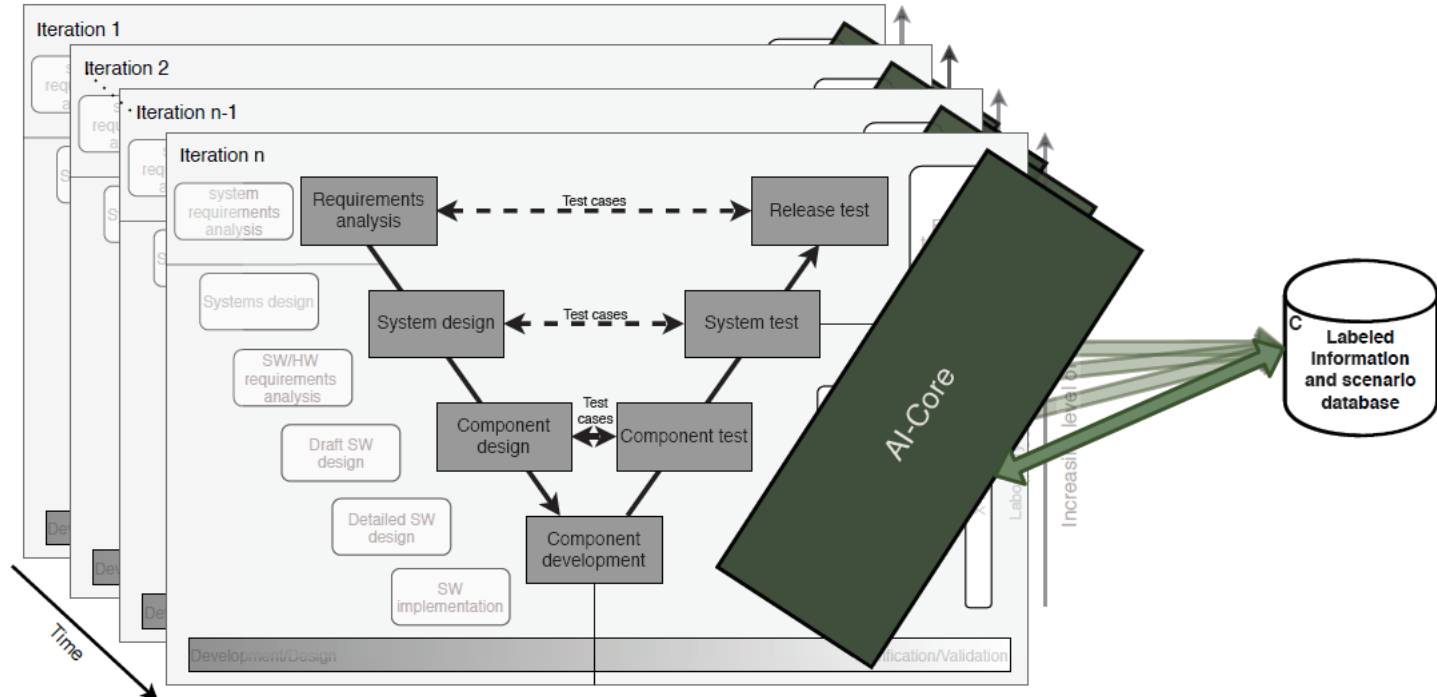


- Example scenario with 5 scenes:
- 5 preceding scenes lead to 5 Quintilian possible scenario variants (5×10^{18})
- Manually scenarios can be developed only if we can think of

AI-CORE APPROACH IN ADAS & AV SCENARIO-BASED TESTING



CENTRAL DATABASE APPROACH WITH AI-CORE



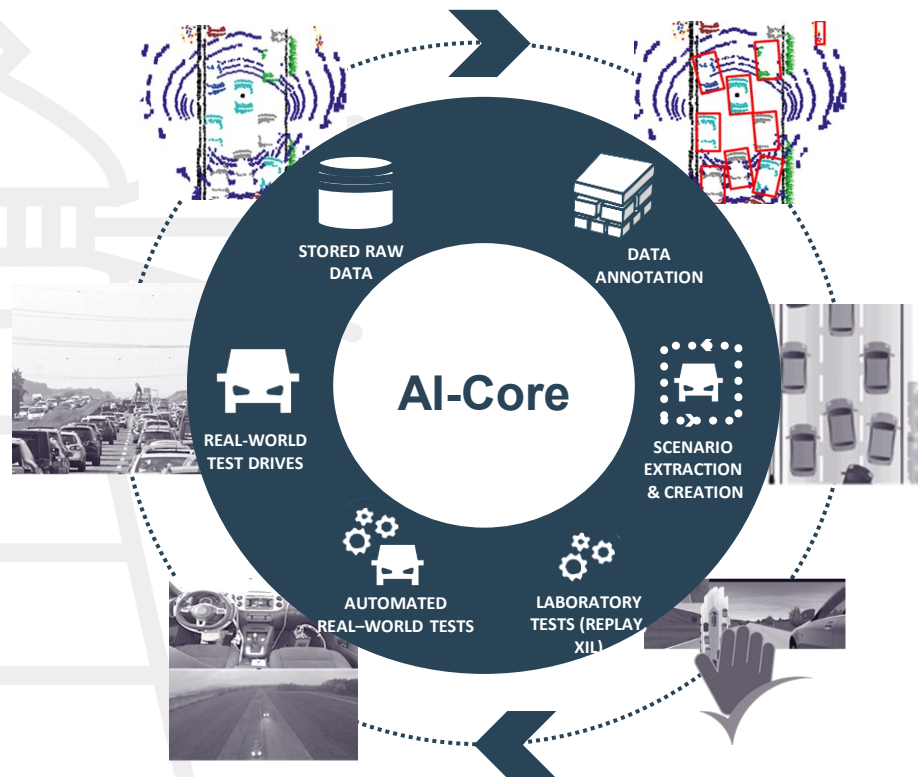
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AI-CORE - NOW IN CLOUD!

