# Open TURNS User's Day #7

Friday 20 June 2014

❖**The Galton Board** (1822 - 1911) **: british explorer, geograph, inventor, meteorologist, proto-geneticist, psychometrician,statistician**

Open TURNS User's Day #7
Contents

9h30 - 10h →

- ➢ **Reception at EDF R&D Clamart**
- ➢ **Introduction: A. Caruso (EDF R&D)**
- ➢ **Open TURNS :**
  - ✓ **Identity card**
  - ✓ **Consortium**
  - ✓ **Imacs: a new partner since 2014**
  - ✓ **Web site**
  - ✓ **Open TURNS trainings**

10h – 11h

- ➢ **New features of the 1.3 & 1.4 releases (to come)**
  - ✓ **Scientific and Technologic New Features**
  - ✓ **A New User Manual**

- ➢ **Perspectives - New Partners?**
- ➢ **Open TURNS and the Kriging Approach**
  - ✓ **« The kriging approach to optimisation » (1h) : R. Leriche (CNRS, Mines de St Etienne)**
  - ✓ **« The kriging approach in Open TURNS v1.3 » (30') : J. Schueller (PhiMECA)**

11h – 12h30

- ➢ **Studies using Open TURNS**
  - ✓ **«Bayesian calibration with Open TURNS » (30') : G. Gamblin (EDF R&D)**
  - ✓ **« Open TURNS and stochastic fields - Simulation of synthetic misorientation maps of alloy 600 specimens » (30') : G. Blatman (EDF R&D)**
  - ✓ **« Complex probabilistic modelling for electromagnetism shield » (30') : S. Haddad (IMACS)**
  - ✓ **« Bayesian updating for degradation prediction » (30') : R. Décatoire (PhiMECA)**
  - ✓ **« Statistical tolerancing taking into account flexibility » (30'): H. Falgarone (Airbus Group)**

14h – 16h30

- ✓ **Discussion**

16h30 – 17h
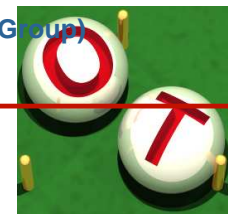
Open TURNS : identity card

Open TURNS aims at **propagating** uncertainties through a model until a given variable of interest. It proposes some functionalities in order to **quantify** uncertainties in order to **rank** their influence on the variable of interest. Open TURNS also enables to build **meta models**.

➢ **Partners 2005 – 2014 : EDF – R&D / Airbus Group / PhiMECA + IMACS (from 2014):**

- ✓ **transparency** : to make the methodology and the associated software be accepted by certification or control entities
- ✓ **genericity** : to benefit from different fields where the same approach is developed (mechanics, hydraulics, ...)
- ✓ **computing performance** : to enable the treatment of complex industrial cases (parallélisation, distribution, ...)

➜ **Open TURNS : an open source platform dedicated to uncertainty treatment by probabilistic methods**

- ✓ **Open** source **T**reatment of **U**ncertainty, **R**isk '**N S**tatistics
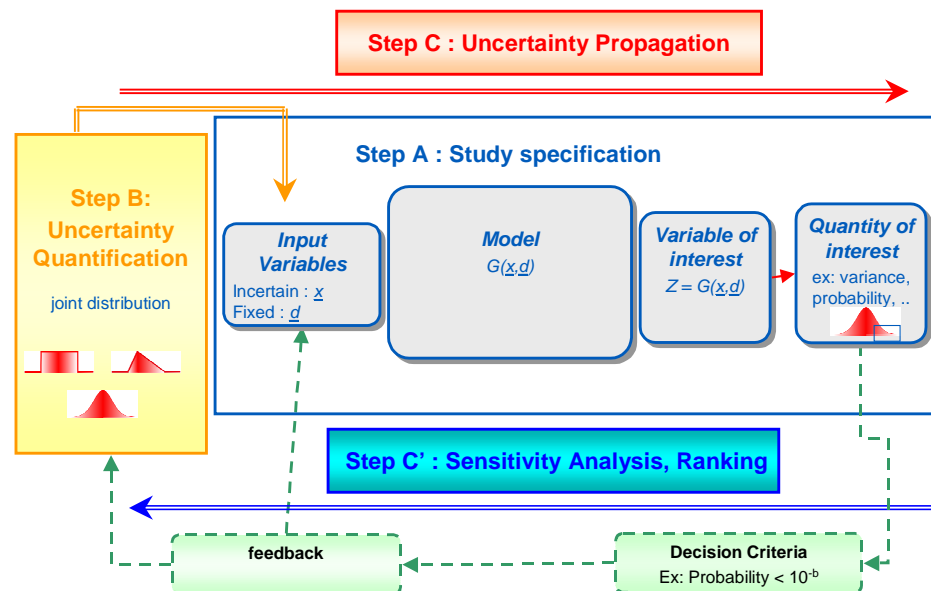- ✓ **sous LGPL licence**

www.openturns.org

Uncertainty Methodology

Open TURNS is the software associated to the Global Methodology of Treatment of Uncertainties developed first at EDF R&D in 1990 and then improved by contributions from other companies :

- ✓ **Step A : Study Specification** : uncertain input variables, model, variable of interest, analysis criteria (range study, central dispersion, probability to exceed an extrem threshold)
- ✓ **Step B : Uncertainty Quantification** : modelisation of the joint distribution of the input uncertain parameters
- ✓ **Step C : Uncertainty Propagation** : quantification of the analysis criteria
- ✓ **Step C' : Uncertainty Ranking**

Step C : Uncertainty Propagation

Step B: Uncertainty Quantification

joint distribution

Step A : Study specification

Input Variables
Incertain : x
Fixed : d

Model
$G(x,d)$

Variable of interest
$Z = G(x,d)$

Quantity of interest
ex: variance, probability, ..

