WORKSHOP EMUE, PARIS

CASOFT, A SOFTWARE TO IMPLEMENT JCGM106

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January 21st-22nd , 2020

LABORATOIRE NATIONAL DE MÉTROLOGIE ET D'ESSAIS

OUTLINE

Focus on the operational functionnalities available in CASoft

- Need
  - JCGM106:2012
  - ISO17025:2017 Standard
- Decision-making based on a particular measured item : Specific risks
- Decision-making based on a future measurement : global risks and acceptance intervals
- A simplified framework for calibration and testing laboratories
- Details on the upcoming release of software

NEED

JCGM106:2012

- JCGM106:2012: « The role of measurement uncertainty in conformity assessment »
  - Provides guidelines for taking in to account measurement uncertainty in decision-making in conformity assessment…
  - … but requires a strong background in statistics and probability
    - The notions of Probability Density Functions (PDF), Cumulative Distribution Functions (CDF) are not easily understandable for many practitioners
    - The consideration of prior knowledge in uncertainty evaluation is still often neglected due to its conceptual and mathematical difficulty (A future « Bayesian GUM » will help to fill this gap)

Since 2012, the pratical application of these guidelines remained quite sparse outside of National Metrology Institutes

NEED

ISO 17025:2017

- 2017 : Revision of ISO 17025 standard
  - Many calibration and testing laboratories are accredited according to this standard
  - "When a statement of conformity to a specification or standard is provided, the laboratory **shall document the decision rule employed**, taking into account the level of risk (such as false accept and false reject and statistical assumptions) associated with the decision rule employed, **and apply the decision rule**"

New source of motivation to apply JCGM106:2012 guidelines :

- The decision rule should be explicitely known by any party involved in the decision-making process, even before any measurement is made.

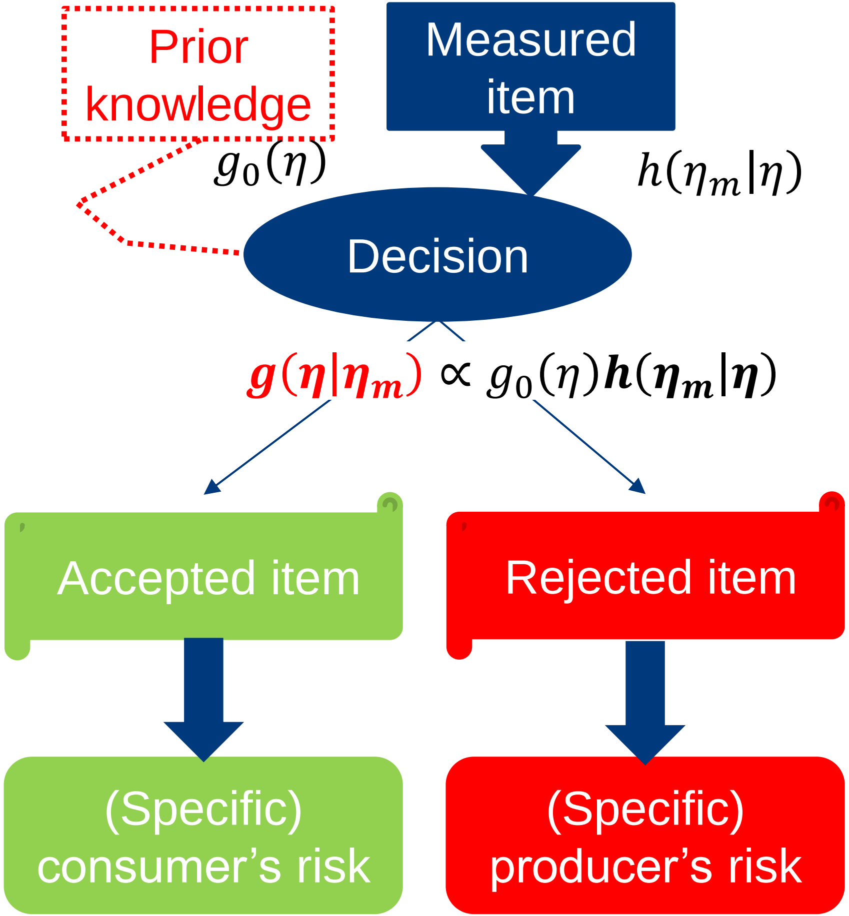
CONFORMANCE PROBABILITY AND SPECIFIC RISKS

- **Conformance probability** p_c : « probability that an item fulfills a specified requirement » (JCGM 106:2012)
  - **« Specific consumer's risk »** : probability that a particular accepted item is non-conforming »