CHALLENGES ADDRESSED WITH AI-CORE: **BIG DATA**,
REAL-WORLD COMPLEXITY AND **AGILITY IN DEVELOPMENT**

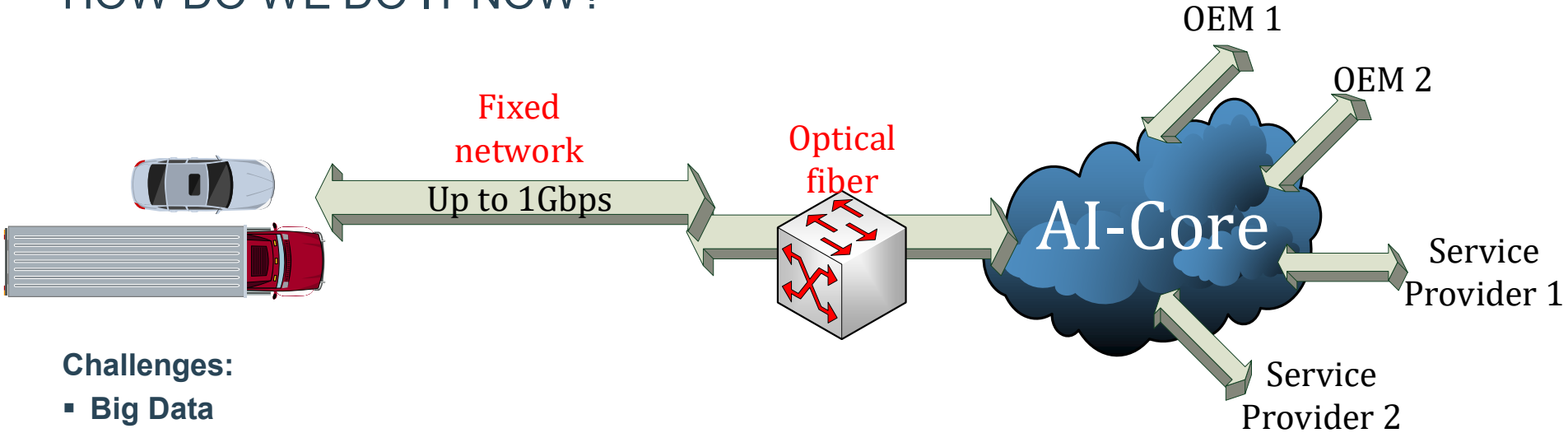
AI-Core offers tools and services for:

- Seamless scenario based lab and real-world testing
 - Scenario extraction and generation
 - Virtual validation as well as selected real-world testing with automated proving ground
 - Faster and agile testing in lab and real-world
 - Efficient use of real-world Big Data
- Test result analysis and evaluation
- Data analysis and data generation
- Hybrid Annotation



AI-Core for seamless, effective, efficient and systematic test, verification and validation

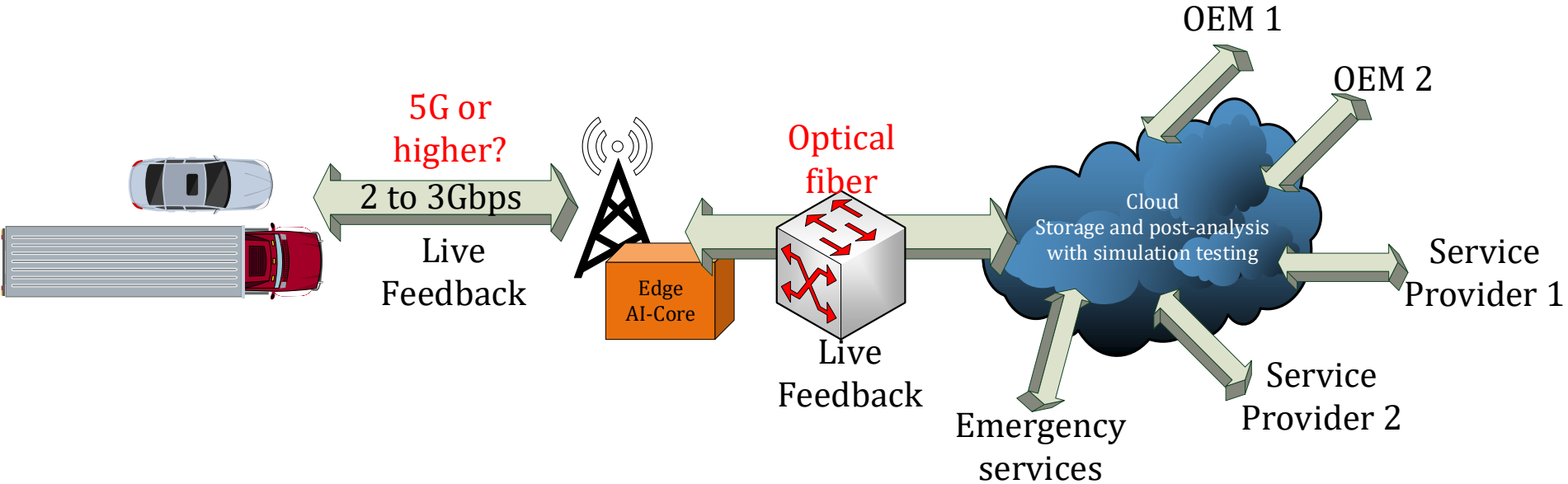
HOW DO WE DO IT NOW?



Challenges:

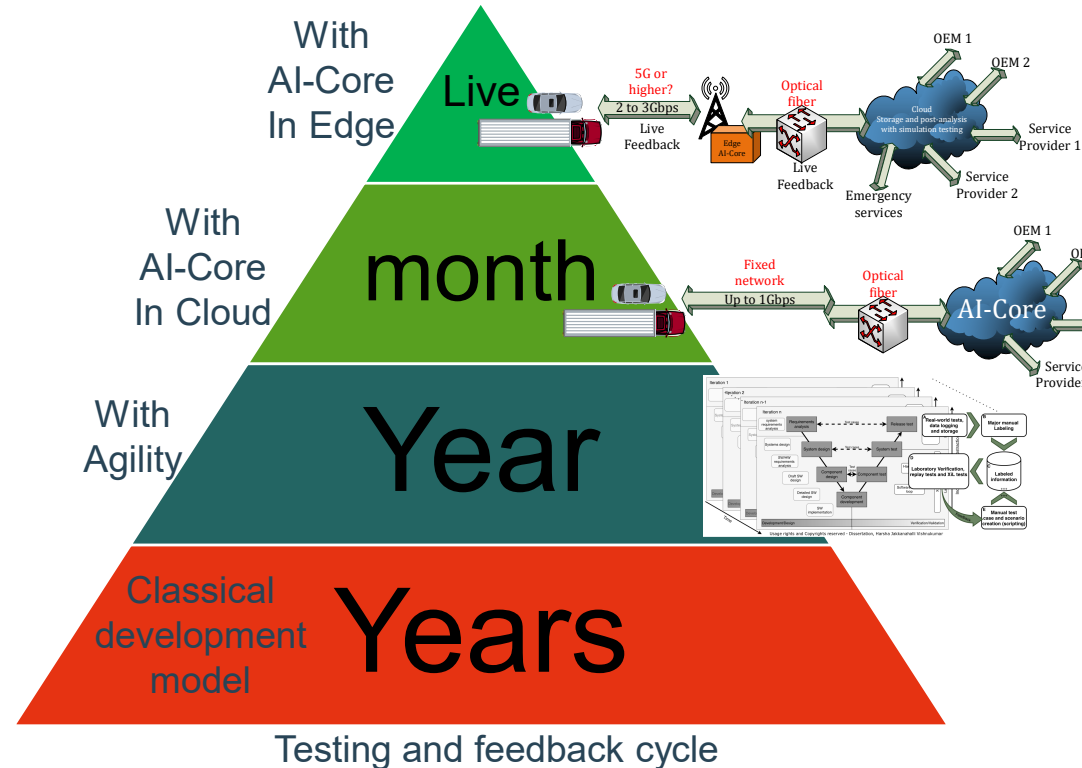
- Big Data
- Large pool of test vehicles
- Cost of data storage
- Cost of computing in vehicles
- No live or real-time feedback
- Time required to test, verify and validate is still large

PROPOSED CONCEPT WITH EDGE AI-CORE



ADVANTAGES OF EDGE IN TESTING AND SUMMARY

- 1 Live KPI calculation and feedback
- 2 Live Big Data visualization on both end
- 3 Closed loop Edge and AI assisted feedback
- 4 Reduce data turn-up time and testing time
- 5 Concentrated testing and agile test planning
- 6 Seamless and live scenario based testing





