Marie Skłodowska-Curie Actions
Innovative Training Networks
European Training Network
number 675919
AdMoRe project

Model Order Reduction for Non Linear Mechanics.

PhD student:
Rubén Ibáñez Pinillo
Supervisors:
F. Chinesta, E. Abisset-Chavane,
A. Huerta
Industrial Correspondants:
E. Abenius, J.L. Duval

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Motivation of the project

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Context:

Automotive industry is moving towards a new generation of cars.

Main idea:

Cars are furnished with radars, cameras, sensors, etc… providing useful information about the environment surrounding the car.

Goals:

Provide an efficient model for the radar input/output.
Reducing computational costs by means of big data techniques.

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Ways to reduce the computational cost:

1.Reduce the complexity of the model.

Maxwell equations need a very fine mesh due to high frequency constraints.

Far-Field approaches tend to be less accurate in near field.

Models	Maxwell Equations	Far-Field Approaches	Geometrical Optics
Real Time			
Accuracy			??

2.Use manifold learning techniques to unveil relevant information.

The Concept of Manifold

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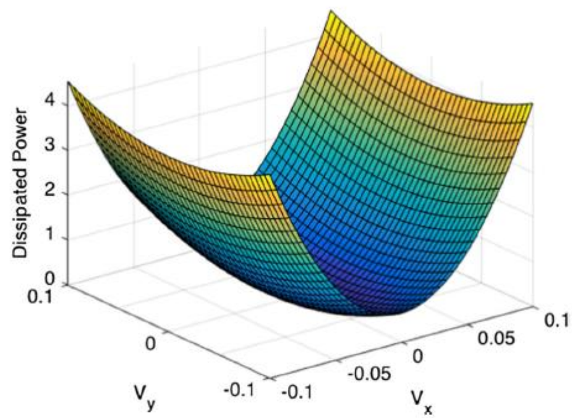
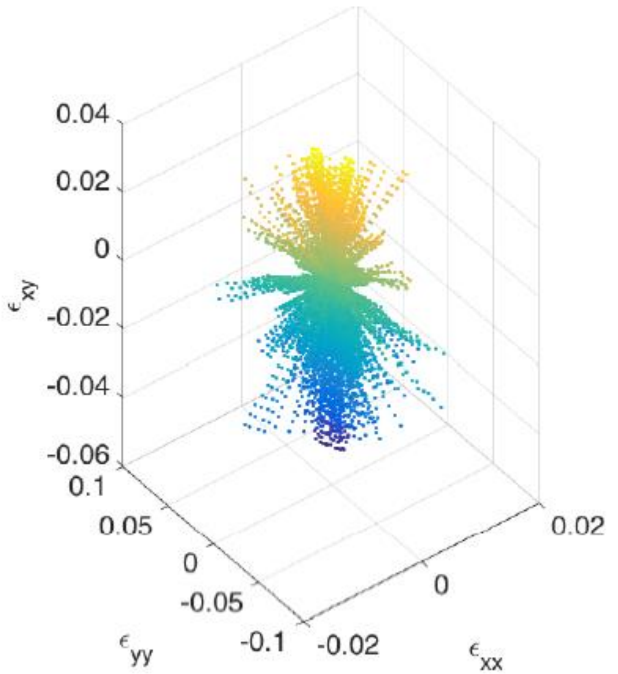
Manifold: A subspace of dimension N belonging to a space of dimension D, where physics is organized.

$$\mathcal{M} = \{\mathbf{x} \in \mathcal{R}^D | \mathbf{f}(\mathbf{x}) = \mathbf{0}\}$$





The Concept of Manifold

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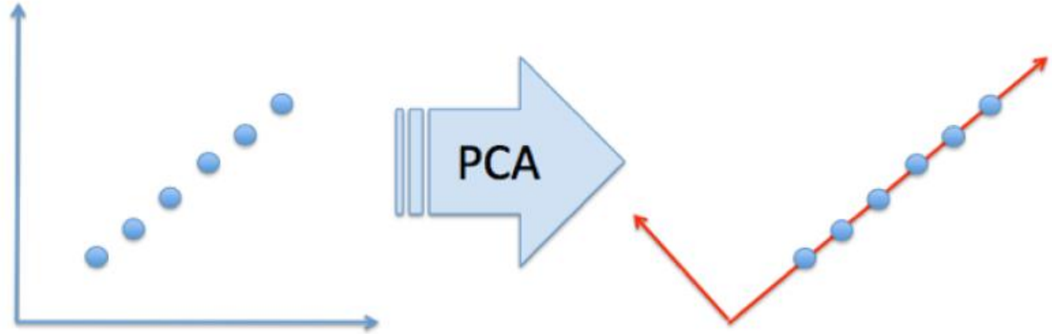
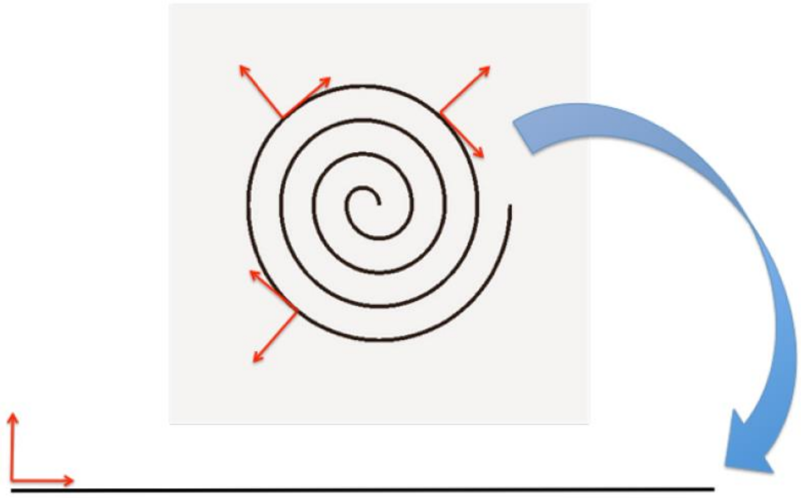
How can a manifold help in model order reduction?





Motivation of the project

Context:

Nonlinear dimensionality reduction becomes a powerful tool for extracting the manifolds that can be then used for making safely interpolations, for extracting the uncorrelated parameters that models involve and for defining general parametric solutions.

Gather the information in the **manifold** as an **off-line** stage, then making simulations **faster** in the **on-line** stage.

Goals:

Extract relevant information is extracted when the data is organized in some specific pattern.

Reduce the computational cost associated to the electromagnetic simulation of the **autonomous car**.

Outline

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-Geometrical Optics

- -Fundaments
- -Scenario
- -Convergence

-Black-Boxing the Scenario

-Scenario Manifold

-Future Work

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GEOMETRICAL OPTICS

Geometrical Optics: Fundaments

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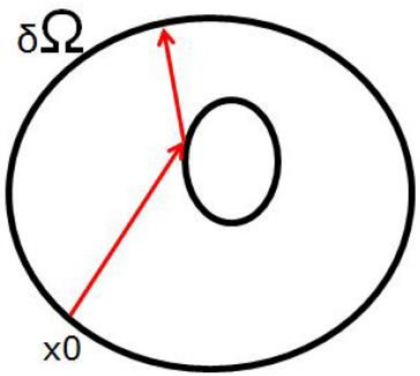
Optical reflections are produced inside the domain.



Each time a reflection is produced, some amount of energy is retained in the surface controlled by a parameter called absorption coefficient.

$$E_{ext}(\mathrm{x}_0) = E_{int}(\mathrm{x}), \mathrm{x} \in \partial\Omega$$

In our case the external energy will be the energy sent out by the radar and we will capture only the energy coming back to the receptor.

