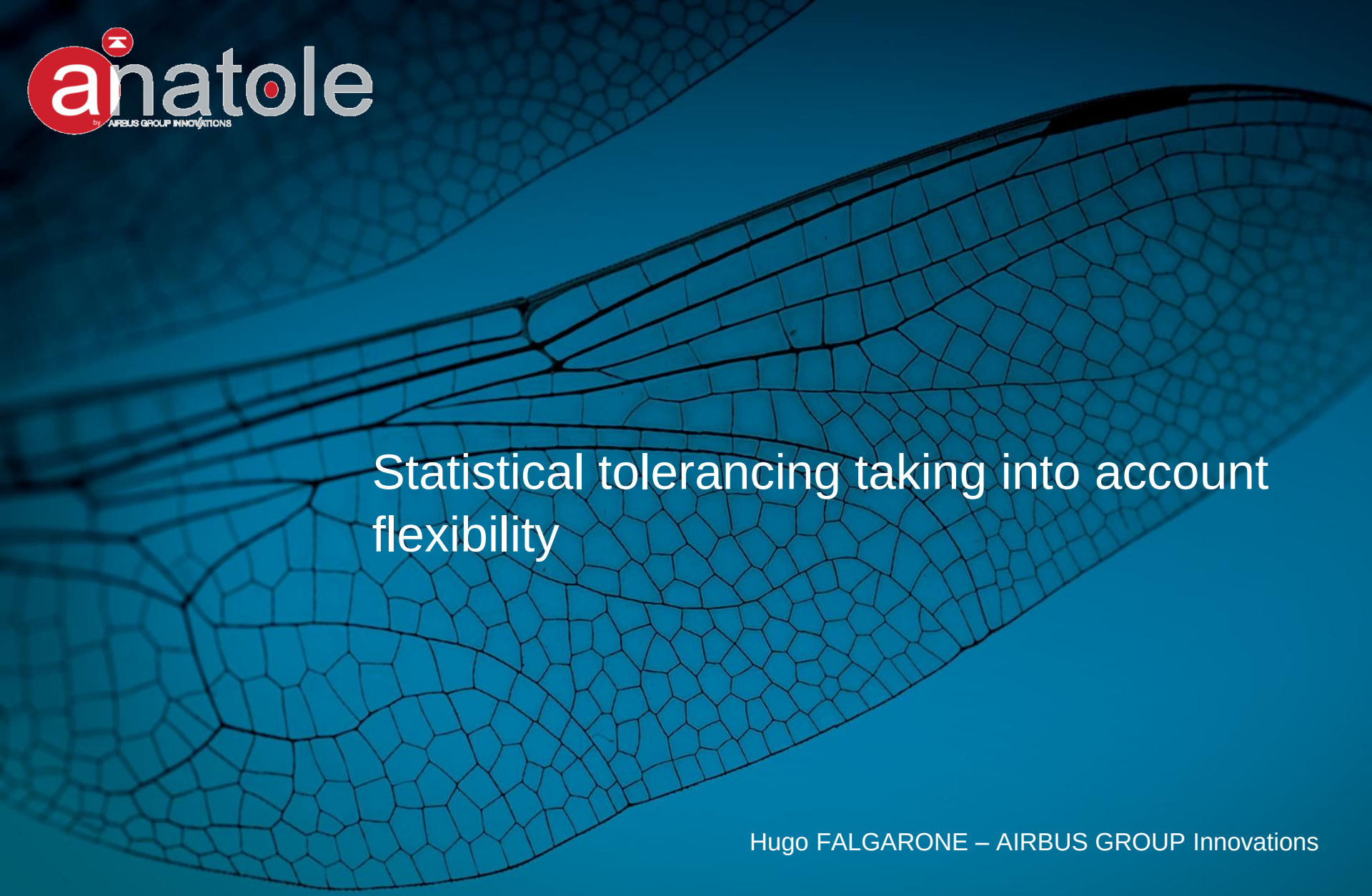


Statistical tolerancing taking into account flexibility

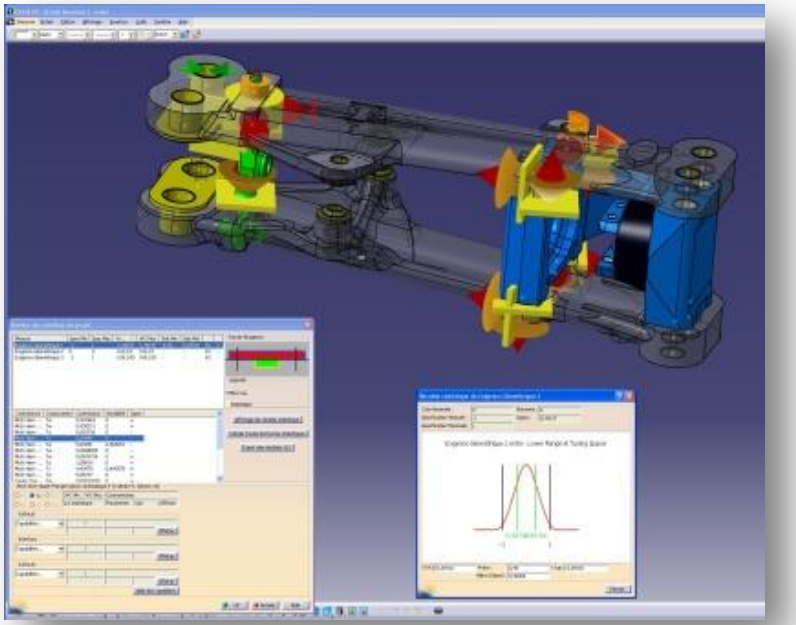
Hugo FALGARONE – AIRBUS GROUP Innovations

Agenda

- Introduction – Global context
- Tolerance Stack chain with uncertainty propagation
- Statistical tolerance specification
- Deviation field for flexible part
- Parameters cascade with analytical propagation of uncertainties

Introduction – Global context

Airbus Group Innovation is editing ANATOLE software dedicated to 3D tolerance analysis in CATIA V5



ANATOLE overview

- Joint modelling with small displacement torsors (Part, Surface, Joint)
- Geometrical variations coming from GD&Ts