$$R_c^* = 1 - p_c$$

  - **« Specific producer's risk »** : probability that a particular rejected item is conforming

$$R_p^* = p_c$$



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CONFORMANCE PROBABILITY AND SPECIFIC RISKS

A calculation based on the … posterior distribution

$$\boldsymbol{g(\eta|\eta_m)} \propto g_0(\eta)\boldsymbol{h(\eta_m|\eta)}$$

- JCGM106:2012 encourages to take into account all available information, that may come from :
  - The measurement itself, modelled by $\boldsymbol{h(\eta_m|\eta)}$
  - Any available prior information, modelled by $g_0(\eta)$

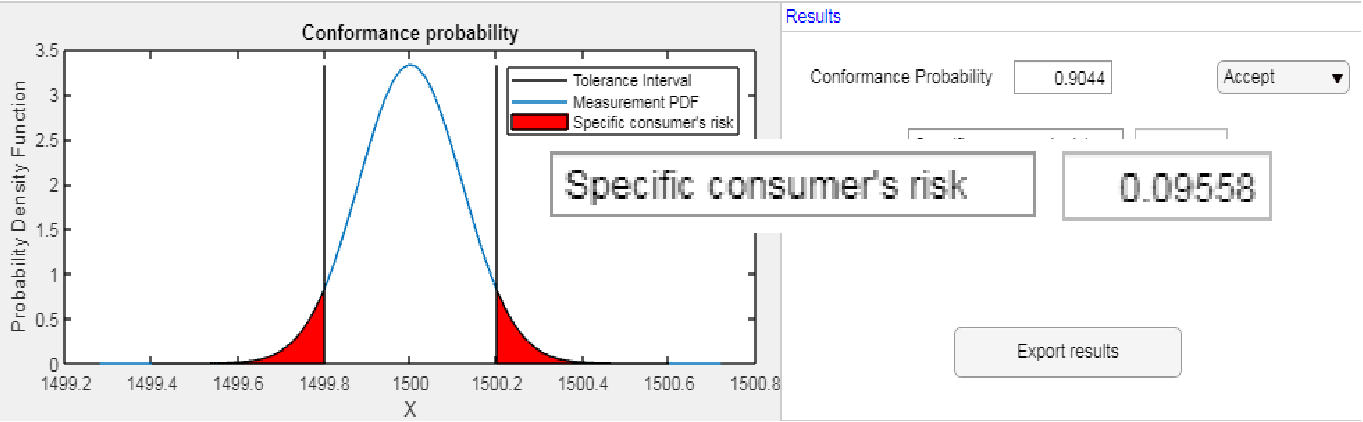
Bayes' theorem $\Rightarrow$ $\boldsymbol{g(\eta|\eta_m)}$

- But …
  - Guidelines are widely available for evaluating $\boldsymbol{h(\eta_m|\eta)}$ (GUM, GUM Supplement 1, …)
  - Not yet for the consideration of prior knowledge and the use of Bayes' theorem (Objective of some of the examples from EMUE project)

CONFORMANCE PROBABILITY AND SPECIFIC RISKS

CASoft for specific risks

- Following JCGM106:2012, CASoft proposes to the end user to choose among some common distributions for both the **prior distribution** and the **measurement distribution**, including the case where no prior distribution is available



$$p_c = 0.9044$$

$$R_c{}^* = 1 - p_c = 9.56\ \%$$

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PRIOR KNOWLEDGE AND SPECIFIC RISK

A warning

The evaluation of specific risks relies on the posterior distribution, that is a **compromise** between :

- The prior distribution
- The distribution associated with the measurement result (obtained using GUM or GUM-S1)

In practice, wheat kind of information can reasonably be used as prior information ?