Step C' : Sensitivity Analysis, Ranking

feedback

Decision Criteria
Ex: Probability < 10^{-b}

eDF

Uncertainty Methodology - Open TURNS

➤ **Numerous functionalities for each step of the Methodology** in particular ....

❖ **Code linked to Open TURNS :**

✓ **Generic Wrapper générique** which enables to wrap OT to any code using input and output text files, with authomatic multithreading functionalities (parallélism multiprocessors / multicores)

✓ **Interface with python functions**, which enables the realisation of complex wrappers without compilation + parallelization fonctionalities

✓ **Standard Interface for the development of wrappers of any complexity** (distributed wrapper, binary data) which require the development of an external wrapper

✓ **Salome compatibility** : OpenTURNS composant of Salome, linked to YACS

❖ **Step B : Uncertainty Quantification**

✓ **Estimation from data :**
- Distribution fittings (parametric or not),
- Validation Tests (quantitative or graphical),
- Estimation of the dependence : copula, correlation coefficient
- Regression

✓ **Modelisation of Joint Distributions of dimension n :**
- Combination Marginals + Copula,
- Parametric Distributions of dimension n (normal, student...)
- Non Parametric Distribution of dimension n : kernel fitting (n), Sklar Copula
- Linear combination of pdf
- Linear combination of random variables,
- Random sum of independent discrete variables according to a Poisson process
- …

Iso-PDF – Example1
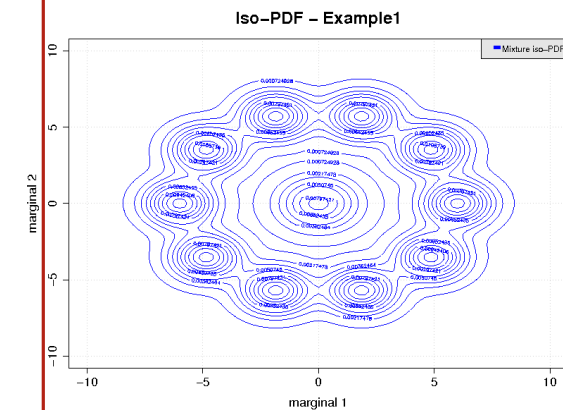
Uncertainty Methodology - Open TURNS

❖ **Open TURNS = repository of innovant or recent algorithms**

   ✓ **the most recent and efficient algorithms of non uniform distribution generation**

- Ziggurat method (2005) for the normal distribution
- sequential reject algorithm (1993) for the binomial distribution,
- Tsang & Marsaglia method (2000) for the gamma distribution,
- Lebrun algorithm (2012) for the MultiNomial distribution,

   ✓ **the most recent algorithms of evaluation of the CDF**

- Marsaglia algorithm for the exact statistics of Kolmogorov (2003),
- Benton et Krishnamoorthy algorithm for the distributions non centered Student and non centered Chi2 (2003).

   ✓ **PhD results**

- Sparse chaos expansion polynomials : G. Blatman (EDF/R&D/MMC) (2010)
- Accelerated simulation algorithm for the evaluation of low probabilities : M. Munoz (EDF/R&D/MRI) (2012)
- Copulas for order statistics distributions: R. Lebrun (EADS) (2013) (in dev)

❖ **Innovation : the internal data model is based on the multidimensional cumulative density function** which enables :

   ✓ **the sampling approach** : estimation of statistical characteristics of the output variable from a large numerical sample

   ✓ and **the analytical approach** : exact partial or total résolution of some problems using the probabilistic modelisation and the implementation in Open TURNS of the functions $R^n \rightarrow R^p$ algebra until order 2:

- exact determination of the distribution of the sum of random variables thanks to the characteristic functions implemented for each distribution,
- exact representation of the distribution of a random variable such that its pdf is a linear comibnation of pdf,
- exact determination of the distribution of a random variable defined as the random sum according to a Poisson process of iid discrete random variables (for ex, cumulated failure times when failures follow a Poisson process)
- **particular manipulations on distributions** : extraction of marginals, extraction of dependence structure, ...
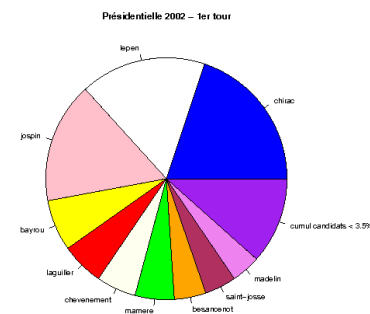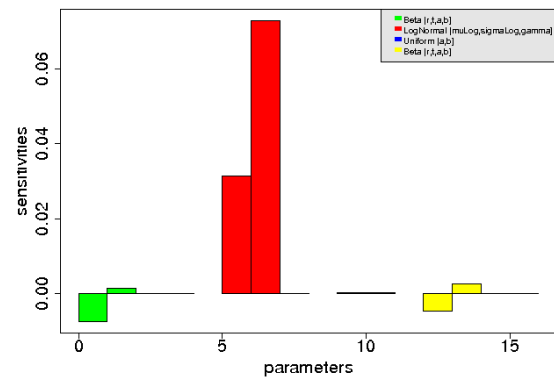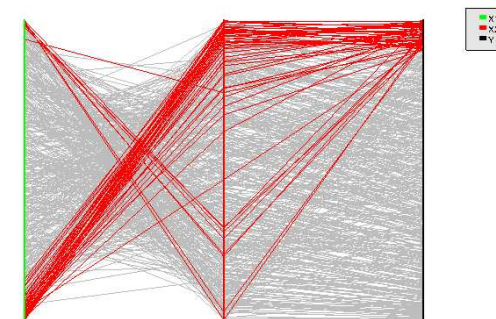
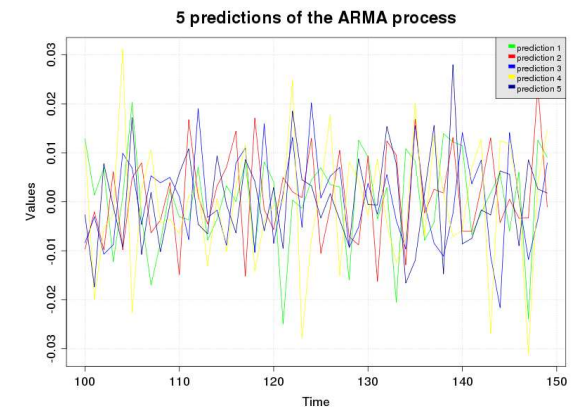# Open TURNS in pictures

Open TURNS in pictures

Iso–PDF – Example2

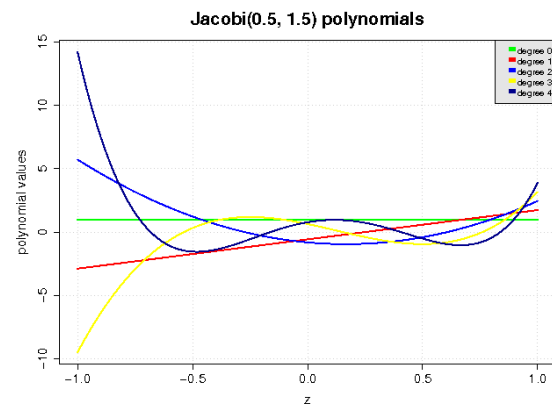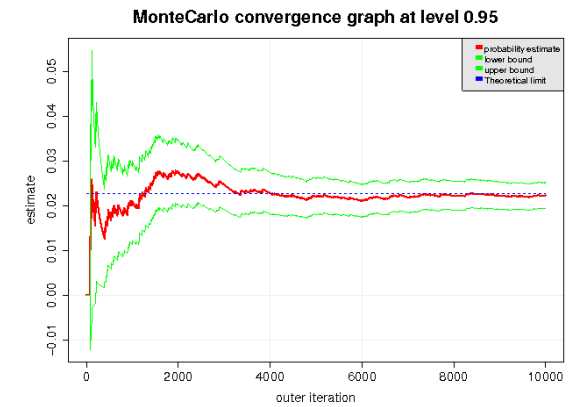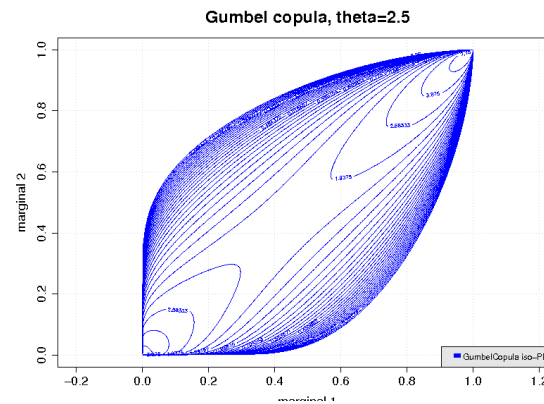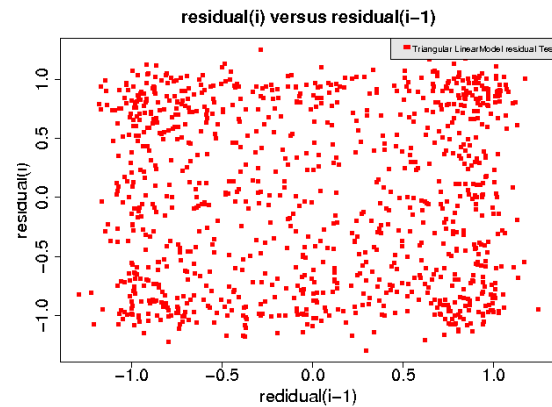Importance Sampling