- Rigid computation with sensibility analysis, worst case and statistical analysis
- Flexible tolerancing for overconstrained use cases with FEM resolution

anatole by AIRBUS GROUP INNOVATIONS

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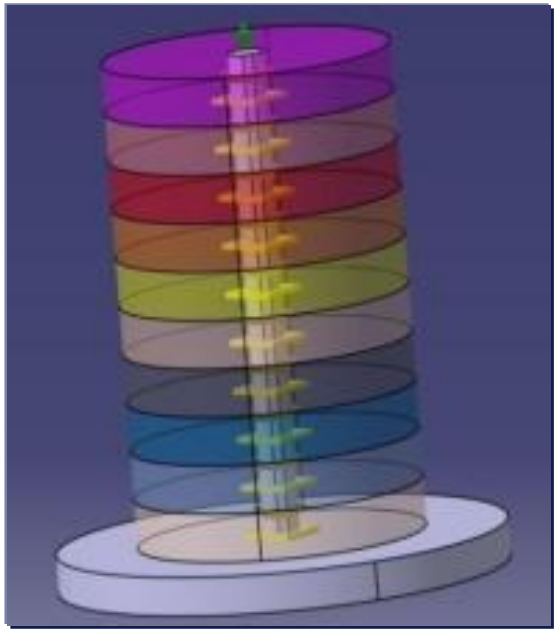
Tolerance Stack chain with uncertainty propagation

- Stack of 10 pebbles
  (Manufacturing capability $\pm$ 0.1)
- 1D stack chain
- Requirement J on the top



	Proba (%)	**J (mm)**
Worst case	100 %	+/- 1
Uniform law	99%	+/- 0,46
Normal law	97%	+/- 0,229
Truncated normal law	98%	+/- 0,245
	99,7 %	[-0,3;0,6]

Statistical tolerancing allows to enlarge tolerances (ie reduce manufacturing cost) with a predicted risk.