Geometrical Optics: Fundaments

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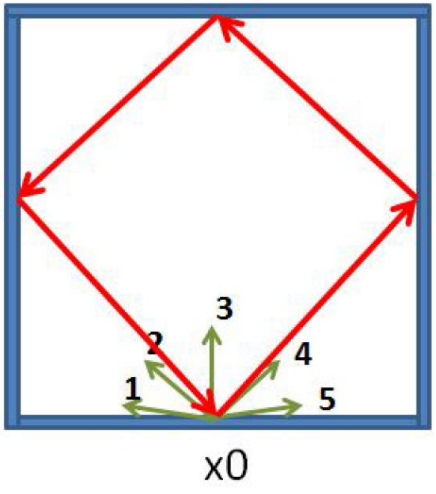
Single Ray Equation emisor and receptor located at x0

$$E_{ext}^{\alpha_4} = rE_{x0}^{\alpha_2}$$



Repeating the procedure for any possible angle of departure:

$$\boldsymbol{e}_{absorbed} = \boldsymbol{M}\ \boldsymbol{e}_{external}$$

The (i,j) component of the matrix is the energy coming back to the source with a discretized arrival angle $\alpha_a = i\Delta\alpha$ which has been thrown from an angle of departure $\alpha_d = j\Delta\alpha$

Geometrical Optics: Fundaments

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Possible Quantities of Interest

Dep./ Arr. Energy $$E_{DA} = E(\alpha_d, \alpha_a)$$

Departure Energy $$E_D = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} E(\alpha_d, \alpha_a) d\alpha_a$$

Arrival Energy $$E_A = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} E(\alpha_d, \alpha_a) d\alpha_d$$

Total Energy $$E_T = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} E(\alpha_d, \alpha_a) d\alpha_d d\alpha_a$$

Geometrical Optics: Simple Case

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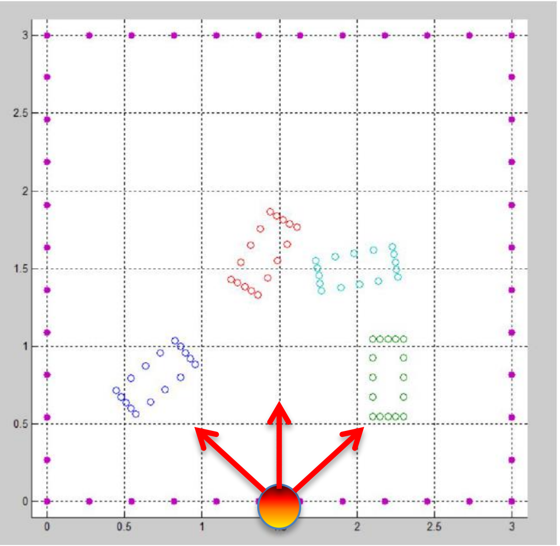
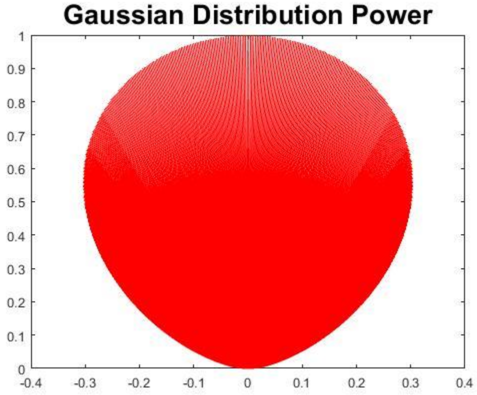
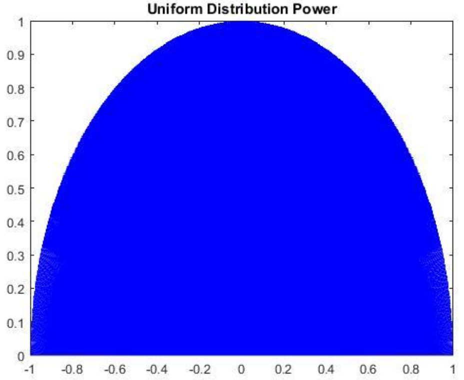
Both source and receptor are located at the middle point of the south wall. (Red point)







Geometrical Optics: Simple Case

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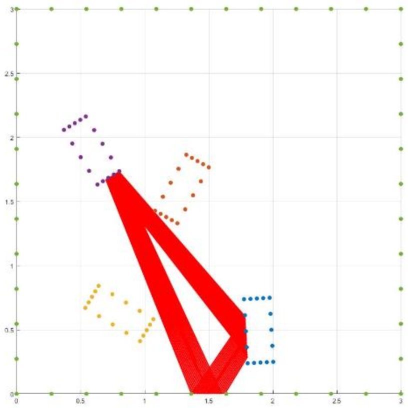
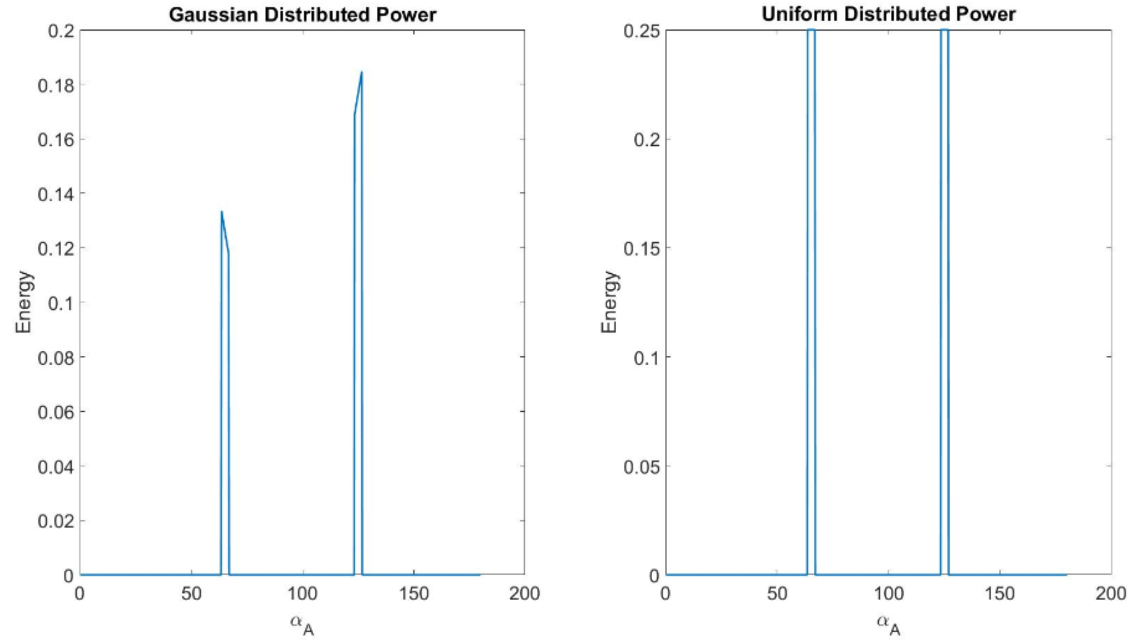


$$E_A = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} E(\alpha_d, \alpha_a) d\alpha_d$$



Geometrical Optics: Convergence

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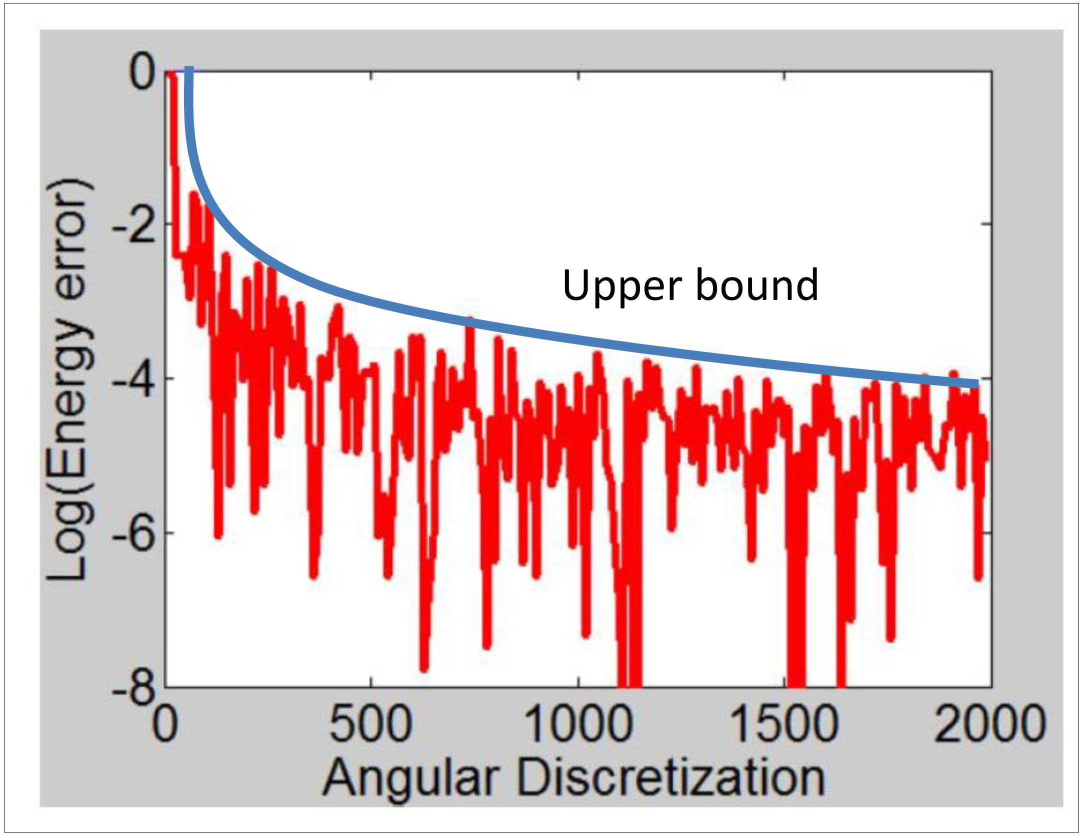
Convergence analysis of total energy coming back to the radar.

$$\mathcal{E} = \frac{||E_T^H - E_T^L||}{E_T^H}$$



It converges!