Parametric estimation of the copula
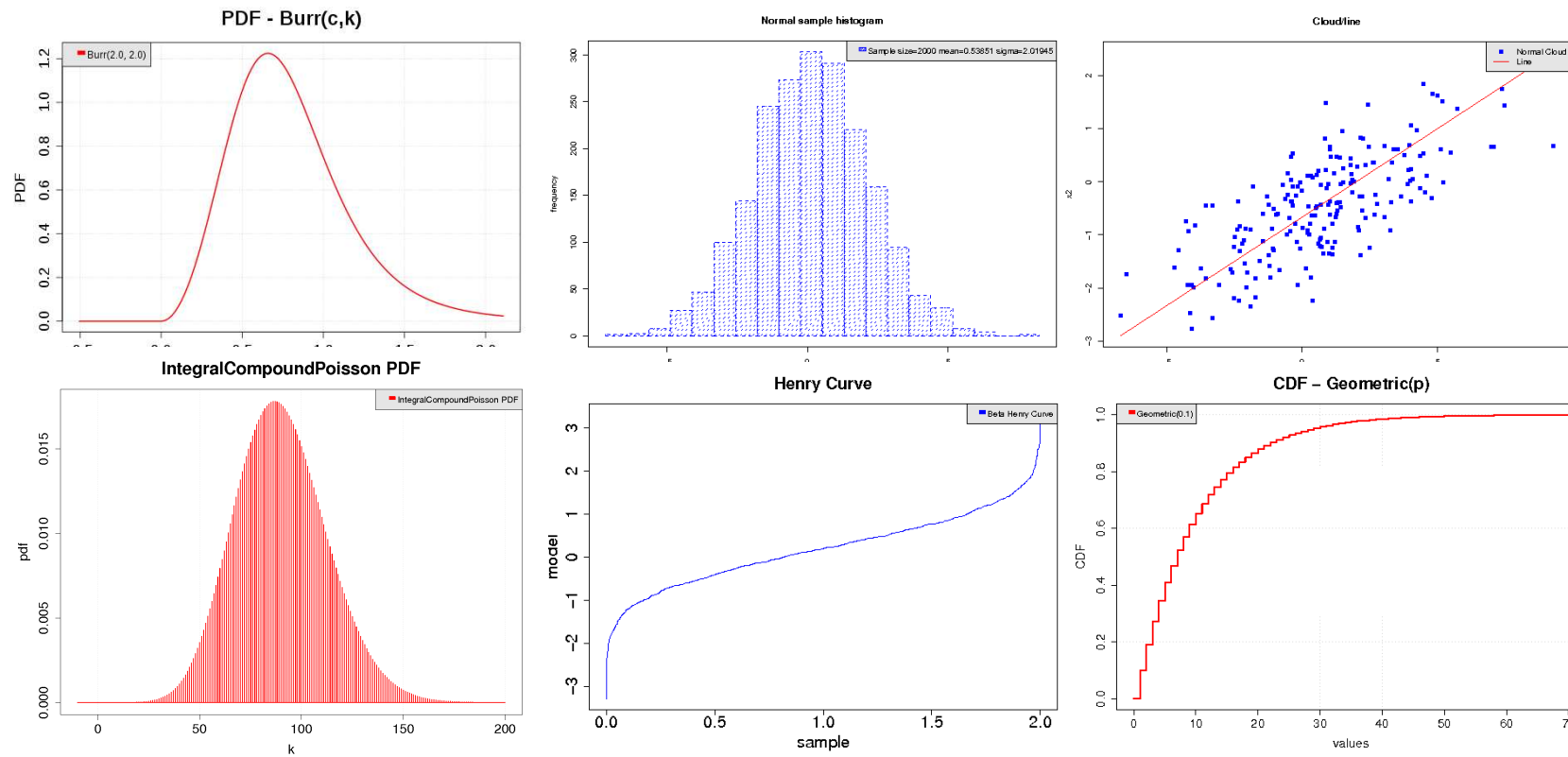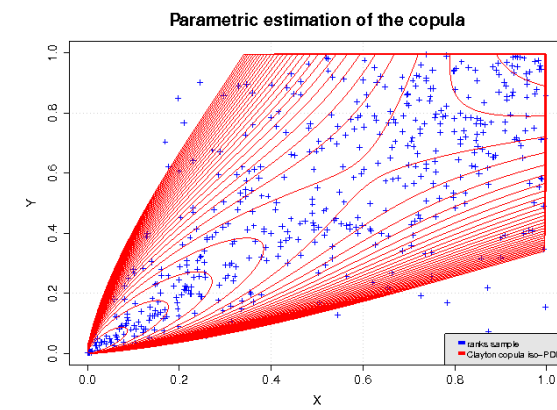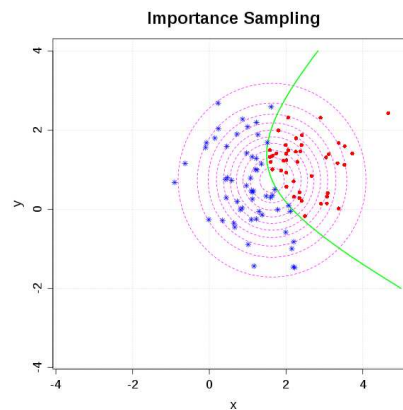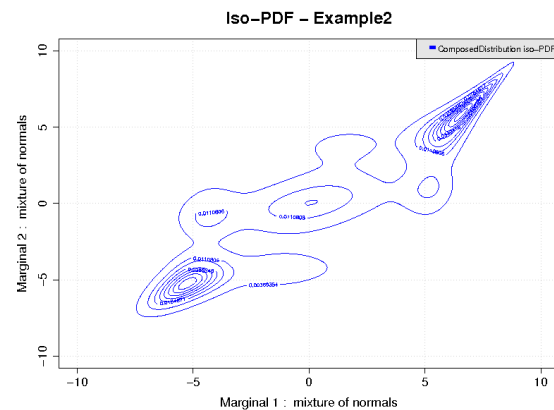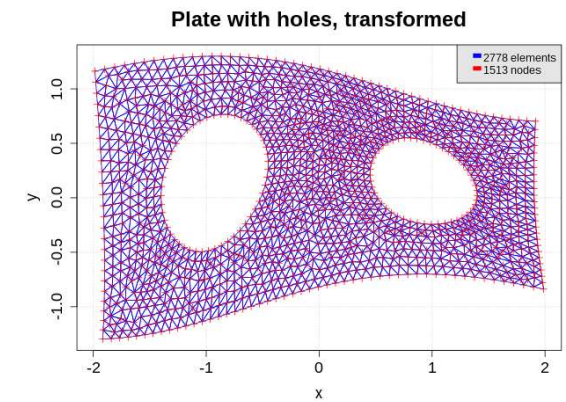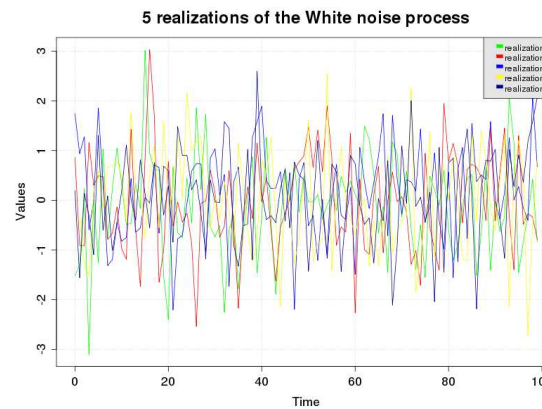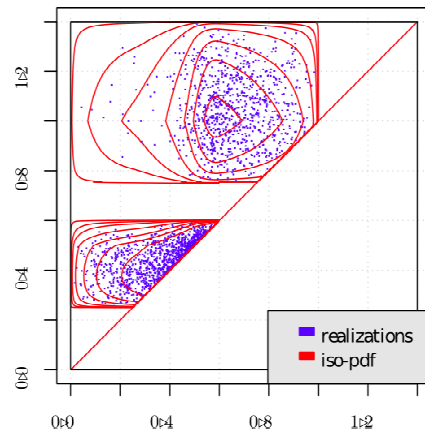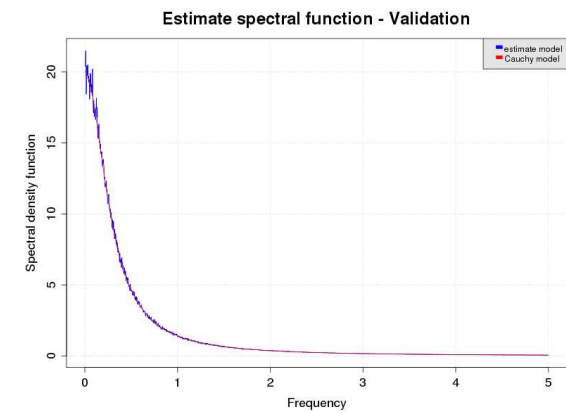