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Tolerance Stack chain with uncertainty propagation

Problem formulation: **Assess quantile** and **probability** to be out of required range for a requirement resulting of a 3D stack chain

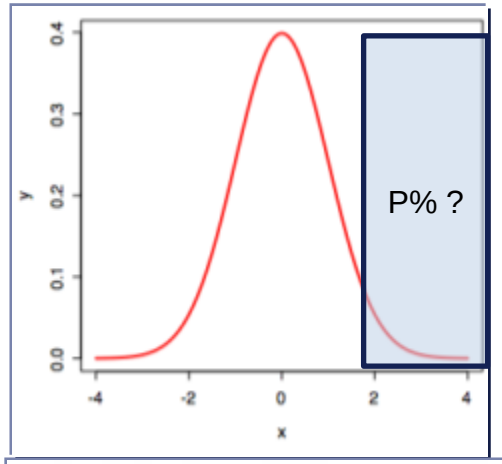
Assumption : Each chain element is **independent linear** function

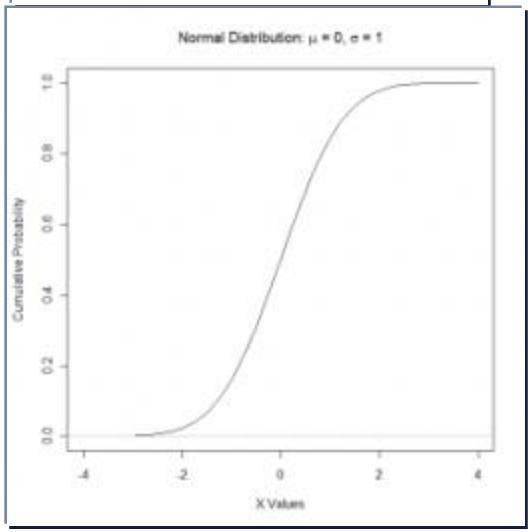
Approach

Random mixture with OpenTurns enable to introduce anykind of statistical law and to get exact quantile evaluation (5 digits) with very short time computation.

Additional features

- Capacity to build function from measurement data
- 2D and 3D approach develop to represent iso-probabilistic 3D cloud of presence





Cumulative distribution function (CDF)

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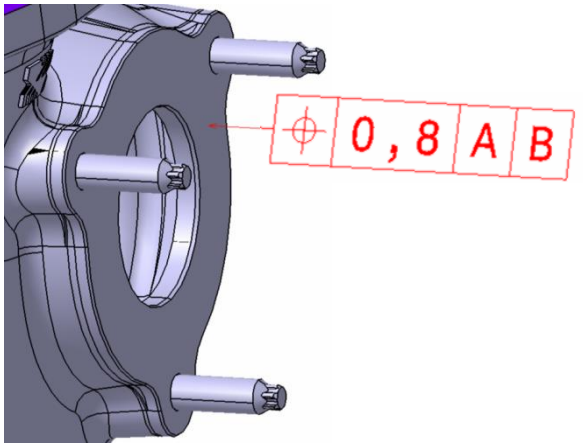
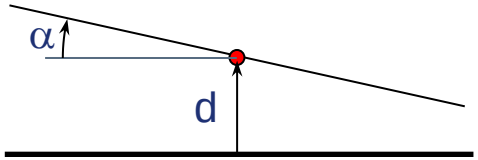
Statistical tolerance specification

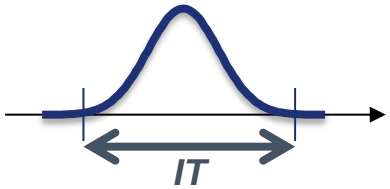


ISO Tolerance specification (GD&T) defines tolerance zone around real surface where it should be.