- The history of the calibrations of the same equipment ?
- Information from the manufacturer ?
- Preliminary measurement for the same item ?

The consideration of prior knowledge leads to a different probability distribution and a different decision. Care should be taken to take into account only reliable information for the considered measurement

APPLICATION : THICKNESS OF A WASTE BAG

Illustration with CASoft

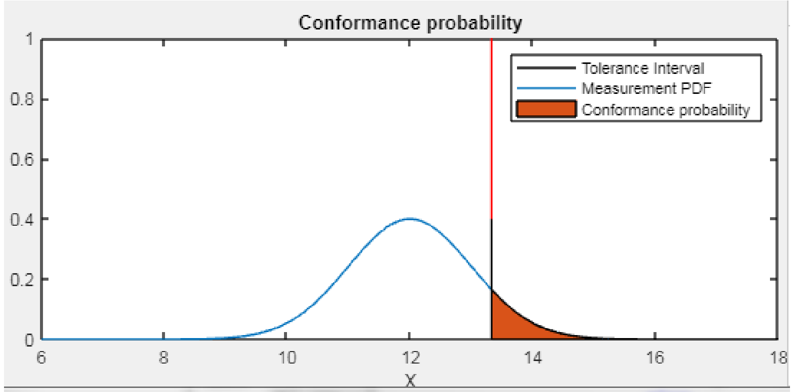
EN 13592:2003+A1 provides a lower tolerance limit T_L for the thickness of a waste bag having a nominal thickness of 20 µm

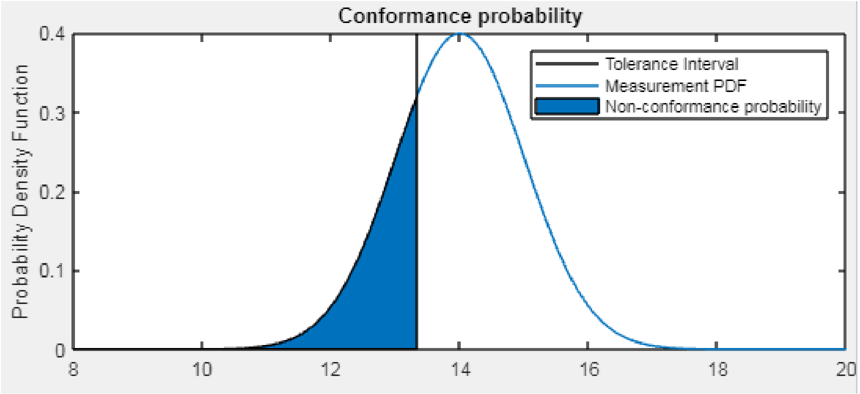
$$T_L = 13.33\ \mu m$$

Measured value (µm)	Standard uncertainty (µm)	Decision (Accept/Reject)	Conformance probability	Specific risk
12	1	Reject	0.092	$\mathrm{R}_\mathrm{p}^* = 0.092$
13	1	Reject	0.371	$\mathrm{R}_\mathrm{p}^* = 0.371$
14	1	Accept	0.749	$\mathrm{R}_\mathrm{c}^* = 0.251$
16	1	Accept	0.996	$\mathrm{R}_\mathrm{c}^* = 0.004$

APPLICATION : THICKNESS OF A WASTE BAG

Measured value (µm)	Standard uncertainty (µm)	Decision (Accept/Reject)	Conformance probability	Specific risk
12	1	Reject	0.092	$R_p^* = 0.092$
14	1	Accept	0.749	$R_c^* = 0.251$





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GLOBAL RISKS

- « Global consumer's risk » : probability that a non-conforming item will be accepted based on a future measurement result

$$R_C = \mathbb{P}(\{\eta \notin [T_L; T_U]\} \cap \{\eta_m \in [A_L; A_U]\})$$

- « Global producer's risk » : probability that a conforming item will be rejected based on a future measurement result

$$R_C = \mathbb{P}(\{\eta \in [T_L; T_U]\} \cap \{\eta_m \notin [A_L; A_U]\})$$

- The calculation of global risks rely on the joint distribution of the prior and measurement distributions