FORM – Event Probability Sensitivities – Marginal parameters – Event
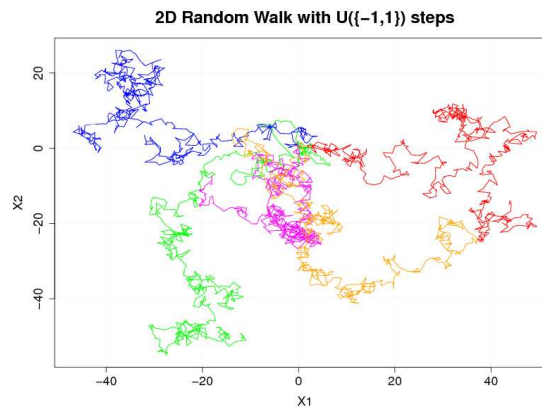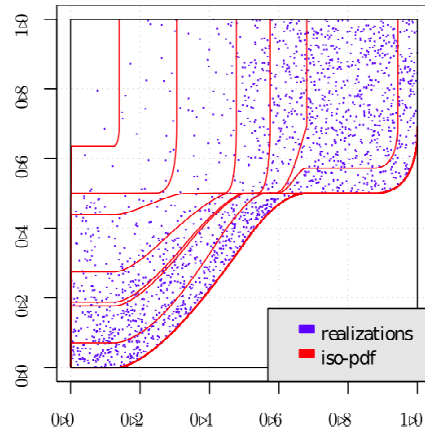

Présidentielle 2002 – 1er tour

Cobweb graph – [Y] vs [X1,X2]

Open TURNS in pictures
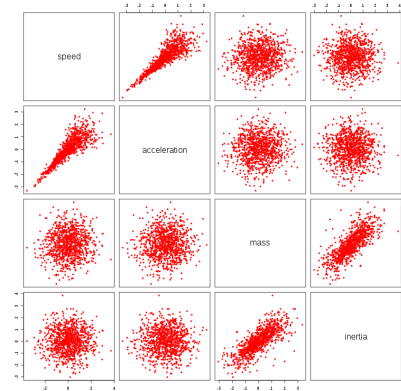
Open TURNS in pictures