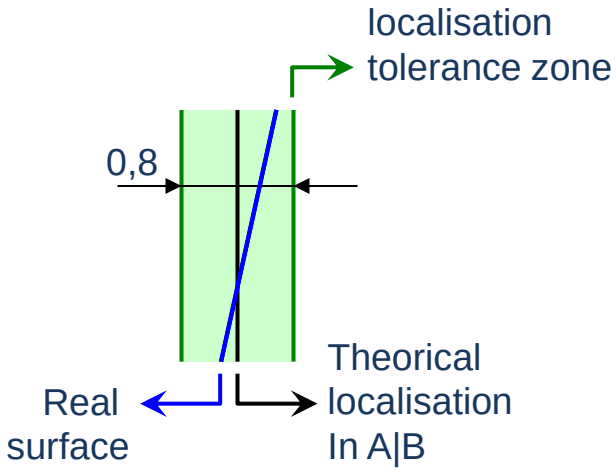
➔ Linear constraints on torsors components (ie Translation d and rotation α)



➔ Linear contraints should be created as random variable with P% to be out of tolerance according to a industrial risk.



Localisation specification understanding:



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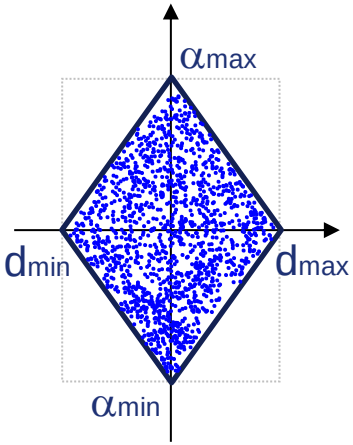
Statistical tolerance specification

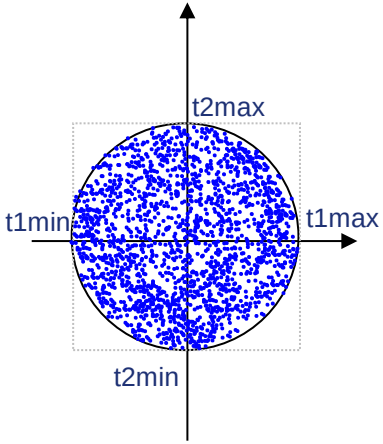
Problem formulation: Add constraints (linear and not linear) between random variables in the random mixture coming from tolerance zones (domain)

Approach

Distribution multivariable with constraints supports defined by inequations (in development)



Planar surface



Cylindrical surface

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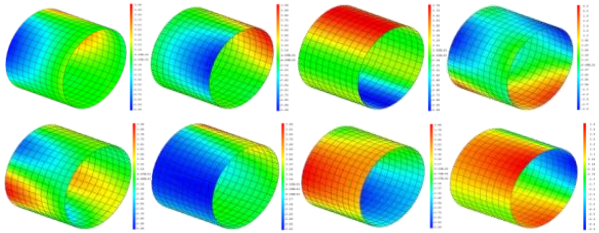
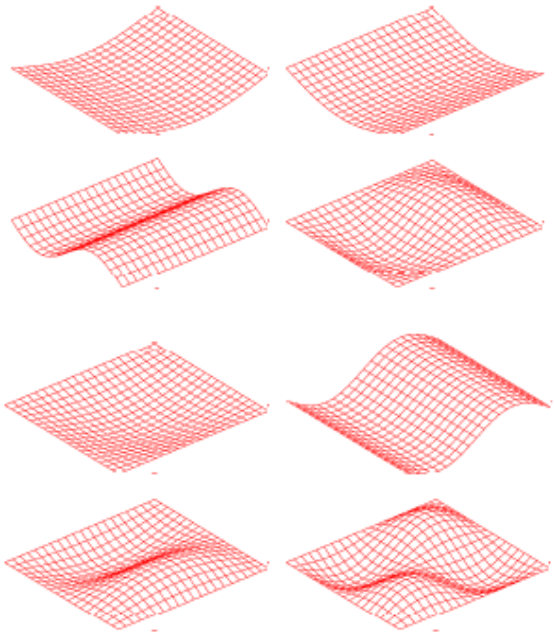
Deviation field for flexible part