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BLACK-BOXING THE SCENARIO

Black Boxing the Scenario

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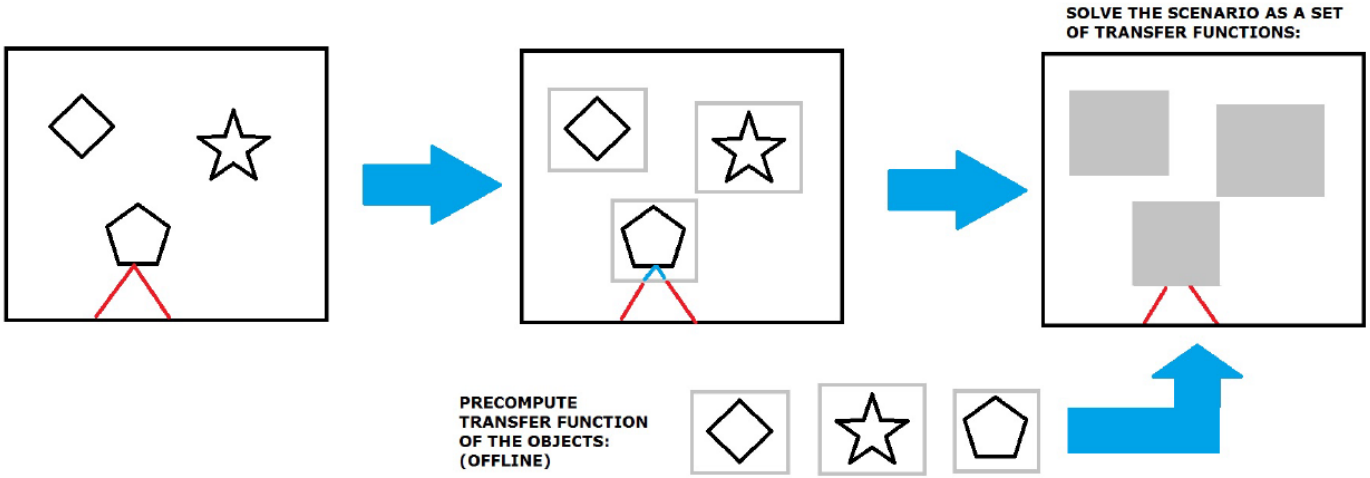
Replace objects inside the scenario by a "black-box" and a transfer function.



Advantages:

-Faster on-line simulations since only a box has to be meshed.

-Parameterization of the scenario becomes easier.

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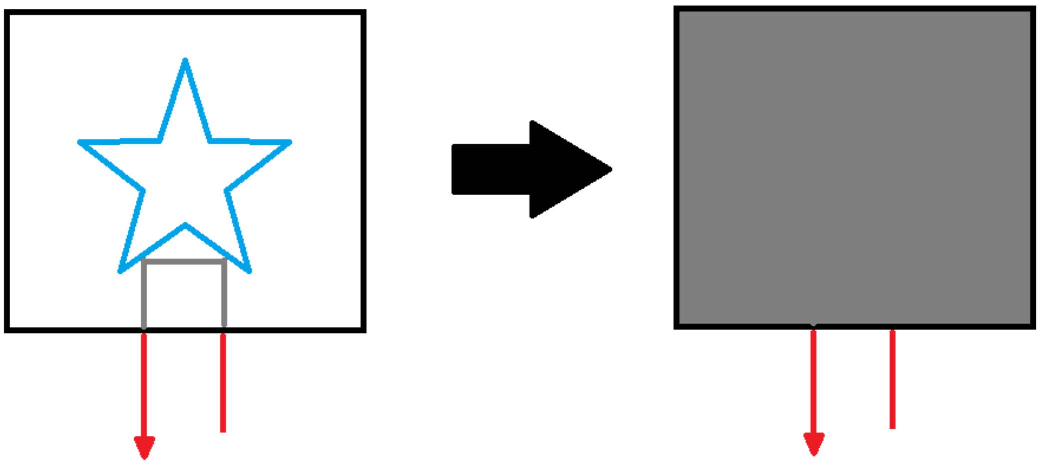
The transfer function can be seen as a manifold establishing geometrical and energetic relationships between input/output ray.



Indeed, input and output position and orientation of the ray just like the ratio of energy between incoming and outcoming ray will appear in the transfer function.

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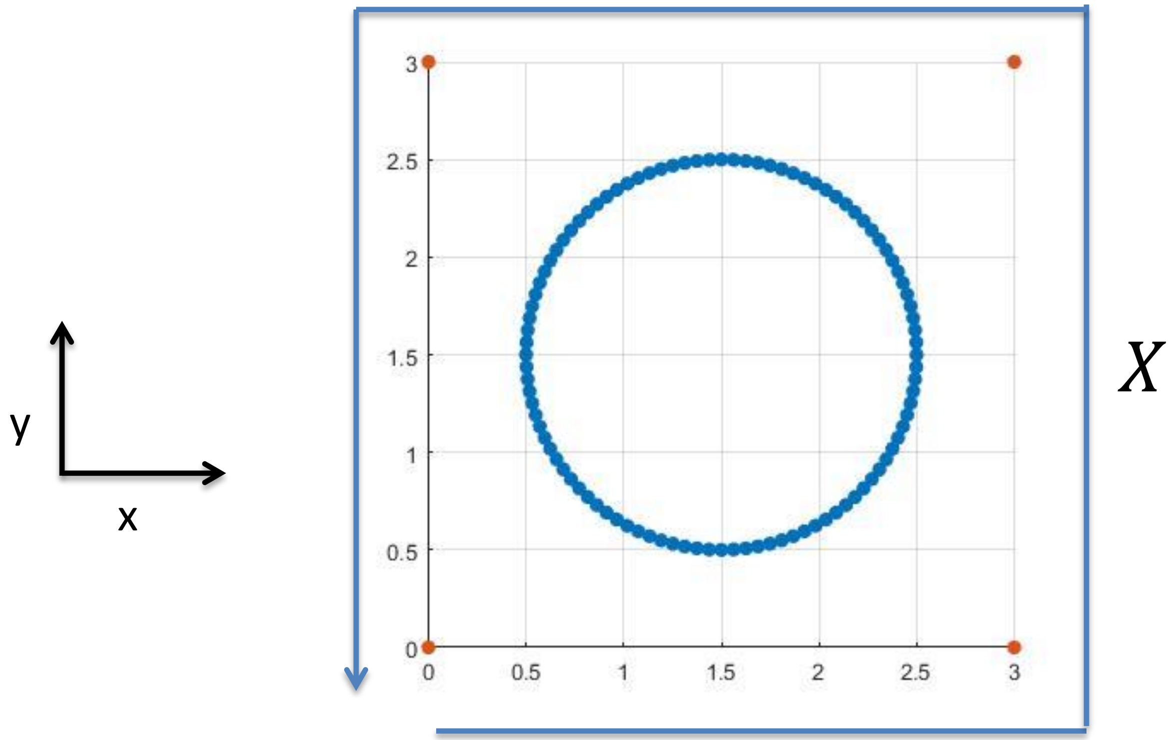
Example: Circle
X axis: Arc length of the square (starting from south-west corner, counterclockwise)
Y axis: Input ray orientation. **Absorption coefficient**: 0.5



