Data analytics and optimization in radar-based pattern recognition

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1. Framework of the project

Advanced driver-assistance systems (ADAS), and particularly radar sensors such as Autonomous Cruise Control (ACC), are more and more useful because they

- **increase safety** while driving by restricting human errors;
- **improve welfare and comfort**, especially for elderly and disabled people;
- reduce insurance costs and **improve fuel efficiency**.

2. Motivation and aim of the project

ADAS rely on **radar sensors detection** of obstacles to avoid hitting other vehicles on the road, but unfortunately, **they are not perfect** and the few accidents happened so far turned out to be fatal.

1. Radar is **NOT good at detecting**
   - stationary objects;
   - vehicles crossing the road perpendicularly to the car.
2. Radar outputs of detected objects **are sometimes ignored** to deal with the generation of "**false positives**".

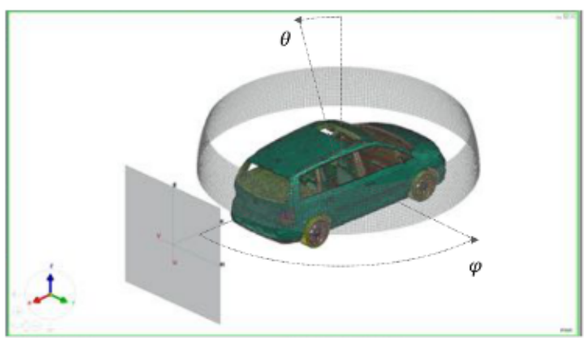
Highway overpass or big truck?
Shall I pass underneath or not?!

Recognition and classification of objects are necessary!

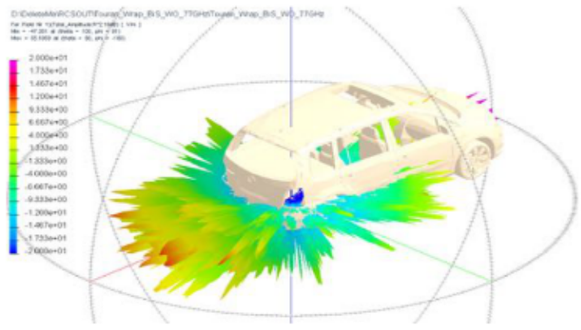
3. Software used

CEM-HF (Computational ElectroMagnetic-High Frequency) solver from **ESI Group** computes the EM field of any object…

Target, Inputs and Outputs



ElectroMagnetic (EM) field Contour

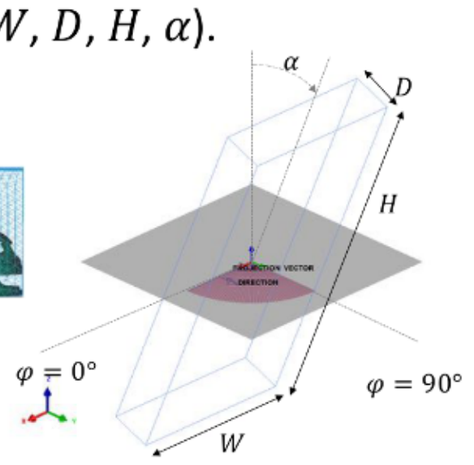


…as well as the **Radar Cross Section (RCS)**, that gives useful information about a target (its material, size, etc.) and it's related to the EM field according to the following *formula:*

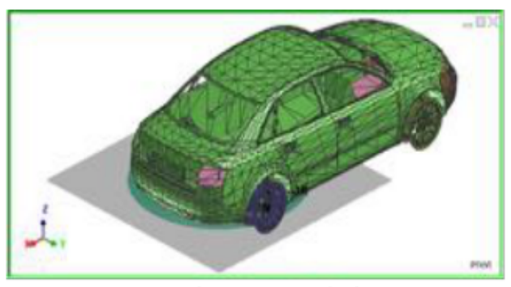
$$\text{RCS } \sigma(\theta,\varphi) := \lim_{r\to\infty} 4\pi r^2 \frac{|\boldsymbol{E}_s(\theta,\varphi)|^2}{|\boldsymbol{E}_i|^2}$$

4. Case study

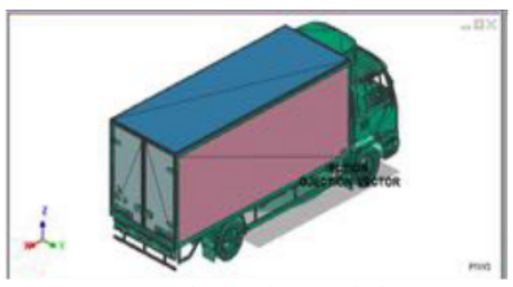
1. We can imagine to study either a pedestrian or a car by considering the box containing them and characterize it by the pattern (W, D, H, α).



2. We also consider a real-car and a real-truck models.



Real-car model.



Real-truck model.

3. We calculate $\sigma(90,\varphi), \varphi \in [0,90]$ for several box configurations (different values of the four parameters).