For flexible assemblies (ie composite aero-structures), ANATOLEFLEX combines geometrical tolerances propagation and mechanical analysis (FEM)

MESH deviation should be defined according to:

- Tolerance envelopp
- Manufacturing process knowledge or simulation model
- Measurement from representative samples



➔ Deviation Field represents geometrical deviation of a flexible part (mesh)

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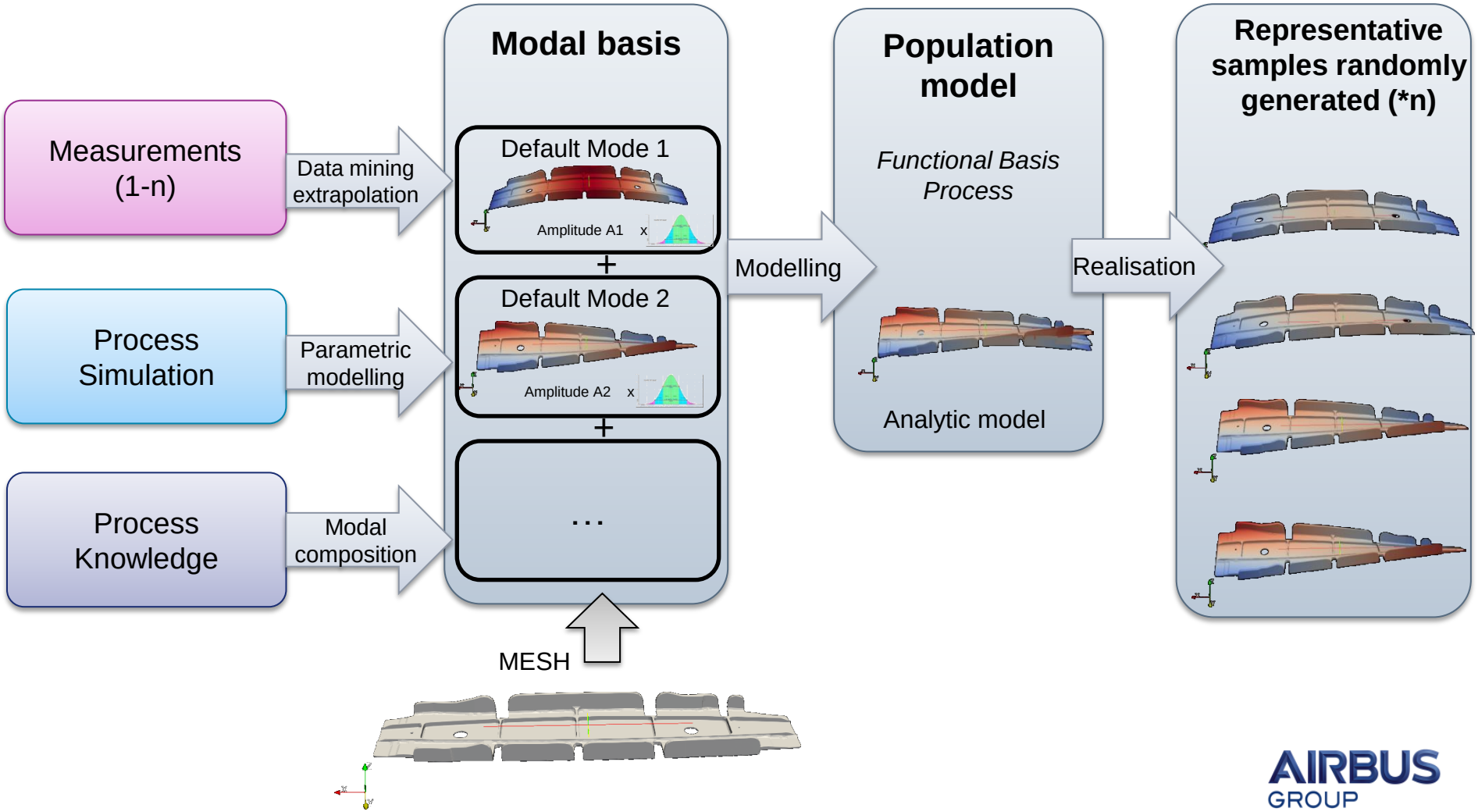
Deviation field for flexible part