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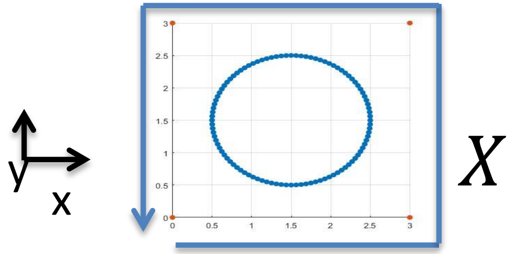
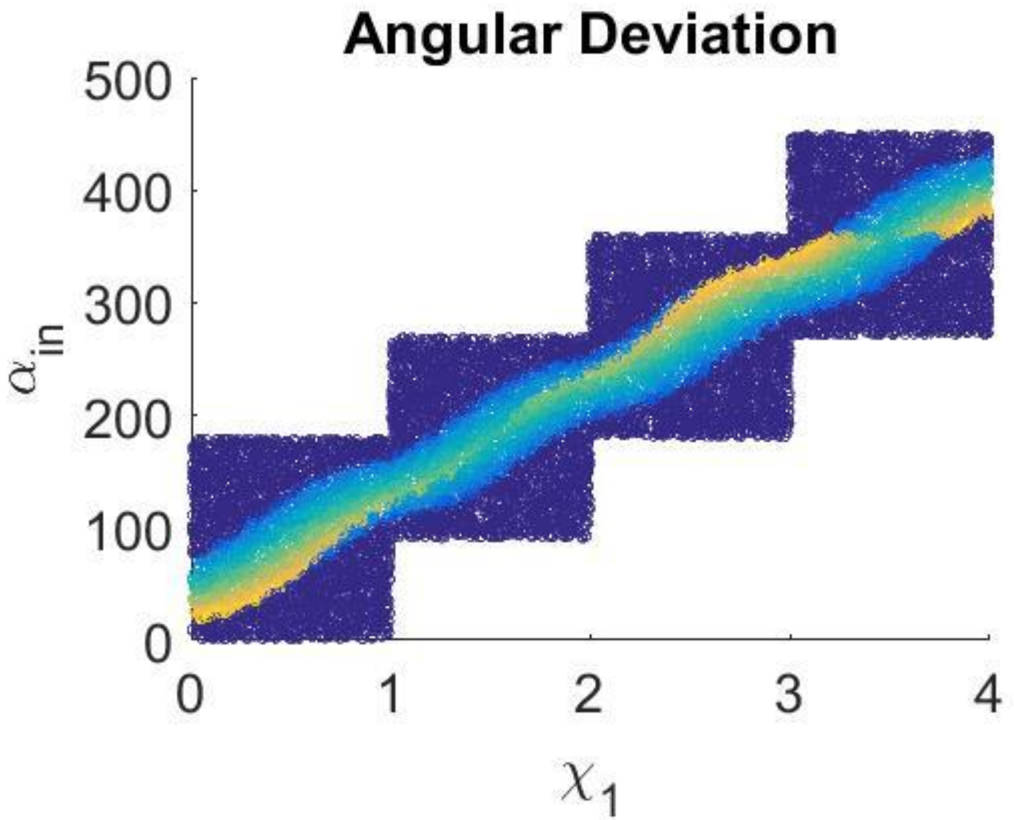
Example: Circle





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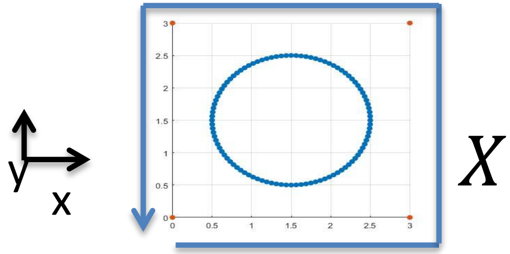
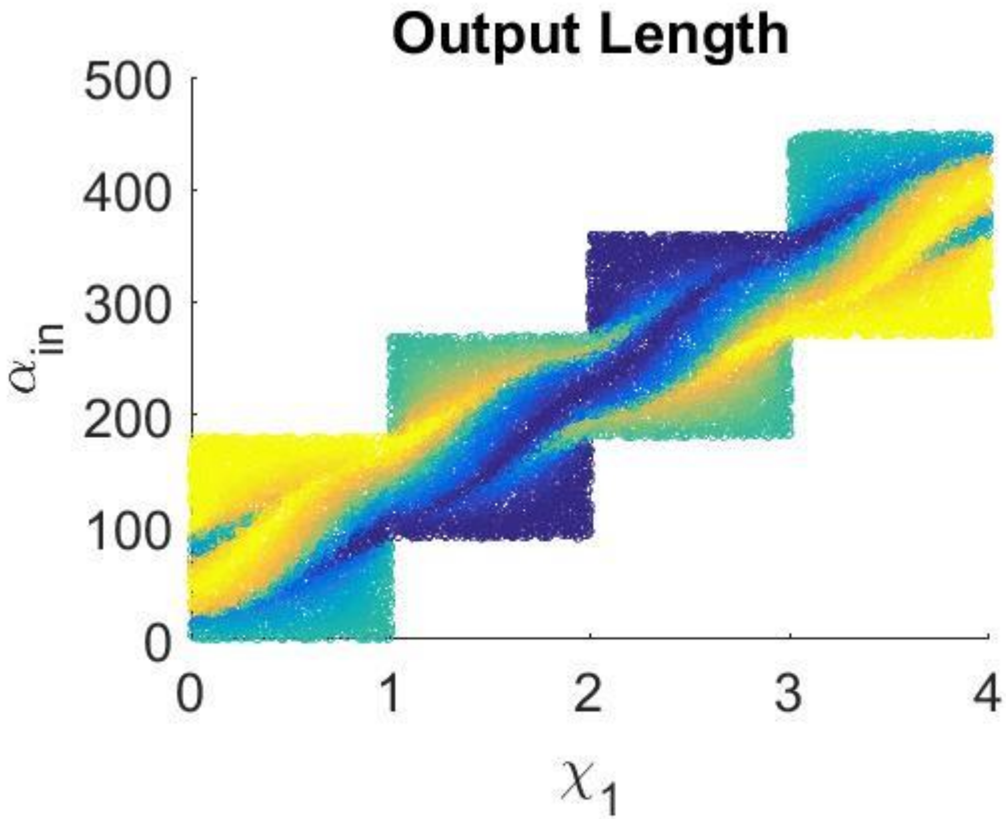
Example: Circle





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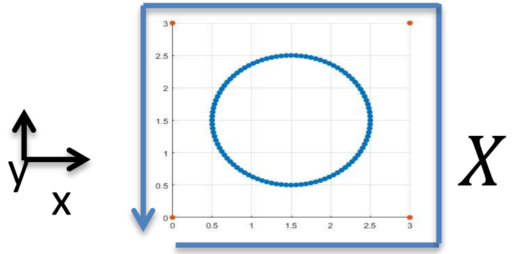
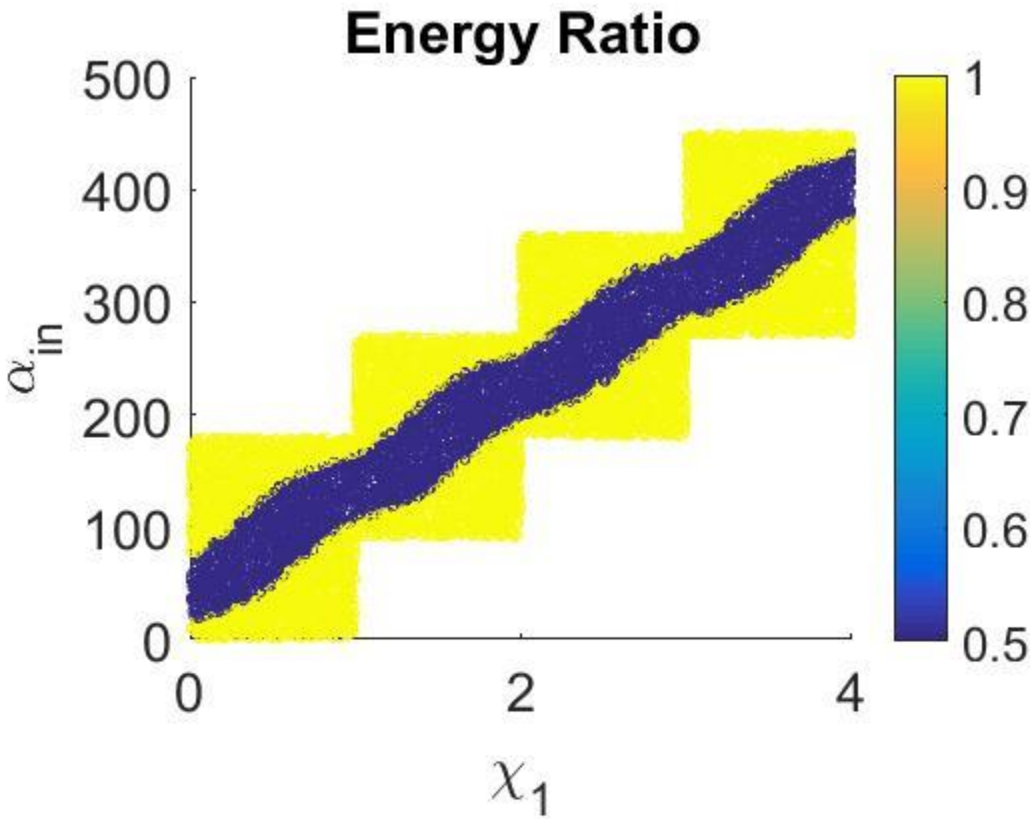
Example: Circle