Forward problem

Input: (W, D, H, α) → Output: RCS $\sigma(\varphi; W, D, H, \alpha)$

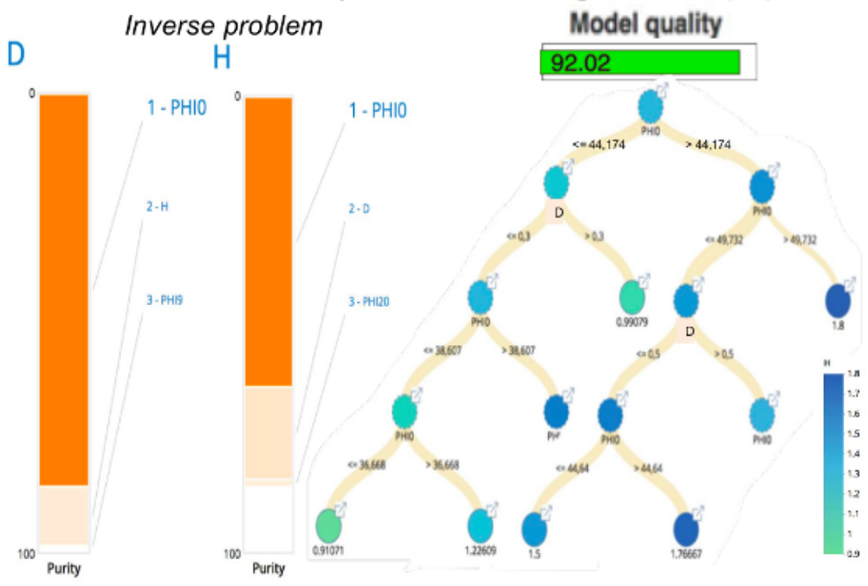
Inverse problem

5. Resolution of the *inverse problem*

MINESET enables users to understand their data, discover patterns, predict the values of our QoIs and prescribe actions through Machine Learning techniques.

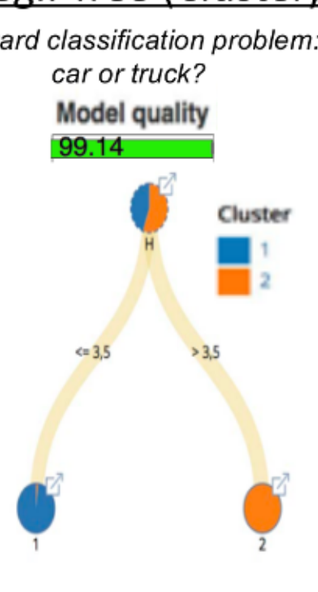
1. Parameter Importance/Regr. Tree (H)

Inverse problem

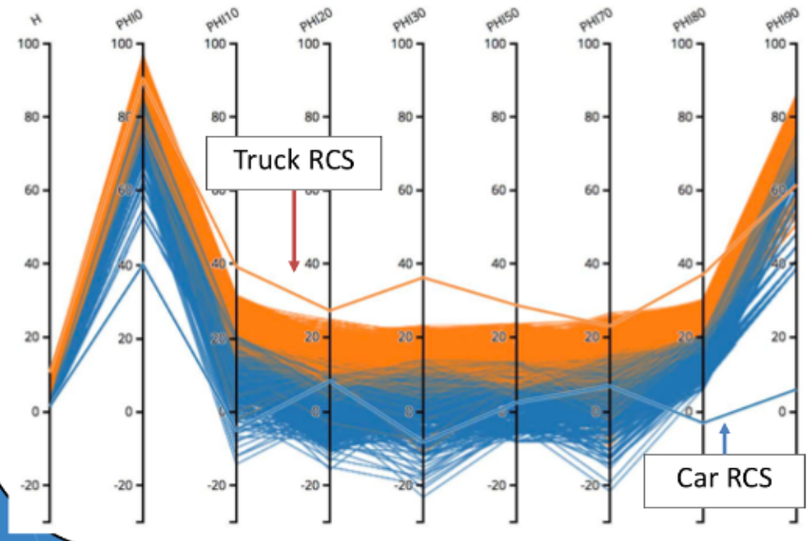


2. Regr. Tree (Cluster)

Forward classification problem: car or truck?

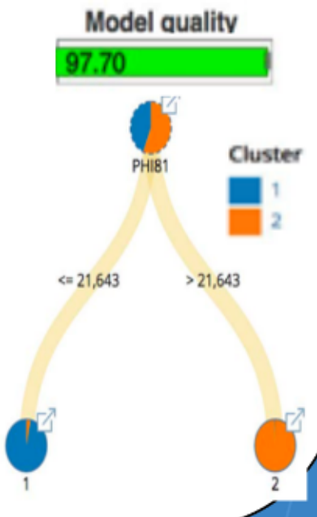


3. Clustering and labelling (Cluster)



4. Regr. Tree (Cluster)

Inverse classification problem



6. Conclusions

Through ESI CEM-One and ESI MINESET we were able to

1. **solve the *inverse problem*** associated to the RCS problem and quantified the error committed.
2. **clusterize the data** according to the height of boxes, H;
3. **assign a car or truck to correct cluster**, knowing its RCS;
4. **infer** if a vehicle is a car or truck with **>90% of accuracy**.

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