**THANK YOU.
QUESTIONS?**





CONTACT

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BACKUP SLIDES

1

ABOUT US

**REVENUE 2019**

€ 1,8 BILLION **worldwide**

| € 519,3 MILLION **GER**

**EMPLOYEES 2019**

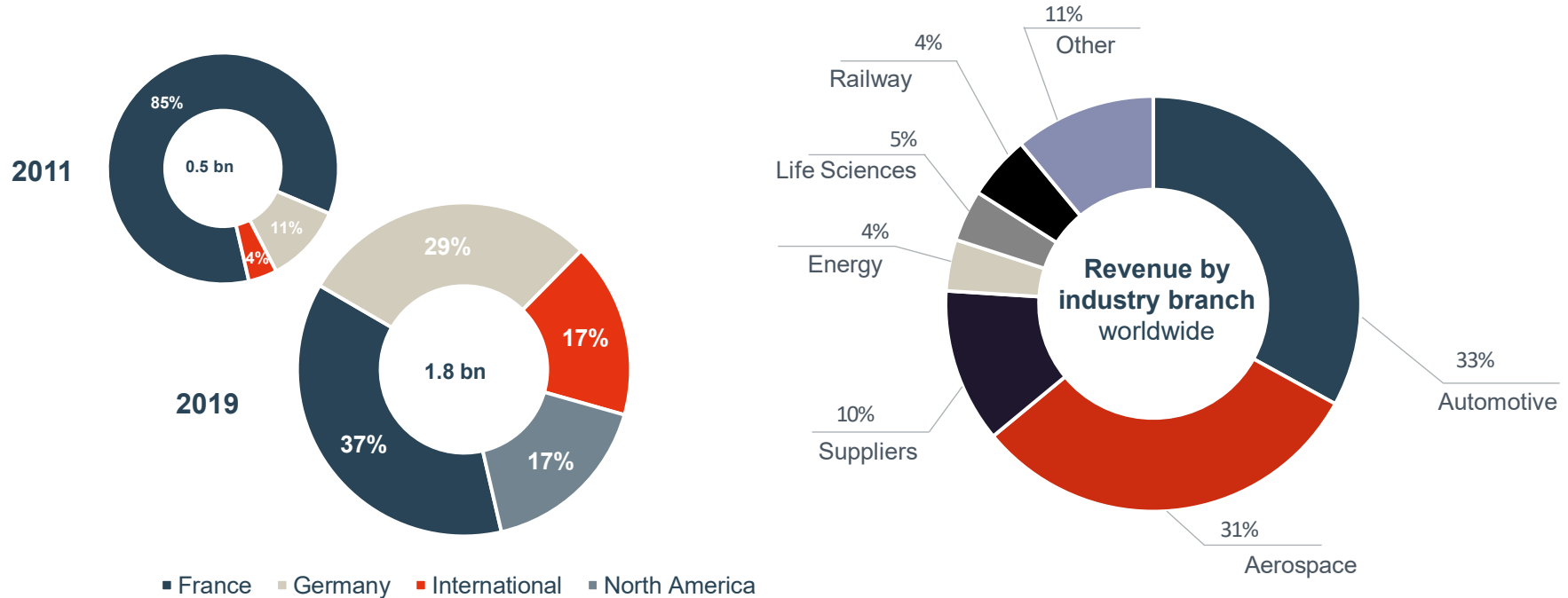
20,624 **worldwide**

| 4,911 **GER**

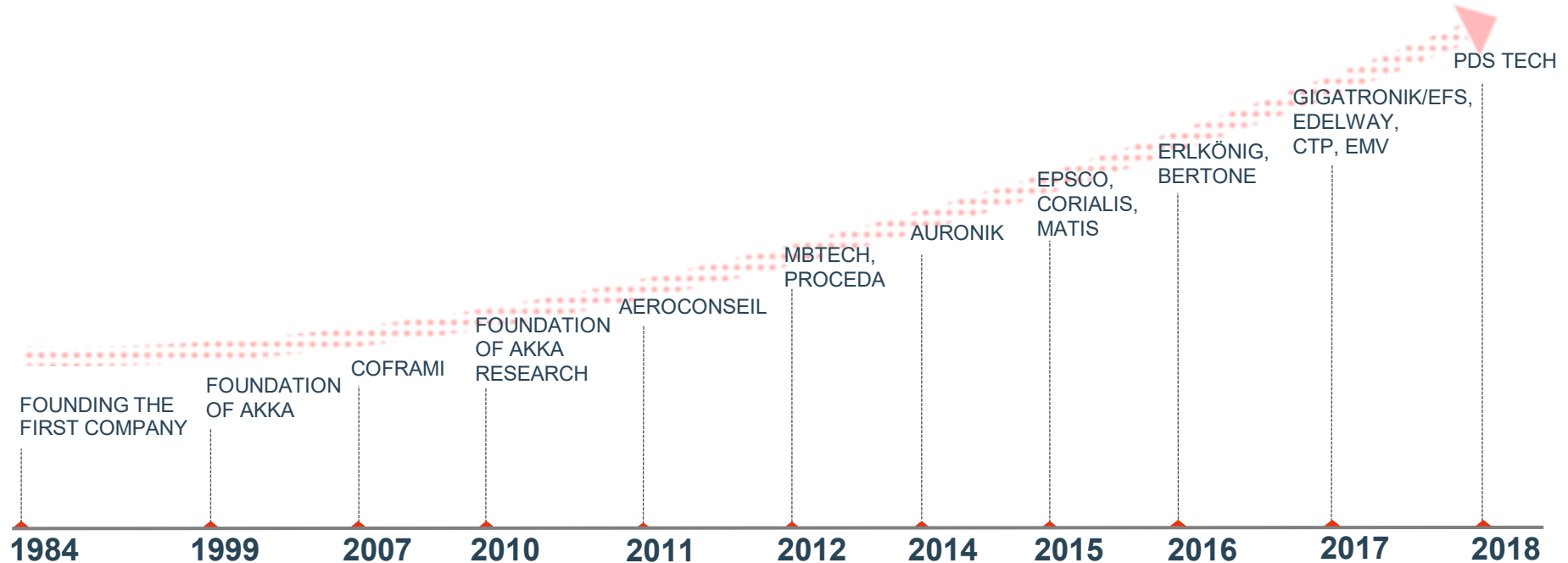
**LOCATED IN**

Europe, Asia, America, The Middle East and Africa

SUCCESSFUL GEOGRAPHIC DIVERSIFICATION OF A GLOBAL MULT-SPECIALIST

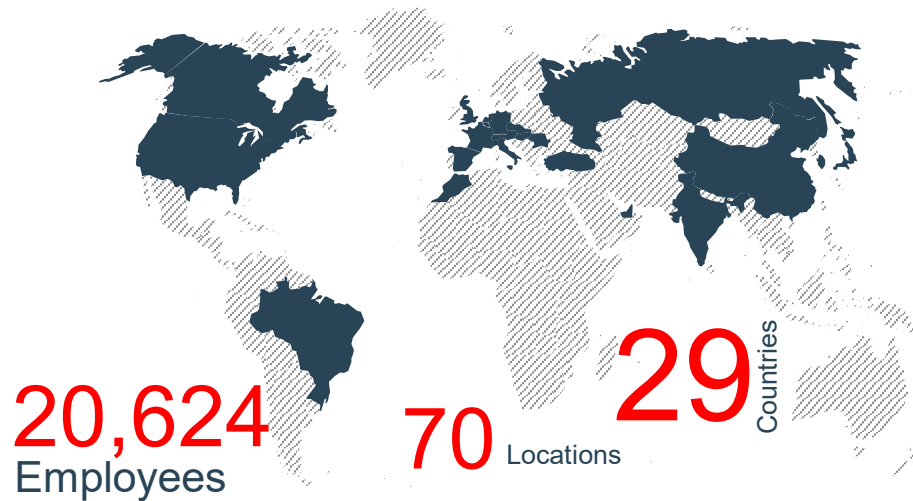


STRATEGIC DEVELOPMENT BASED ON FUTURE TOPICS

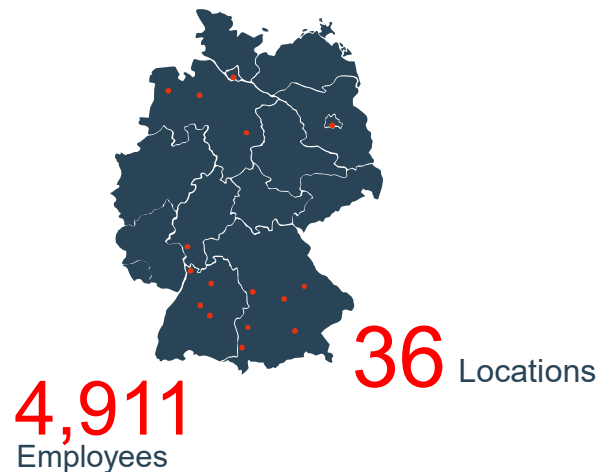


INTERNATIONAL PRESENCE

Worldwide



Germany



BELGIUM | CHINA | GERMANY | FRANCE | GREAT BRITAIN | INDIA | ITALY | JAPAN | CANADA | MOROCCO | THE NETHERLANDS | AUSTRIA | ROMANIA | RUSSIA | SWITZERLAND | SINGAPORE | SPAIN | THE CZECH REPUBLIC | TURKEY | HUNGARY | UNITED ARAB EMIRATES | UNITED STATES