Open TURNS : software, doc and Users

Open TURNS is ….
- ✓ **a C++ library** giving functionalities for the treatment of uncertainties
- ✓ **a pyhton module** offering high level operators

With a detailed documentation :
- ✓ **scientific documentation : Reference Guide,**
- ✓ **Users documentation : Use Cases Guide, User Manual, Examples Guide,**
- ✓ **technical documentation : Developer's Guide.**

… and a nice community :
- ✓ **www.openturns.org : official web site**
- ✓ **a particular page** *share* **to communicate about the sofware**
- ✓ **the annual Users day**

Open TURNS and its Consortium

➢ **The Open TURNS Consortium is organised around two main committees in close collaboration :**

    ✓ **Steering Committee** : driving the evolution of the scientific content and the architecture, responsible for the releases, organisation of the User's Day

    ✓ **Technical Committee :** responsible for the scientific and technological content, audit of the different contributions, pro active to propose evolutions and partnerships

➢ **How to contribute to / interact with Open TURNS ?**

    ✓ **Level 1 : the contributor wants to share around the tool** by proposing new functionalities (developed under C++ or python with the module mechanism), a script (pre / post processing of data, coupling with other tools, ….)

        ➔ **GO TO share.openturns.org**

    ✓ **Level 2 : the contributor wants to contribute to the official version of Open TURNS**

        Contribution to the C++ library, to the python TUI python

        ➔ **Open TURNS quality criteria to be respected (*at the end*) : code source + documentation, detailed in the Developer's Guide**

❖ **don't hesitate to contact the Open TURNS Consortium as soon as possible!**

IMACS : a new partner since January 2014

➢ **IMACS :**

- ✓ Research and technology provider specialised in numerical modelling, applied mathematics, scientific computing & HPC
- ✓ Fields: Computational Electro-Magnetics, Computational Vibro-Acoustics (SONATE distribution by LMS), Optimization, CAD-CAE link.
- ✓ Collaborative R&D (UMEPS, RAFFINE, CHORUS, Hi-BOX)
- ✓ Some references: Airbus Group, EDF R&D, PSA Peugeot Citroën, Thales Systèmes Aéroportés, Thales Avionics, Renault, Cegetel, ITO33, SAGEM, Dassault Aviation, Metravib R.D.S…

➢ **IMACS: free contributor for a few years**

- ✓ development of the stochastic processes based on specifications made by the consortium in 2011 et 2012
- ✓ Denis Barbier : scientific packager of the Debian distribution and in charge of the Open TURNS package for the Debian project

➢ **For the Open TURNS consortium:**

- ✓ it improves the scientific development task force
- ✓ it improves the expertise on the development of open source software
- ✓ it improves the expertise on HPC
- ✓ it improves the expertise in numerical analysis (EDP, mesh, ...)

Open TURNS – Web Site

> ➢ **Quick access to main parts of the website by left and upper menu**
>
> ➢ **Share page is the good place to share python scripts !**
>
> ➢ **Feel free to propose illustrations for the Home Page…**

Open TURNS – Trainings

➢ **EDF**

- ✓ **« Uncertainty Management : Open TURNS »**
- • **3 days to learn the use of Open TURNS : python TUI, wrapping aspects, application of the methodologie from step A to step C & C'**
- • **next session : 22-24/09/2014, ITECH ref : 4888**

- ✓ **« Uncertainty Management : Methodology »**
- • **3 days to learn the Uncertainty Methodology**
- • **next session : 15-17/09/2014, ITECH ref : 4888**

- ❖ **contact : Corine Tripet : 01 47 65 58 41**

➢ **PHIMECA**

- ✓ **Several 2 days sessions on the different steps from the methodology:**
  - ✓ **Probability & Statistics** => 17-18 Septembre 2014
  - ✓ **Response Surfaces Models** => 24-25 Septembre 2014
  - ✓ **Uncertainty propagation methods for sensitivity & dispersion analysis** => 8-9 Octobre 2014
  - ✓ **Uncertainty propagation methods for reliability evaluation** => 14-16 Octobre 2014

- ✓ **Introduction to the use of OpenTURNS : 2 days** => 19-20 Novembre 2014
- ✓ **Introduction to the use of PimecaSoft : 2 days** => 3-4 Décembre 2014
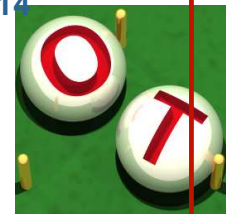
New features of the 1.3 & 1.4 releases

> **Last Releases : 1.3** in January 2014; *1.4 in July 2014.*

> **Scientific aspects :**
>   - ✓ **Kriging: cf. next presentation**
>   - ✓ **New distributions: Skellam, Wishart, InverseWishart, MeixnerDistribution, CompositeDistribution**
>   - ✓ **Processes: extension of all the classes to random fields (TemporalNormalProcess, CompositeProcess, FunctionalBasisProcess, WhiteNoise), new covariance models (ExponentiallyDampedCosineModel, SphericalModel, AbsoluteExponential, GeneralizedExponential, SquaredExponential), new data container (Field, Mesh, LevelSet), meshing facilities (MeshFactory, IntervalMesher)**
>   **cf. presentations of this afternoon**
>   - ✓ **Numerical models: Parametric functions (so simplified Bayesian calibration parameterization)**
>   - ✓ **Numerical facilities: KDTree, GaussKronrod**
>   - ✓ **New algebra on distributions and functions: (somewhat experimental…)**
>   **d = Normal() + Uniform()**
>   **d = (Normal().cos()-(Uniform()*3).exp()).sin()**
>   **f = NumericalMathFunction(''x'', ''sin(x)'') * NumericalMathFunction(''x'', [''x^2'',''tan(x)''])**