Deviation Modeller in ANATOLE



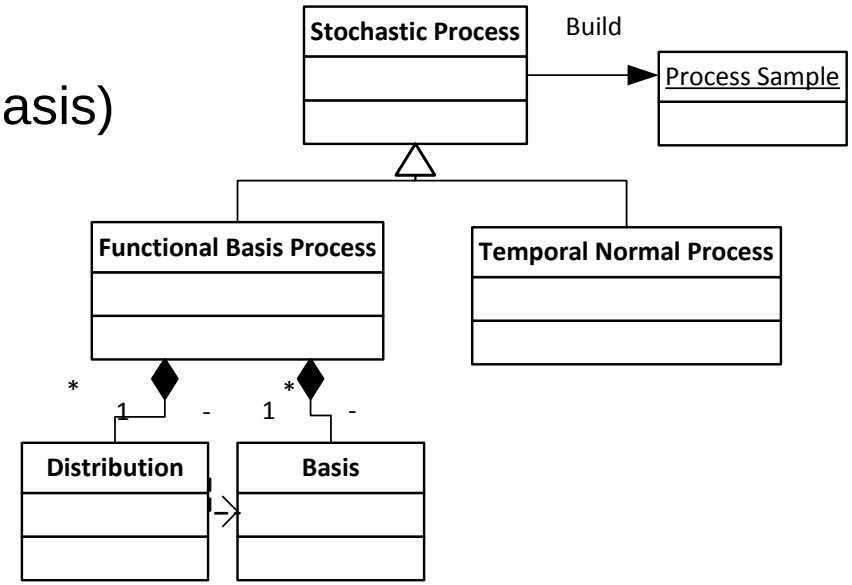
Deviation field for flexible part

Problem formulation: Describe probabilistic modelling of geometrical uncertainties on a 3D mesh.

Approach:

- Use Field as deformed Mesh
- Create process with modal basis (KL basis)
- Build realization from process

Available in OpenTurns 1.3



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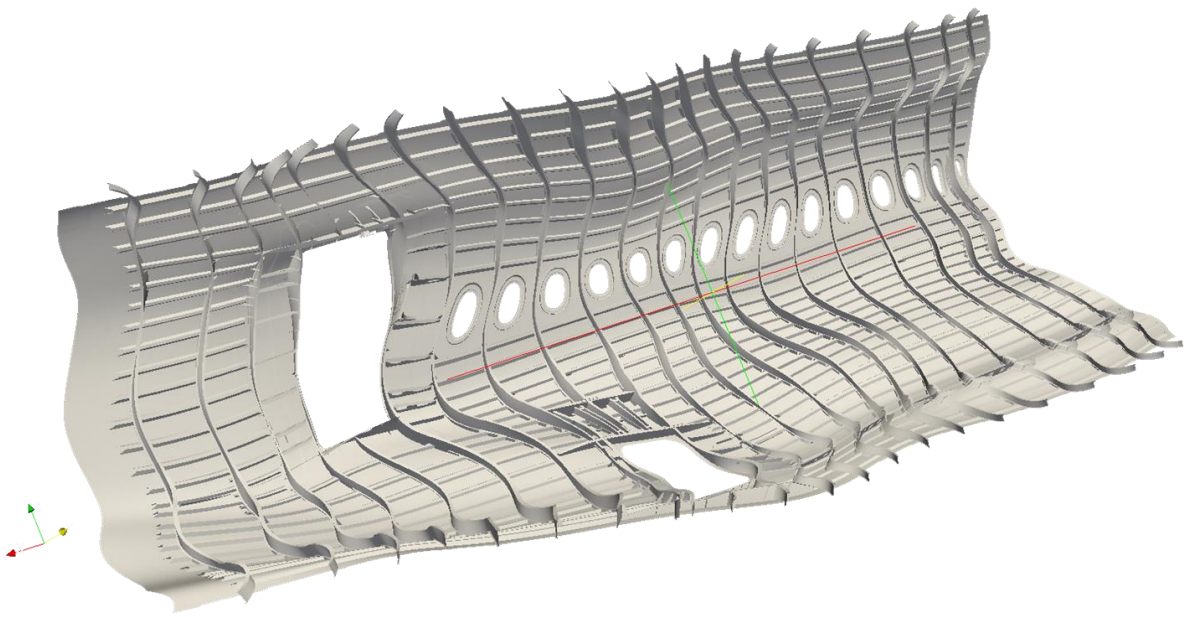
Deviation field for flexible part