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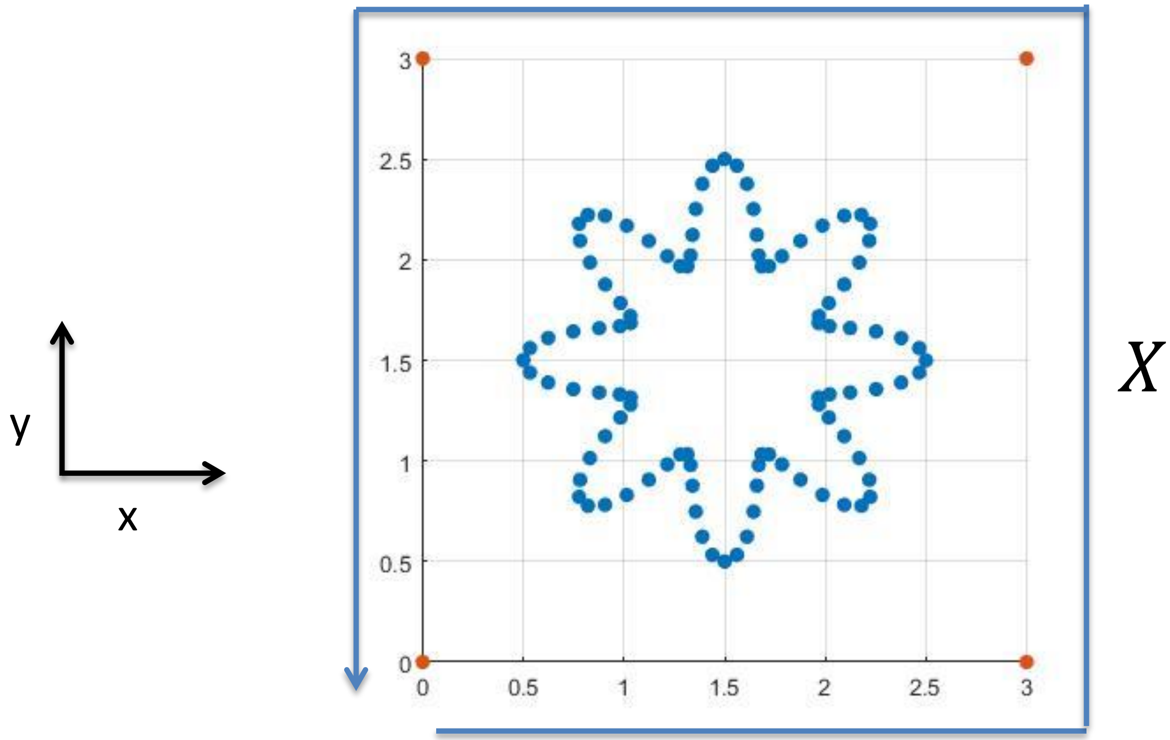
Example: Star

X axis: Arc length of the square (starting from south-west corner, counterclockwise)

Y axis: Input ray orientation. **Absorption coefficient**: 0.5



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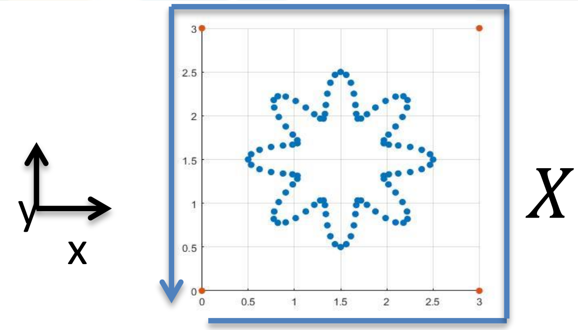
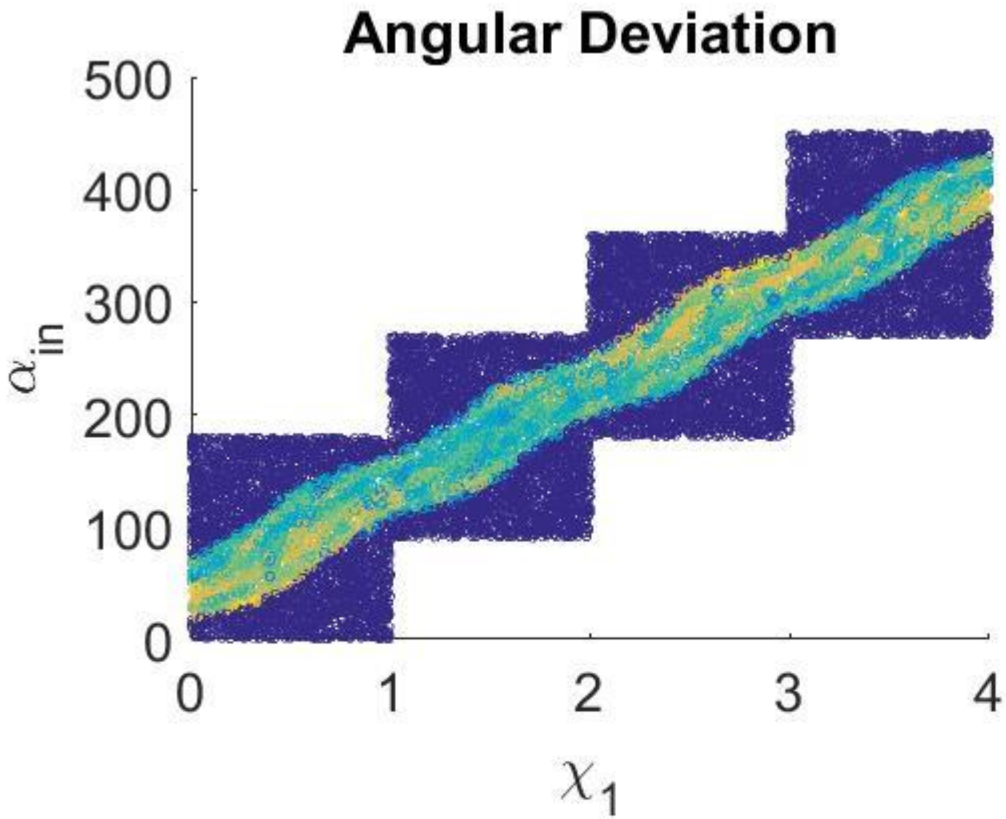
Example: Star