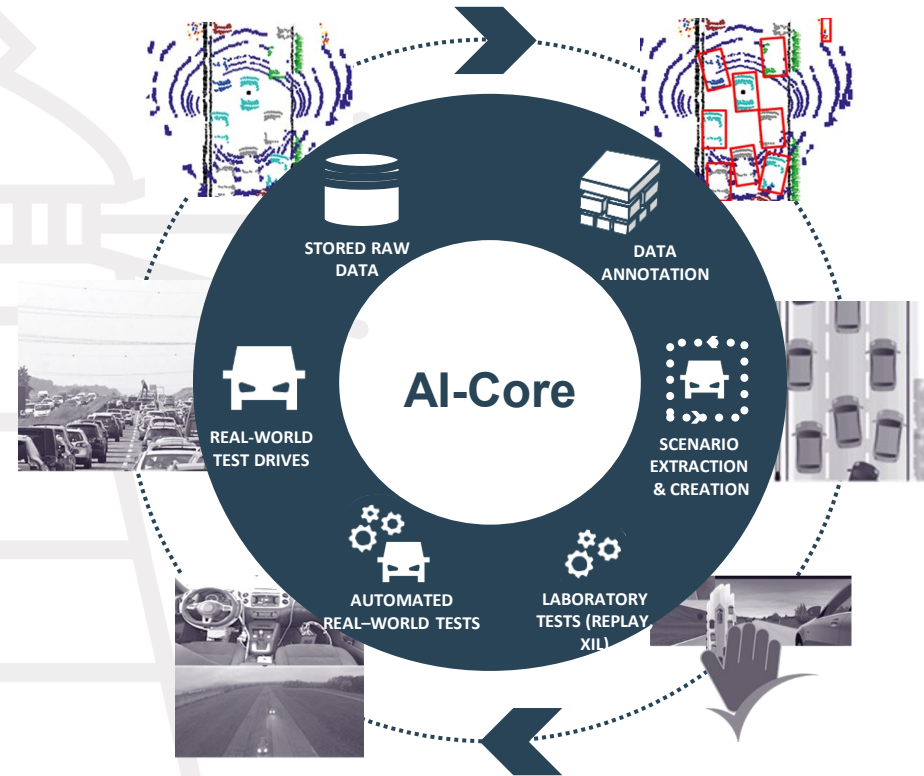
2 AI-Core

AI-CORE NOW IN CLOUD!

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REAL-WORLD COMPLEXITY AND **AGILITY IN DEVELOPMENT**

AI-Core offers tools and services for:

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 - Virtual validation as well as selected real-world testing with automated proving ground
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AI-Core is your partner for seamless, effective, efficient and systematic test, verification and validation

AI-CORE

WHAT IS DONE TODAY?

- 2D/3D Object annotation in Camera and LiDAR data
- Tools and services for seamless scenario-based testing
 - Scenario classification
 - Scenario extraction
 - Scenario clustering
 - New scenario creation
- 3D Map generation
- UI: TestAid HMI testing tool
- Tool for digitalizing classical systems with retro-fitment for Industry 4.0 applications
- Video data anonymization
- Result analysis

1 KPI calculation

2 Big Data visualization

3 Closed loop AI assisted simulation testing

4 AI-based co-driver for real-world testing

5 Workshop inspector for quality analysis in production line

6 Audio data analysis

***Classified
scenarios
and
clustering
approach.
Example:
Different
types of
overtaking
scenarios***

AI-Core data visualization
Timelapse mode, Dynamic time length overtaking scenarios: 4 classes

Scenarios: 4906
Dimension: 800

Note: Each point is a scenario

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Classified scenarios and clustering approach. Example: Different types of overtaking scenarios

