A Reduced Order Model using Machine Learning: application on car crash optimization

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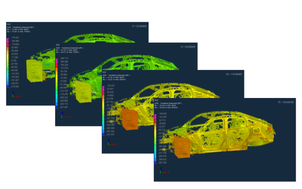
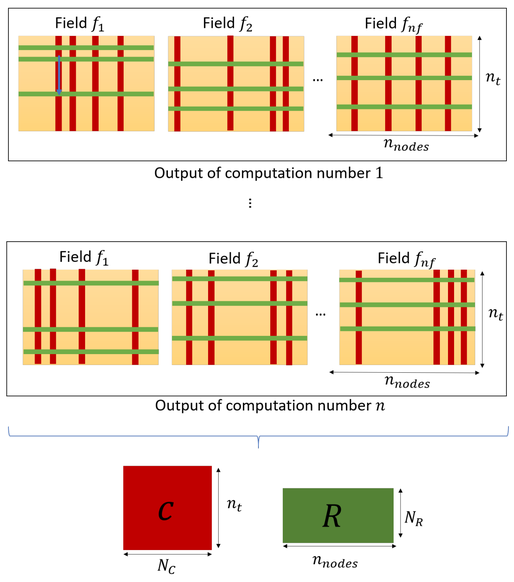
Classic optimization studies in vehicle projects are time and CPU consuming requiring hundreds of simulations. The aim of this project is to provide a new way to carry out optimization studies reducing dramatically the number of numerical simulations. [1]

A new method : Regression - CUR

1 Snapshots extraction from numerical simulations



2 Data processing: « modes » extraction

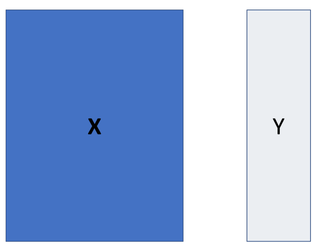


Modes selection methods

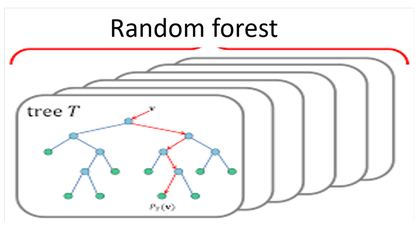
- kMeans clustering
- Empirical Interpolation Method [2]

3 Features and target building

One sample = one node at one timestep of one field from one numerical simulation



4 Machine Learning model

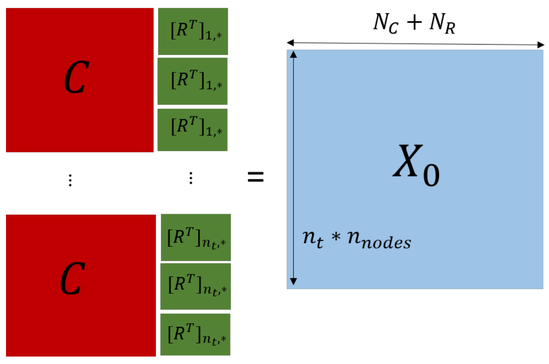


Models that can be used

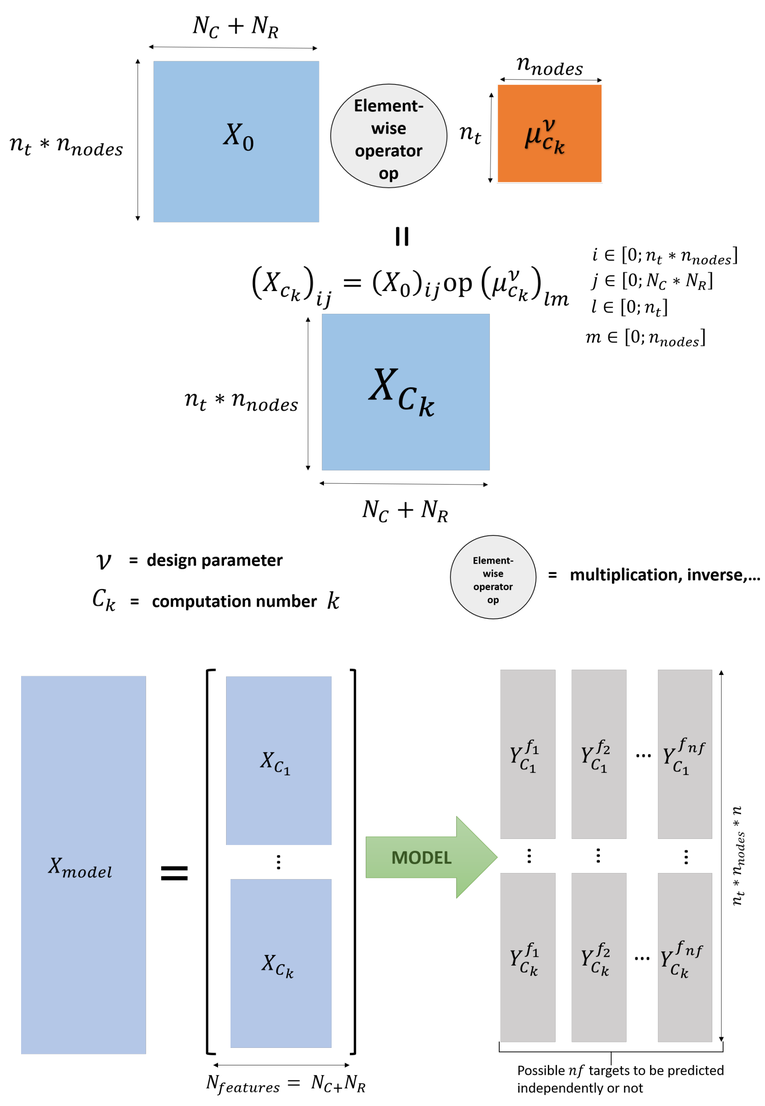
- Linear Regression
- Random Forest [1]
- Neural networks (future work)

Details of features construction in ReCUR

- A features matrix X_0 in which each line describes one node at a timestep is built.
- X_0 matrix is the basis containing all the extracted modes from the processed simulations.