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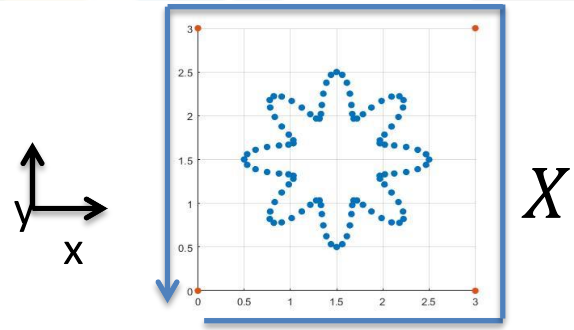
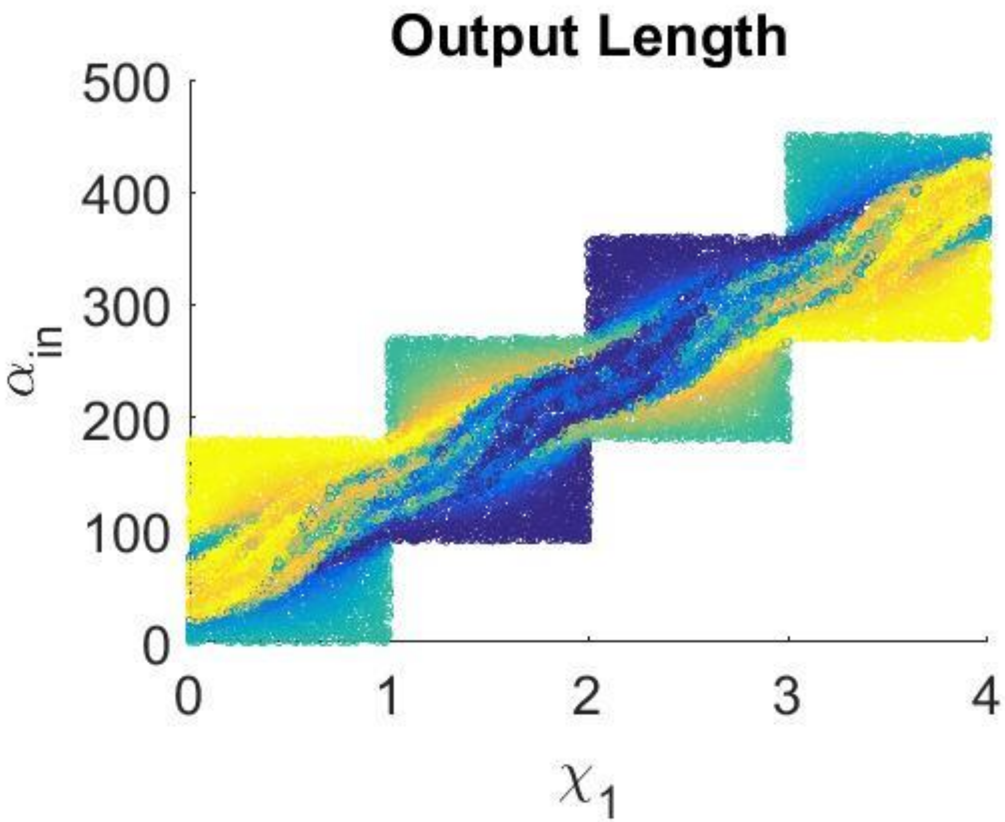
Example: Star





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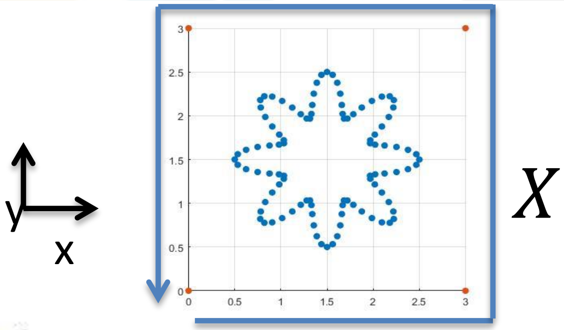
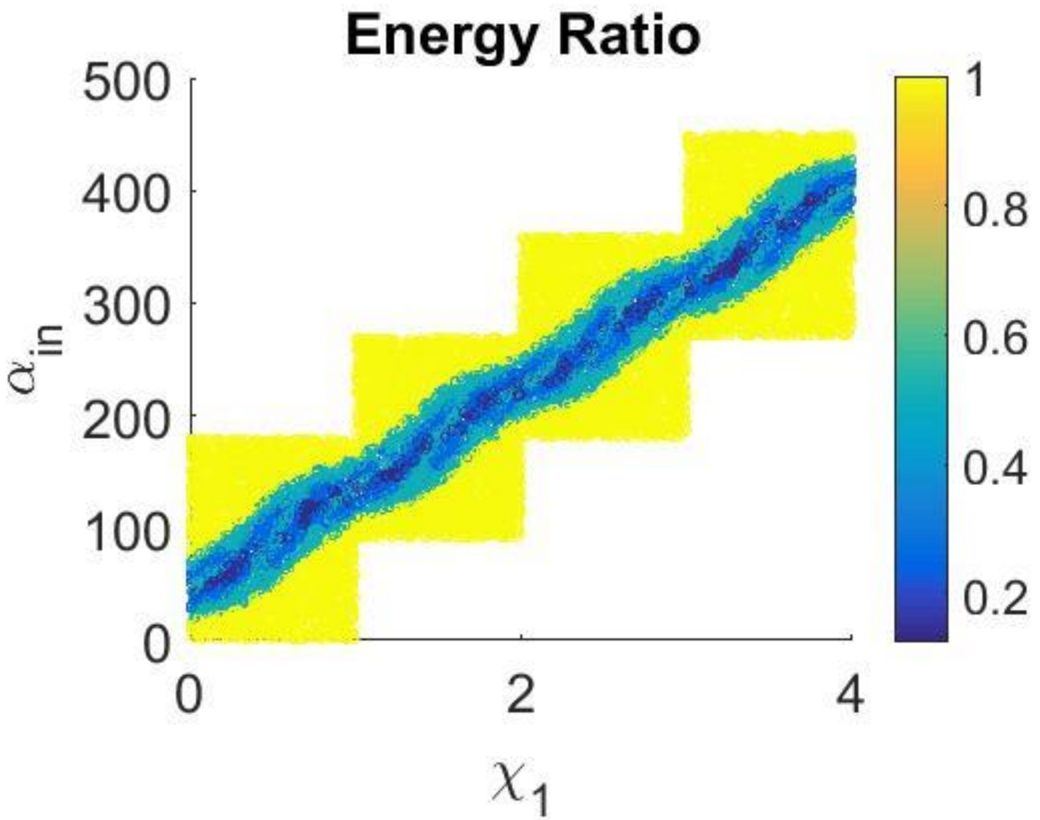
Example: Star





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SCENARIO MANIFOLD

Scenario Manifold

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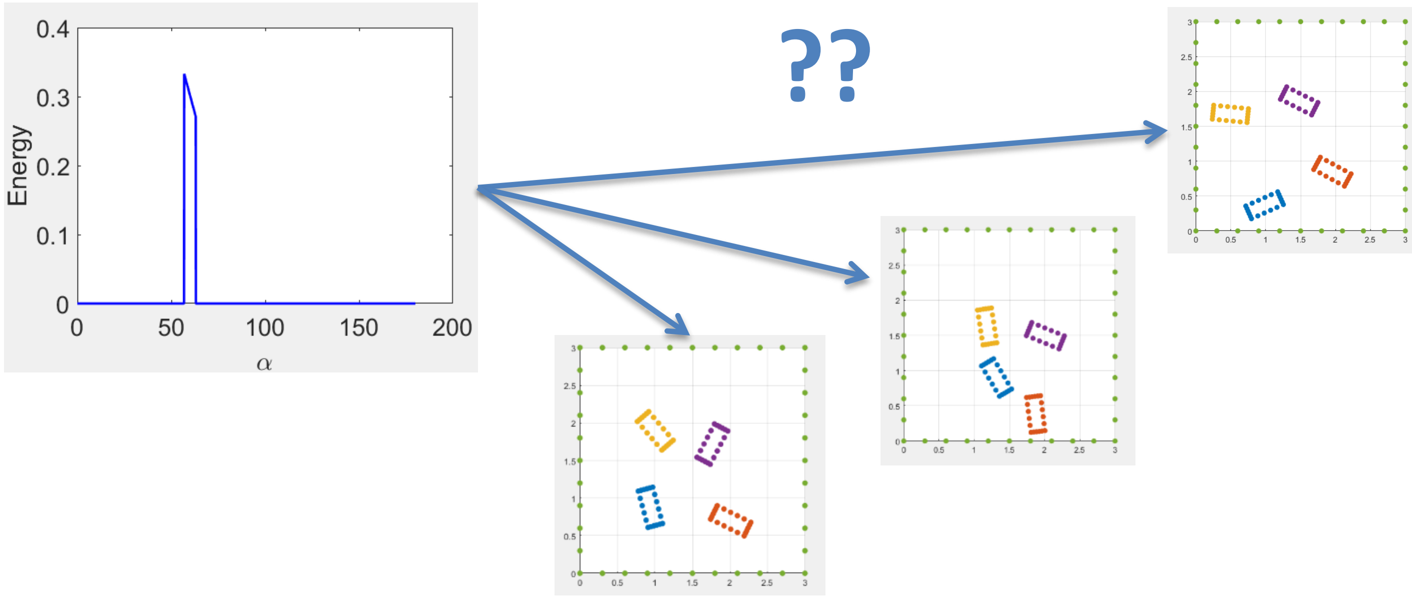
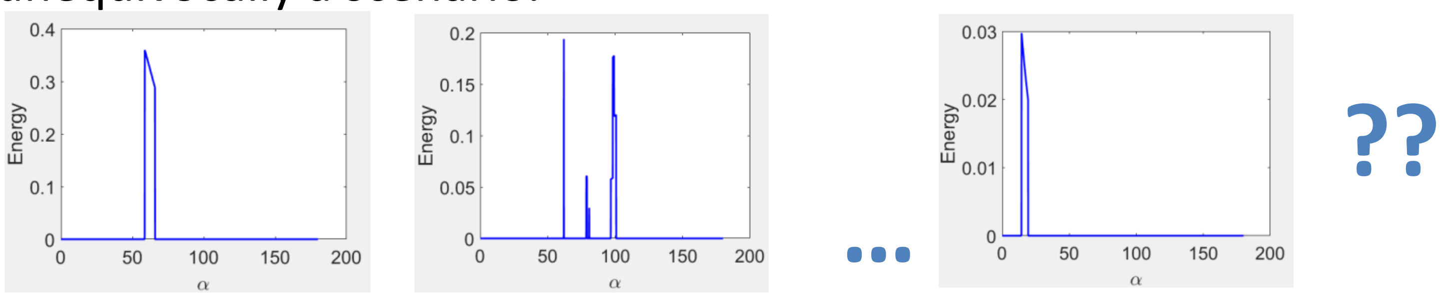
Goals: Scenario identification knowing the electromagnetic response.