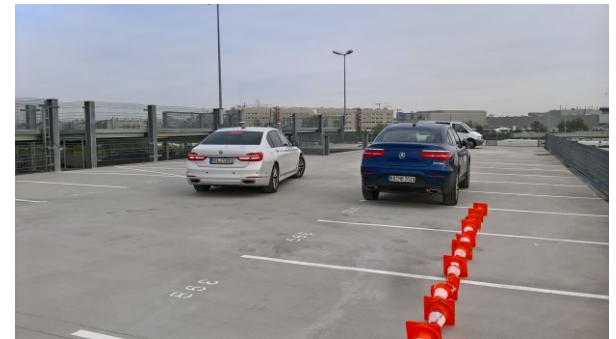
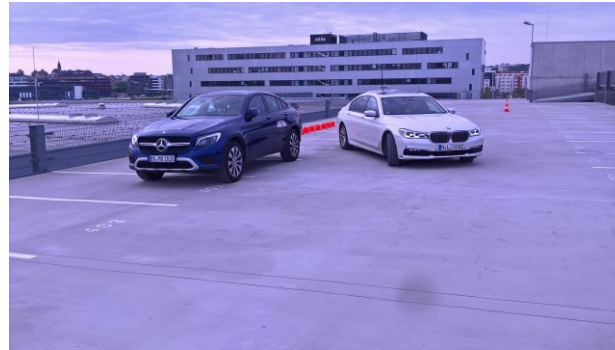
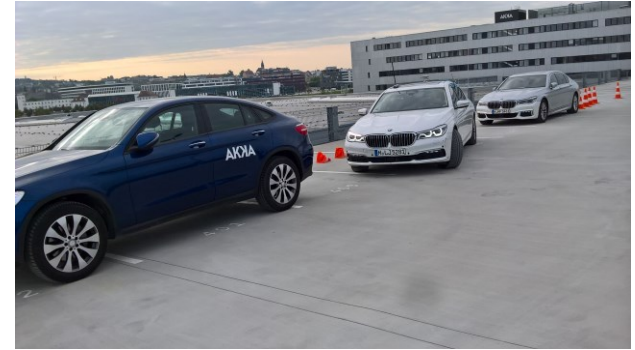
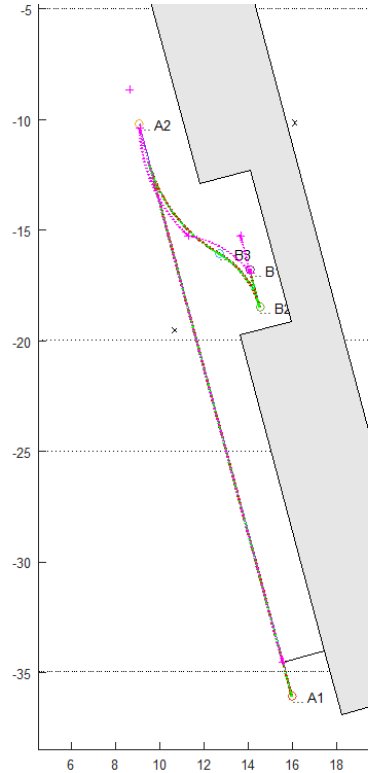
AI-Core data visualization
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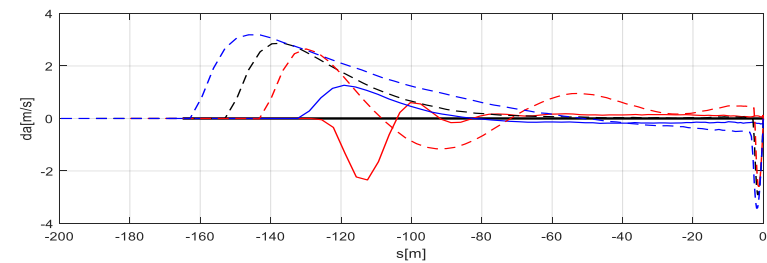
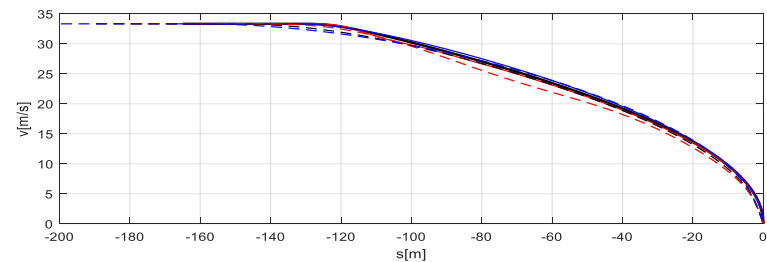
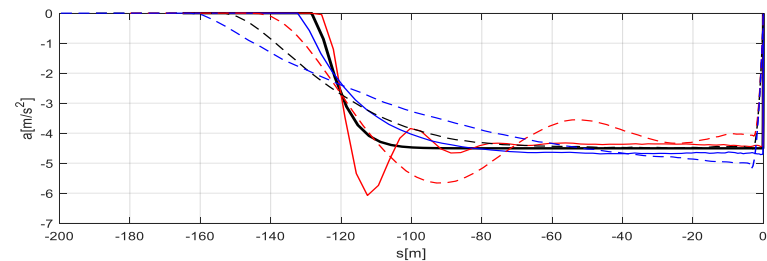
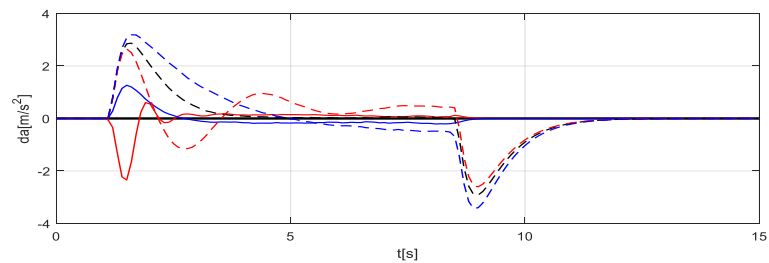
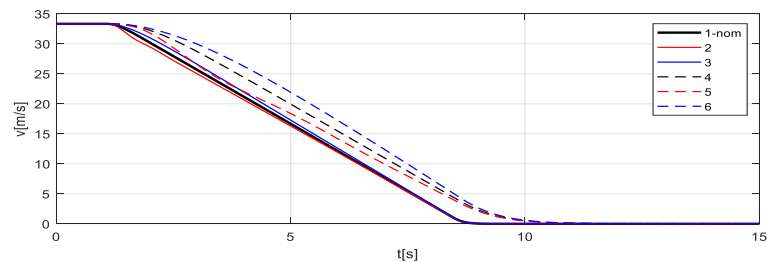
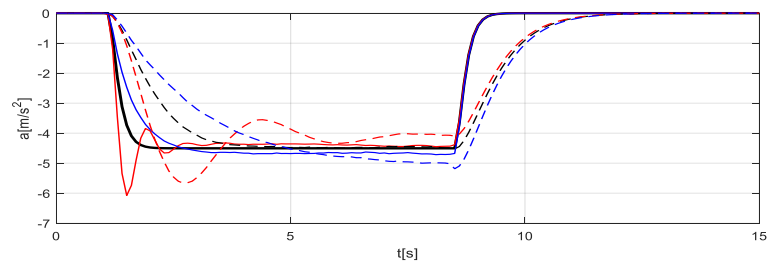
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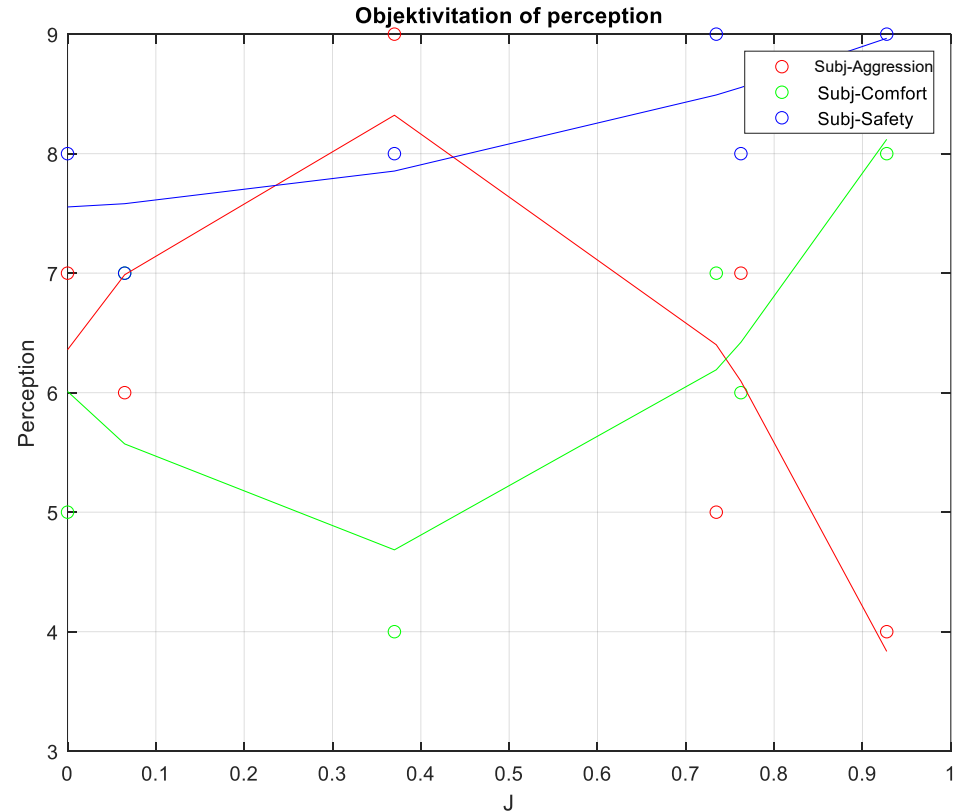
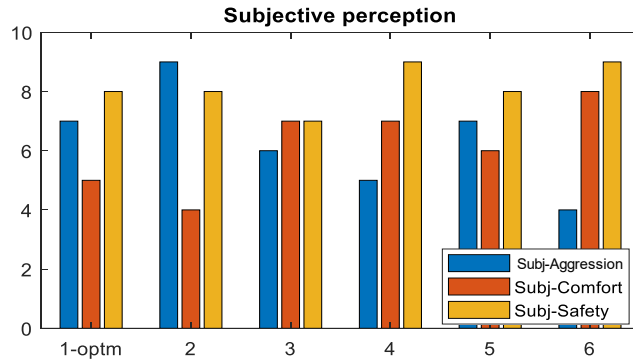
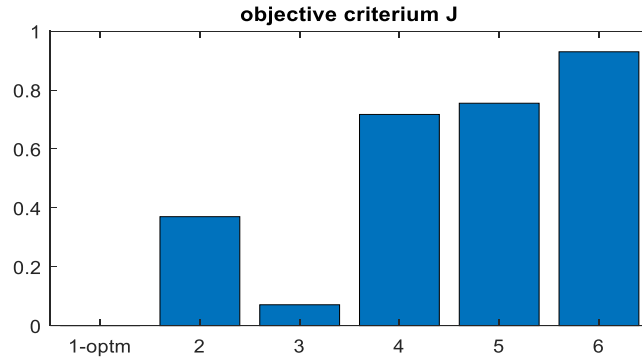
TETSING IN AUTOMATED PROVING GROUND