- To obtain the training set that will enable to learn structure behavior according to the design parameters, X_{C_k} matrices corresponding to each C_k simulation are built.

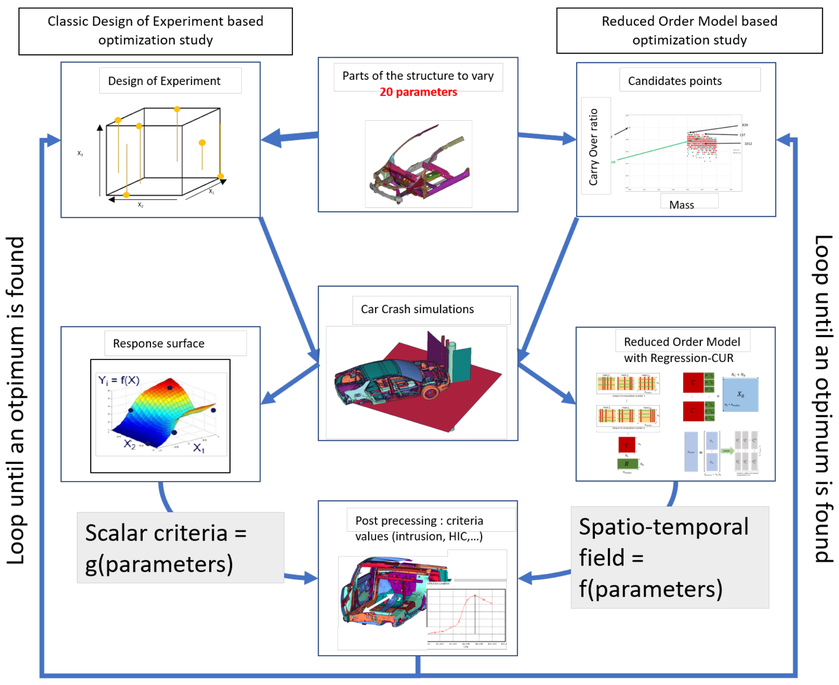


- Once the model is built, the future simulations will be predicted using the initial values of the design parameters.
- The prediction base $X_{prediction}$ is then built thanks to these values and the X_0 basis previously set, just as X_{model}.

Advantages of Random Forest

- Fast and cheap to implement (only few CPUs needed)
- Non linear model
- Highly scalable

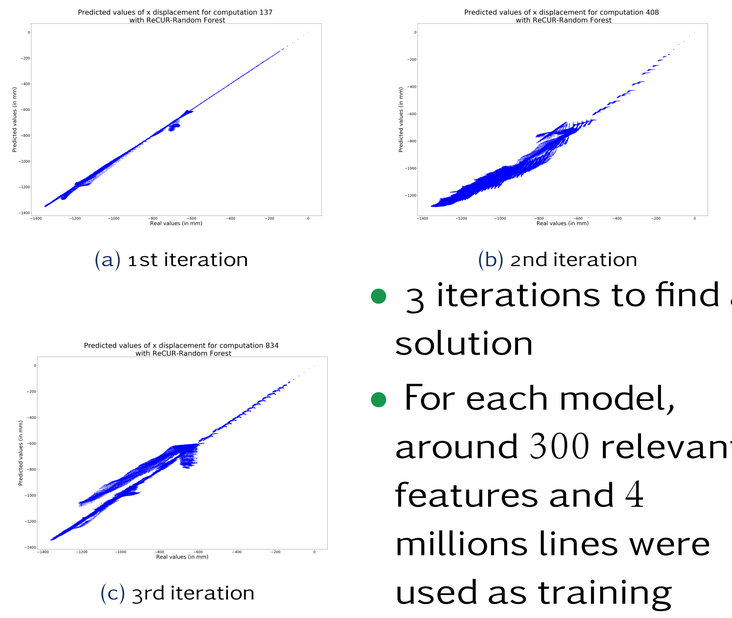
Classic DOE versus Reduced Order Model Example in frontral crash with 20 parameters



Total cost
Hundreds of numerical simulations

Total cost
8 numerical simulations
Number of numerical simulations lower than the number of parameters

Figure – Quality of the three models when applied on a new configuration to predict. They are accurate enough to predict the specifications values and guide the optimization study.



(a) 1st iteration (b) 2nd iteration

(c) 3rd iteration

- 3 iterations to find a solution
- For each model, around 300 relevant features and 4 millions lines were used as training data.

Conclusion

- An optimization study carried out with a number of simulations less than the number of parameters
- Non intrusive reduced order method that can be used in other physics context (combustion, NVH)

[1] Sonia et al. A reduced model using random forest : Application on car crash optimization. *SeMA Journal*, 2019.

[2] Gstalter et al. Towards disruptive methods for optimization study in automotive industry. *NaFEMS world*, 2019.