First test with a representative Mesh (10^6 nodes) . Promising



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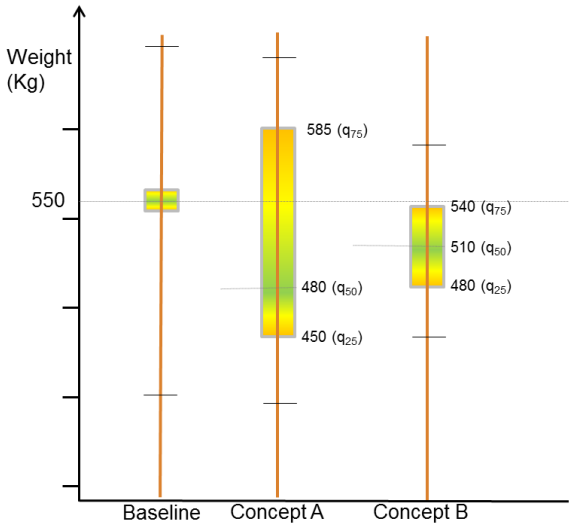
Analytical propagation of uncertainties

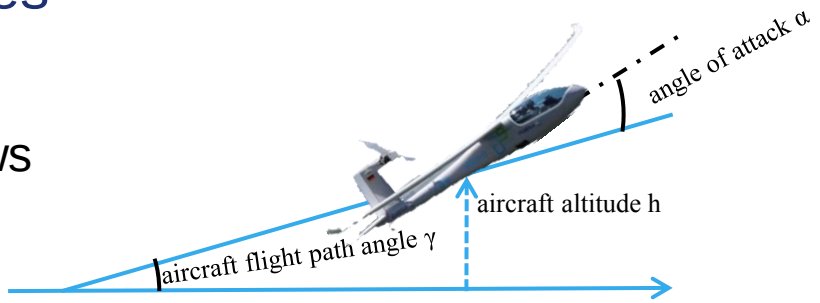
GAIA enables to describe cascade parameter during early design cycle (architecture phase).
Parameter could be functional criteria (range), design principles (fuselage diameter), interface requirement (Effort), Requirements (gaps), …
GAIA helps to cascade all parameters to consolidate evaluation.