AKKA OBJECTIFICATION EXAMPLE OF PERCEPTION ON BRAKING COURSE

$$J_{obj} = 0.5 * norm(A_{var} - A_{Nom})^2 + 0.5 * norm\left(\frac{d}{dt}A_{var} - \frac{d}{dt}A_{Nom}\right)^2$$



EXAMPLE: HEAT MAP FOR GIVEN TRIALS

		Distance to TOF (m)															
		0,25	0,5	0,75	1	1,25	1,5	1,75	2	2,25	2,5	2,75	3	3,25	3,5	3,75	4
Negative A (m/s ²)	-0,5	2,25	2,5	2,68	2,86	3,04	3,21	3,39	3,57	3,75	3,93	4,11	4,29	4,46	4,64	4,82	5,05
	-1	2,17	2,61	2,86	3,18	3,49	3,81	4,16	4,4	3,83	4,92	4,77	4,44	4,43	4,14	4,52	5,18
	-1,5	2,08	2,65	3,05	3,5	3,95	4,4	4,93	5,3	4,86	5,54	5,42	4,95	4,88	5,15	4,82	5,32
	-2	2,03	2,68	3,23	3,82	4,41	5	5,7	6,2	5,9	6,15	6,06	5,46	5,33	5,45	5,11	5,45
	-2,5	1,95	2,71	3,41	4,14	4,87	5,59	6,46	7,1	6,93	6,77	6,71	5,98	5,77	5,74	5,41	5,58
	-3	1,86	2,75	3,6	4,46	5,32	6,19	7,23	8	7,97	7,38	7,35	6,49	6,22	6,04	5,7	5,72
	-3,5	1,78	2,78	3,78	4,78	5,78	6,78	8	9	9	8	8	7	6,67	6,33	6	5,85
	-4	1,7	2,95	4,2	5,45	6,7	7	9	10	10	9	9	8	7,56	7,11	6,67	5,98
	-4,5	1,61	3,11	4,61	6,11	7	8	9	10	10	10	9	8	7,52	7,05	6,57	6,12
	-5	1,53	3,03	4,53	6,03	7	8	8,5	9	10	10	9	8	7,34	6,98	6,62	6,25
	-5,5	1,45	2,97	3,64	5,14	5,57	7,5	7,8	8	9	9	8	7	7,15	6,91	6,67	6,38
	-6	1,36	2,66	3,29	4,57	5	5,14	5,57	7,24	8,12	8,35	7,63	6,85	6,96	6,84	6,72	6,52
	-6,5	1,28	2,35	2,93	4	4,43	4,64	5,07	6,48	7,24	7,47	7,25	6,7	6,78	6,77	6,77	6,65
	-7	1,2	2,04	2,57	3,43	3,86	4,14	4,57	5,72	6,36	6,59	6,88	6,55	6,59	6,7	6,82	6,78
	-7,5	1,11	1,74	2,21	2,86	3,29	3,64	4,07	4,96	5,48	5,71	5,94	6,17	6,4	6,63	6,86	6,92
	-8	1	1,43	1,86	2,29	2,71	3,14	3,57	4,2	4,58	4,95	5,33	5,7	6,08	6,45	6,83	7,05

- The values in the matrix are β : which indicates a summation of Agression/sporty feeling, Safety feeling, and comfort
- **10: Best case**
- **1: Worst case**
- It is possible to generate required heat maps together with PROVEtech tools and AI-Core (This is AKKA's own IP)

EXAMPLE: HEAT MAP FOR GIVEN TRIALS

		Distance to TOF (m)															
Negative A (m/s ²)		0,25	0,5	0,75	1	1,25	1,5	1,75	2	2,25	2,5	2,75	3	3,25	3,5	3,75	4
	-0,5	2,25	2,5	2,68	2,86	3,04	3,21	3,39	3,57	3,75	3,93	4,11	4,29	4,46	4,64	4,82	5,05
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	-3,5	1,78	2,78	3,78	4,73	5,78	6,78	8	9	9	8	8	7	6,67	6,33	6	5,85
	-4	1,7	2,95	4,2	5,45	6,7	7	9	10	10	9	9	8	7,56	7,11	6,67	5,98
	-4,5	1,61	3,11	4,61	5,11	7	8	9	10	10	10	9	8	7,52	7,05	6,57	6,12
	-5	1,53	3,03	4,53	6,03	7	8	8,5	9	10	10	9	8	7,34	6,98	6,62	6,25
	-5,5	1,45	2,97	3,64	5,14	5,57	7,5	7,8	8	9	9	8	7	7,15	6,91	6,67	6,38
	-6	1,36	2,66	3,29	4,57	5	5,44	5,57	7,24	8,12	8,35	7,63	6,85	6,96	6,84	6,72	6,52
	-6,5	1,28	2,35	2,93	4	4,43	4,64	5,07	6,48	7,24	7,47	7,25	6,7	6,78	6,77	6,77	6,65
	-7	1,2	2,04	2,57	3,43	3,86	4,14	4,57	5,72	6,36	6,59	6,88	6,55	6,59	6,7	6,82	6,78
	-7,5	1,11	1,74	2,21	2,86	3,29	3,64	4,07	4,96	5,48	5,71	5,94	6,17	6,4	6,63	6,86	6,92
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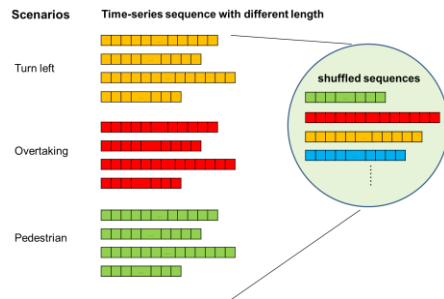
- Objectified the desired area for best case vehicle braking due to 'follow vehicle stop' function