New features of the 1.3 & 1.4 releases
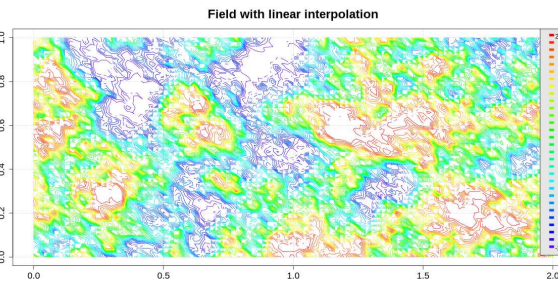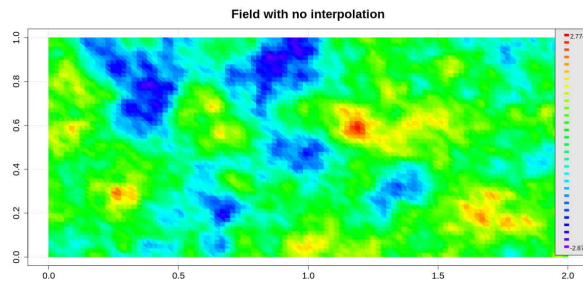
➢ **Illustration of some new distributions:**

- ✓ **Skellam: usefull for sensor noise modelling (CCD and CMOS cameras)… and soccer matchs analysis** *(Karlis, D. and Ntzoufras, I., « Bayesian modelling of football outcomes: using the Skellam's distribution for the goal difference », IMA Journal of Management Mathematics, 20 (2), pp133-145, 2009.)*
  X~Skellam(a,b) iff X=Y-Z with Y~Poisson(a), Z~Poisson(b) and Y,Z indep.

- ✓ **MeixnerDistribution (do not confuse with Meixner polynomials!): infinitely divisible distribution, to model marginals of time series with tails heavier than Gaussian**

- ✓ **Wishart and InverseWishart: to build exact confidence regions for the estimation of covariance and precision matrices for multivariate Gaussian data**

- ✓ **CompositeDistribution: the exact distribution (ie not based on sampling) of f(X) where X is an absolutely continuous random variable with known density and f a continuously differentiable scalar function with isolated extrema (may be used in more general context with appropriate constructor). E.g:**
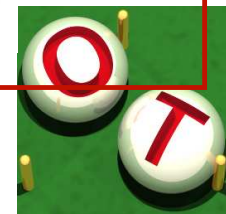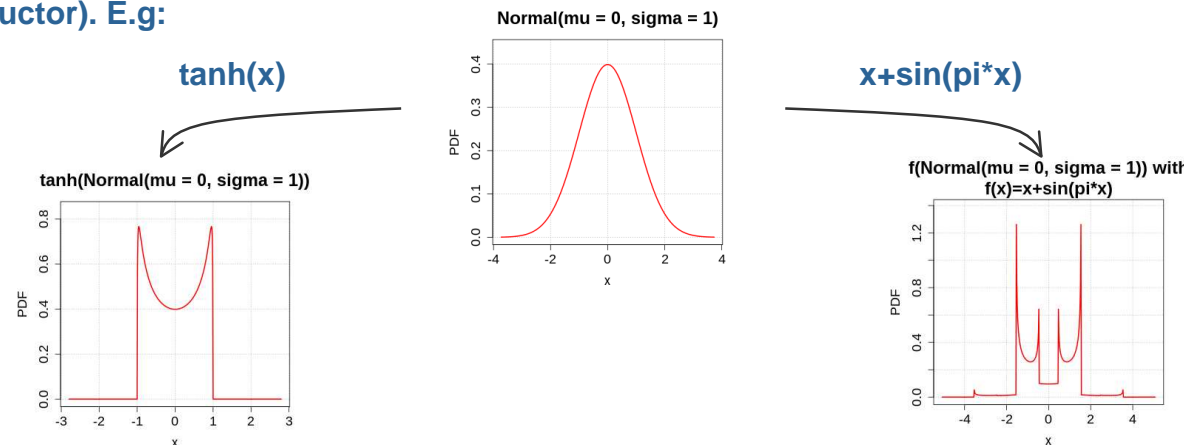
➢ **Random fields, some pictures:**

✓ **Visualization with OpenTURNS:**

Field with no interpolation

Field with linear interpolation

Using paraview export
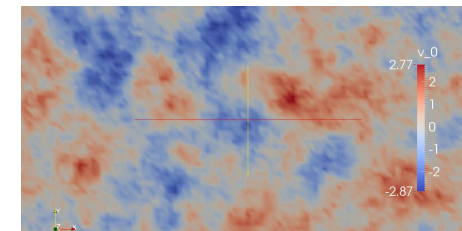
✓ **Covariance model and estimation:**

Exponential C as a function of (s,t)