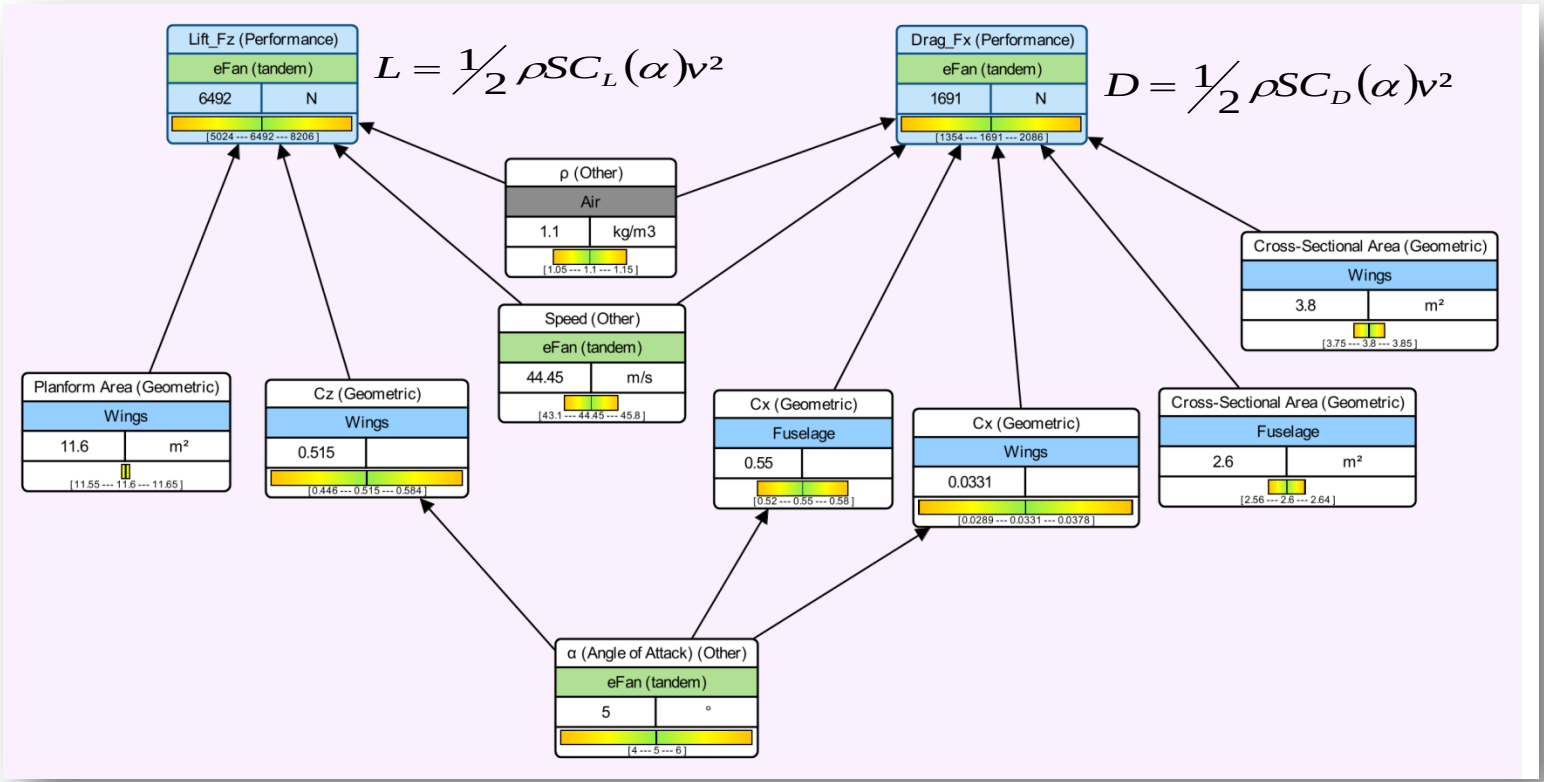
The objective of this new feature is to add a quality indicator representing maturity of evaluation and to propagate them.



Analytical propagation of uncertainties

Example on some simple flight physics laws





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Analytical propagation of uncertainties

Problem formulation: Propagate quality indicators within parameter cascade (based on parameters functional dependencies $p_i = f(p_j, p_k, \ldots)$

Assumption : Each parameter are considered independant

Approach

Non linear transformation of 1D random variables independants.

We will developp analytical algebra of independant random variable

Available in OpenTurns v1.4 + future algorithm optimisation to be done in next release)

Conclusion

Many implementation of OpenTurns have been developed to offer new features on GAIA and ANATOLE => competitive advantages.

A main challenge remain on supporting end users with appropriate methods to explain new probabilistic approach.

Sometimes it’s seems difficult to believe for user than we could compute 10^6 time faster with 10 time more figures a same computation compared to previous algorithm.

Thank you for your attention !

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