Determine where and how many receptors are needed to determine unequivocally a scenario.



Scenario Manifold

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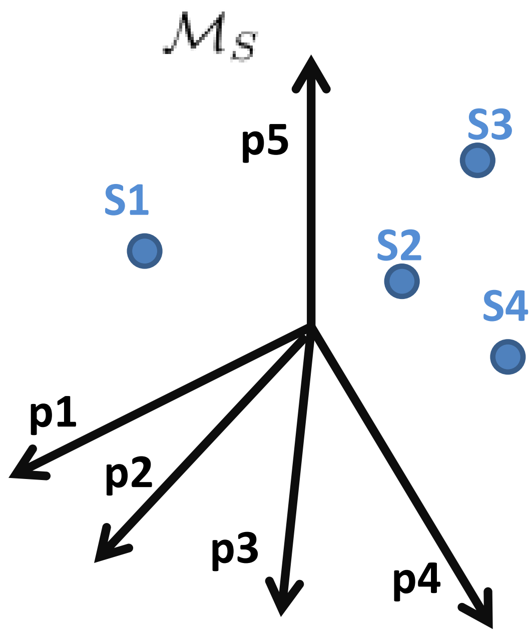
Let's assume that *M* scenarios are precomputed off-line.

The electromagnetic reponse of a single scenario is written as:

$$f(\alpha; \mathbf{p})$$

Where the blue terms are angular coordinates and the red ones are the parameterization of the manifold.



$$min(||f(\alpha; \mathbf{p}_n) - f(\alpha; \mathbf{p}_i)||_{L_2}) \; \forall \; \mathbf{p}_i \in \mathcal{M}_S$$

Those scenarios minimizing the functional will potential candidates for $\mathbf{p}_n$.

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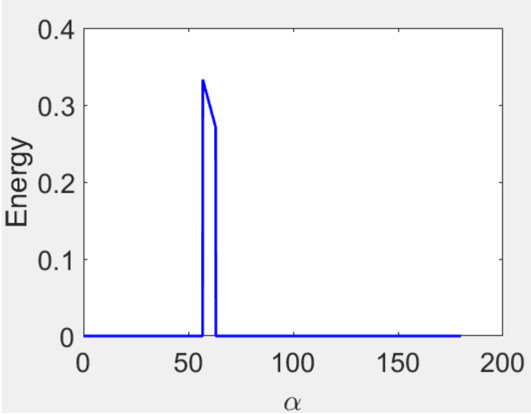
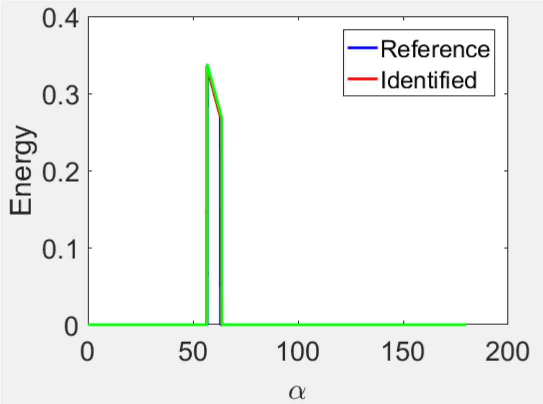
Step 1: Find among all the data set, those scenarios with “similar” electromagnetic response.





Result: Many scenarios satisfied the same electromagnetic response, but they were geometrically different.

Scenario Manifold

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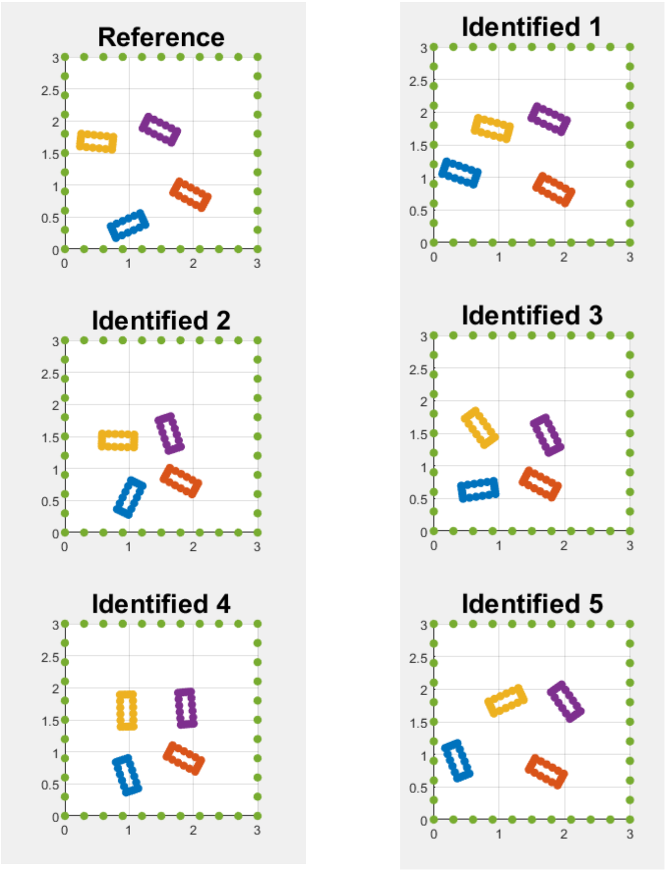
Step 2: A small subset of scenarios sharing the electromagnetic reponse is obtained.
Therefore, there will be some obstacles causing an impact in the electromagnetic response and some other which does not.

That is what we will call, **active** and **non active** scenario, respectively.

Making a covariance analysis:

Colour				
Covar. (%)	63	92	60	61



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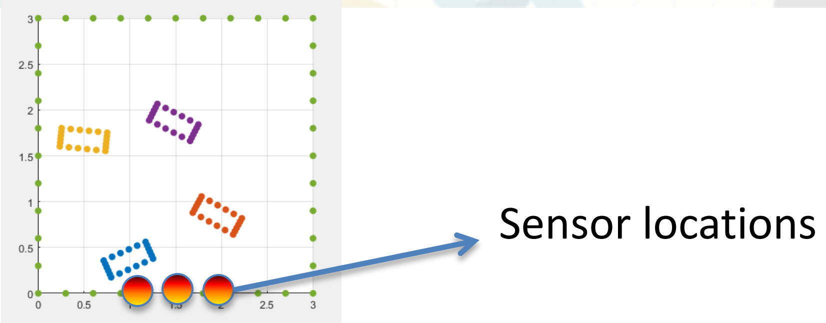
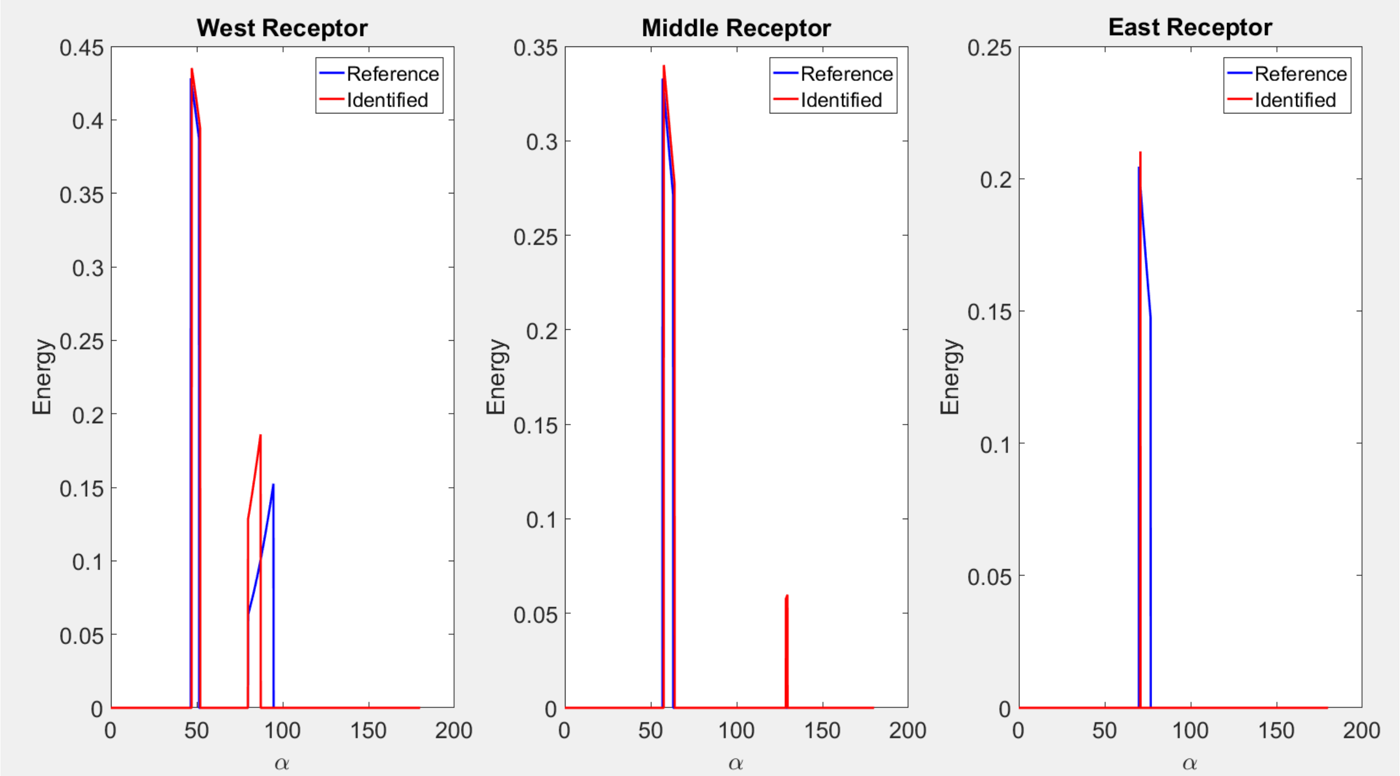
Using three sensors..





Scenario Manifold

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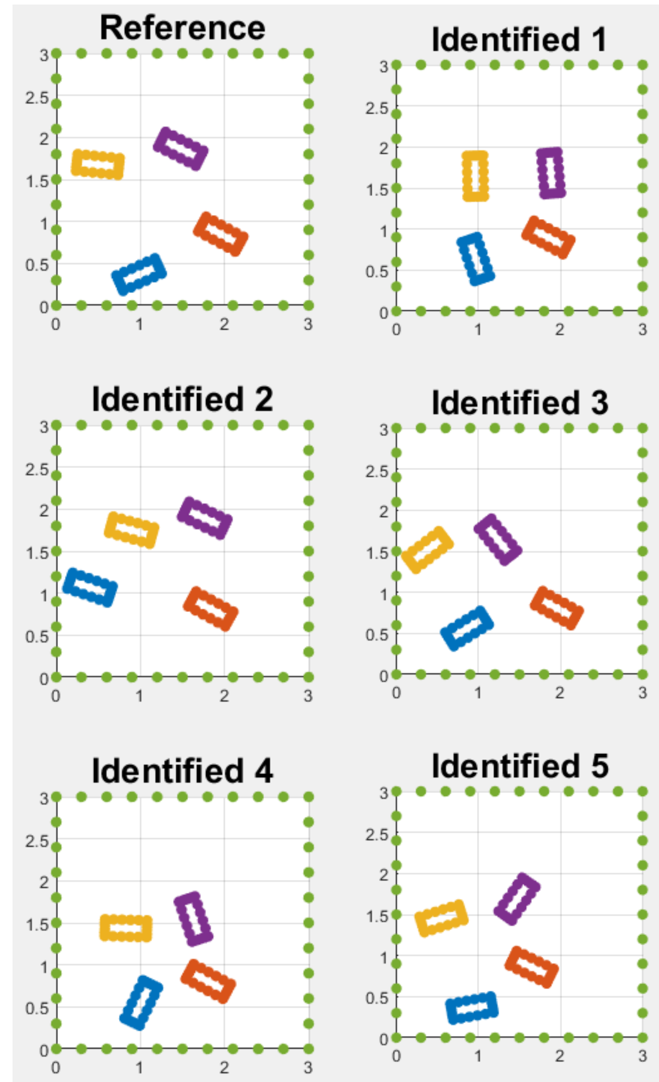
New subset of scenarios gives a covariance.

3 Sensors covariance

Colour				
Covar. (%)	68	95	61	65

1 Sensor covariance

Colour				
Covar. (%)	63	92	60	61



Scenario Manifold

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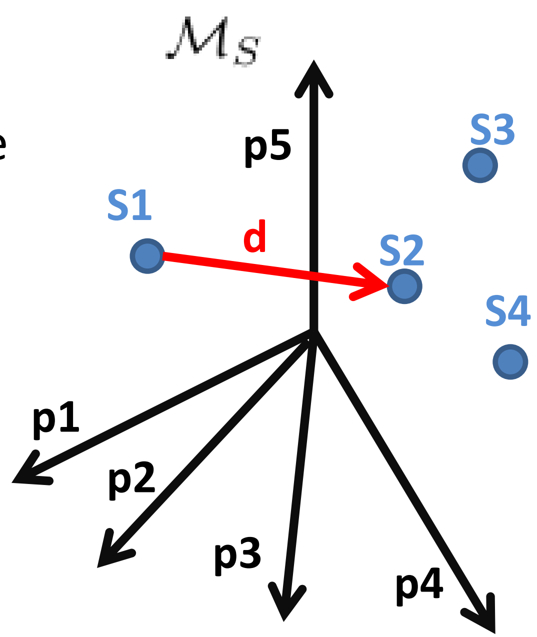
How to distinguish redundant data in the parameterizarion of the manifold?

Computing the difference of the electromagnetic reponse between two scenarios (red line) can be seen as a directional derivative in the manifold.

$$\nabla_{\mathbf{p}} f \cdot \frac{\mathbf{d}}{||\mathbf{d}||} \simeq \frac{f_{S2} - f_{S1}}{||\mathbf{d}||}$$

Making all pairwise combinations in the local neighbourhood allows to estimate the gradient in a point.

All **p** parameters whose derivative is negligible can be inferred as redundant data.



Future prospects

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Geometrical Optics

-Comparison with Maxwell Equations.

Black-Boxing the Scenario

-Reduce the cost of computing a transfer function. Smart selection of query points to do interpolation in the rest of the input domain.

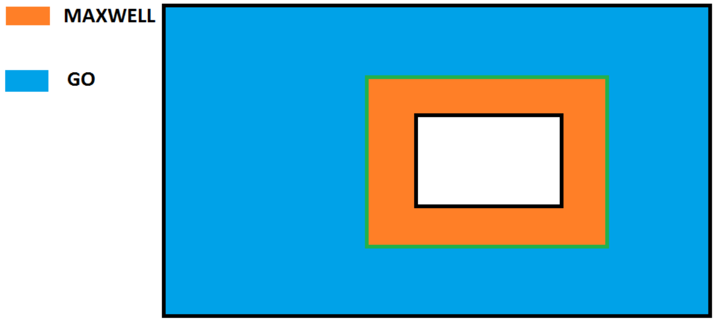
Scenario Manifold

-Add more sensors to better distinguish different scenarios.

-Differenciate active obstacles from redundant obstacles based on the directional derivative or covariogram based.

Domain Decomposition

-Having a physical domain partitioned in such a way that in some areas geometrical optics is solved and in another areas Maxwell equations.



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THANK YOU FOR THE ATTENTION.

QUESTIONS?