NonStationary C as a function of (s,t)

Spherical C as a function of (s,t)
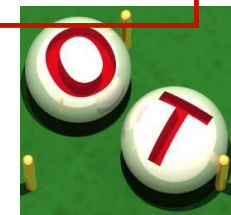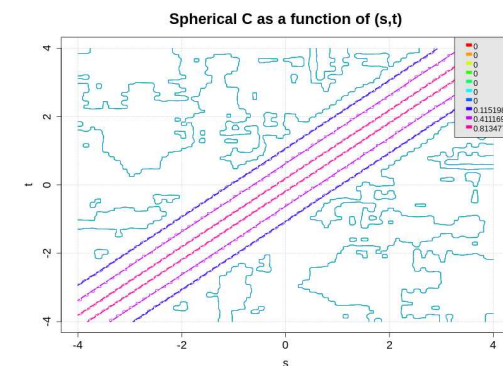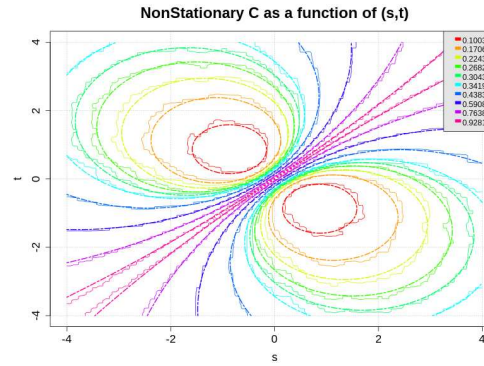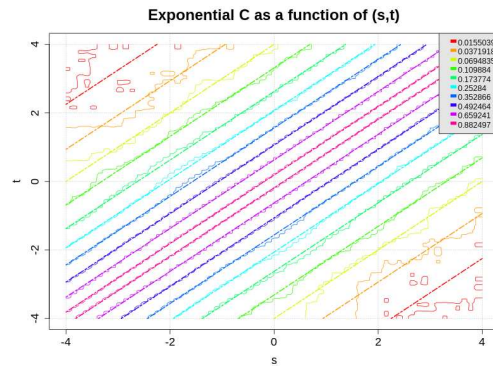
New features of the 1.3 & 1.4 releases

➢ **Technological new features**

  ✓ **see the wiki on the website www.openturns.org**

A New User Manual

➢ **User manual new look**

     ✓ **see the wiki on the website www.openturns.org**

Open TURNS Documentation: how to survive?

« I want to use Open TURNS! » →
Wiki: packages for standard environments
Care Users EDF: special process from Pléiades !
(https://forge-pleiade.der.edf.fr/projects/incertitudes/wiki/InstallationOTCalibreLogitheque)

« I want to write my first script Open TURNS! » →
Use Cases Guide: load a script
Examples Guide: a complete study
Wiki: « Quick start with Open TURNS »

« I want to adapt my first script to my study » →
Reference Guide: all the methodology
Use Cases Guide: almost all the scripts
User Manual: the openturns objects

« I want to wrap my code to Open TURNS » →
Developer's Guide: section « Wrappers »
Use Cases Guide: some wrappers examples

« I have a problem with Open TURNS» →
Mailing list: ask others!
If needed, **create a ticket**

« I want to contribute to Open TURNS » →
Developer's Guide: for a contribution in the library as well in the python module
Mailing list: ask others!
Share site to share your python development

« I want to use an Open TURNS module » →
Wiki: for the compatibility matrix of the module vs the library releases & links towrads the Debian packages (Windows & Linux) & Documentation

A New Documentation: some general advice

« I have a question about Open TURNS! »

about the installation
how to use a method, a module, ...
I don' t find what I want
I have a bug
how to implement what I want
...

Mailing list !

All the Open TURNS community

Perspectives

> **Works in progress in 2014 - 2015**
>> ✓ **native windows compilation**
>> ✓ **improvement of the bayesian techniques**
>> ✓ **improvement of the chaos polynomial fonctionalities**
>> ✓ **development of copulas of order statistics**
>> ✓ **links with optimisation libraries**
>> ✓ **...**

Open TURNS and the Kriging Approach

> ➢ **« The kriging approach to optimisation » : R. Leriche (CNRS, Mines deSt Etienne)**

> ➢ **« The Kriging Approach in Open TURNS v1.3 » : J. Schueller (PhiMECA)**
> > ✓ **voir la page wiki du site www.openturns.org**

Studies with Open TURNS

> **Study 1 :** « Bayesian calibration with Open TURNS » - G. Gamblin - **EDF R&D**

> **Study 2 :** « Open TURNS and stochastic fields - Simulation of synthetic misorientation maps of alloy 600 specimens » – G. Blatman - **EDF R&D**

> **Study 3 :** « Complex probabilistic modelling for electromagnetism shield » - S. Haddad – **IMACS**

> **Study 4 :** « Bayesian updating for degradation prediction » – R. Décatoire - **PhiMECA**

> **Study 5 :** « Statistical tolerancing taking into account flexibility » – H. Falgarone - **Airbus Group**

Discussion

> **Some ideas ...**

- ✓ **points on which you would like some improvements ?**

- ✓ **additional functionnalities ?**

- ✓ **how to improve the Open TURNS diffusion ?**

It's up to you !

The end ....

Thanks for your participation
... and see you next year !