- It is possible to generate required heat maps together with PROVEtech tools and AI-Core (This is AKKA's own IP)

- Scenario set characteristics
- Manually labeled + Synthetically created scenarios for training and validation + Dynamic length scenarios (XML files)
- Totally 843k scenarios were used
- 70% scenarios for Training (590k)
- 30% scenarios for Validation (253k)
- Shuffled sequence is used for training

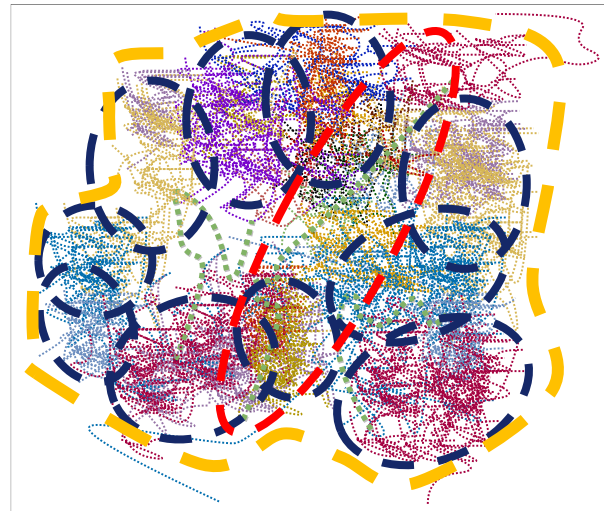
13 classes of scenarios were considered for proof of concept

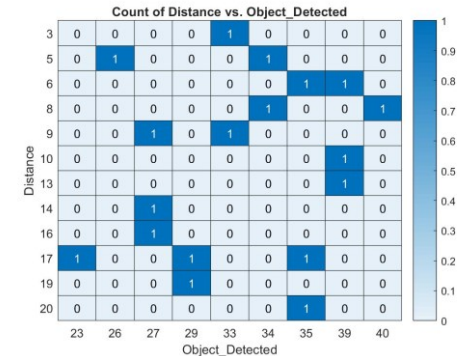
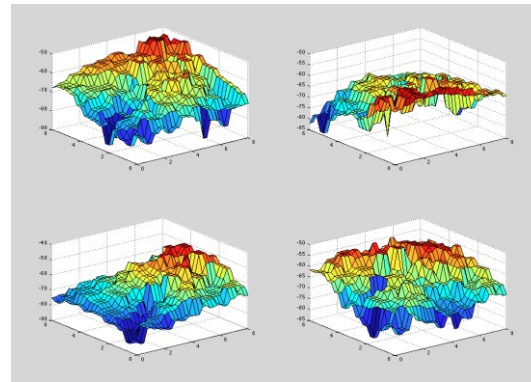
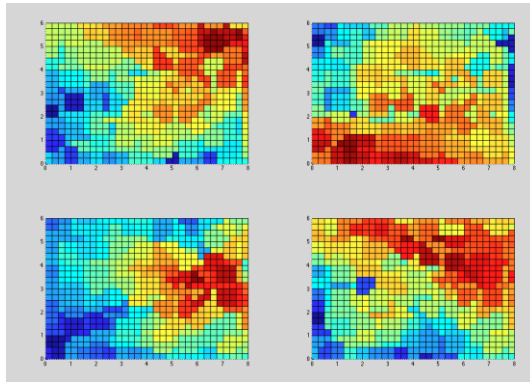
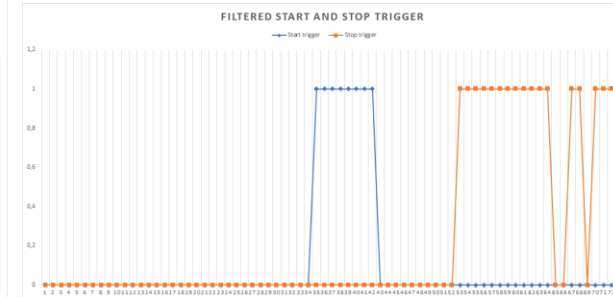
- | | |
|--------------------------------|--------|
| 1. Over taking | (70k) |
| 2. Pedestrian (LRFB) | (30k) |
| 3. Intersection | (30k) |
| 4. Free travel | (150k) |
| 5. Following Scenario | (80k) |
| 6. Lane change only | (55k) |
| 7. Complex left turn | (110k) |
| 8. Complex right turn | (20k) |
| 9. Traffic light | (60k) |
| 10. Traffic jam | (30k) |
| 11. Bicycle (LRFB) | (80k) |
| 12. Motorcycle (LRFB) | (68k) |
| 13. Obstacle on the road (Any) | (35k) |
| 14. Emergency vehicle (Any) | (55k) |



- RV23 using:
- Model based approach
- Real-world real-street test data
- Manually labeled scenarios: 80K (Labels used for verification)
- Scenario extraction and classification results
- Accuracy: 96.3%
- 79.5k extracted and classified out of 80k labeled scenarios
- Additional Scenarios detected: ~44k
- 361 scenarios were wrongly classified

- Results and observations:
- The 13 scenarios were classified using DNN classifier
- Multidimensional feature vectors are extracted, it is observed that features from the same class are concentrated in the same region as intended
- Results shows that not only classification but clustering of scenarios are also possible
- Real-world scenario boundary condition can be found
- Variable length (thick green) LS-sampling is made to produce new scenarios
 - Scenarios are visualized using Carla™





examples: to show the heat maps
(Random values used)