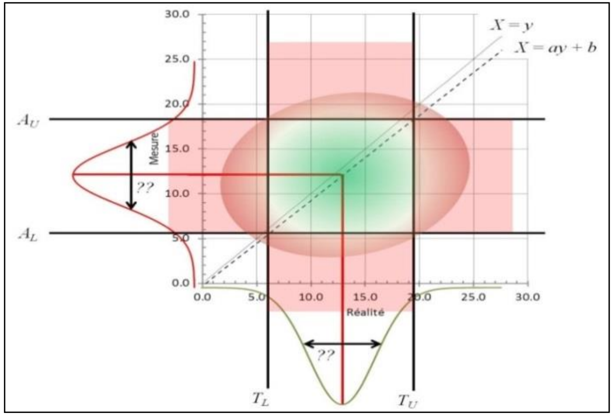
Measurement

$h(\eta_m|\eta)$

Reality

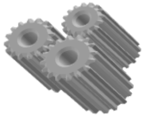
$g_0(\eta)$

	Accepted	Rejected
Conforming	Valid Acceptance	False rejection
Non Conforming	False acceptance	Valid rejection

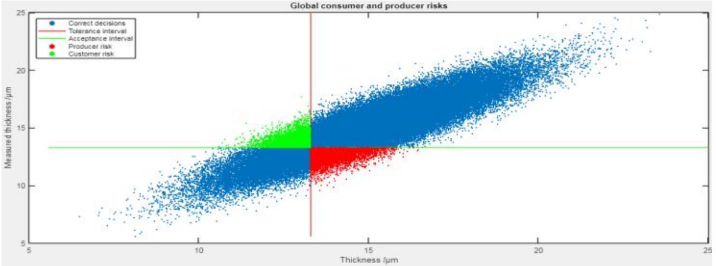


APPLICATION : THICKNESS OF A WASTE BAG

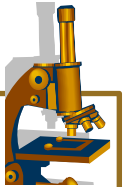
Use of CASoft for the optimization of the production process



Production :
$y_0 = 15\ \mu m$
$u_0 = 2\ \mu m$

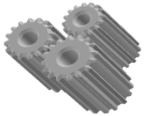


$$\begin{cases} R_C = 4{,}2\% \\ R_P = 6{,}7\% \end{cases}$$

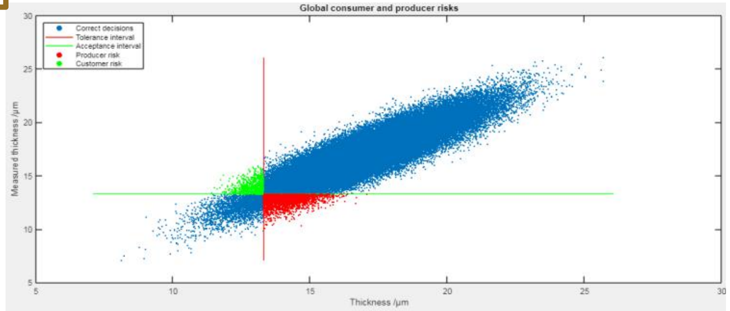


$u_m = 1 \mu m$

6,7% of the production is falsely rejected : the producer decides to produce waste bags with a higher mean thickness



Production :
$y_0 = 17\ \mu m$
$u_0 = 2\ \mu m$



$$\begin{cases} R_C = 0{,}9\% \\ R_P = 2{,}6\% \end{cases}$$

Conclusion

CASoft will be used to check the impact on decision-making of different possible changes:

- A modification of the prior distribution
- An improved measurement uncertainty
- The consideration of a different acceptance interval

Posterior distribution/joint distribution

- The difference between the **posterior PDF** and the **joint PDF** is not straightforward for practiotioners who already have difficulty in understanding the concept of a PDF.

- The concept of prior information is often misunderstood in the community
  - Lack of guidance on the choice of prior PDF
  - Risk of neglecting completely the information from the measurement itself if the prior PDF is very tightened.

USERS' NEED

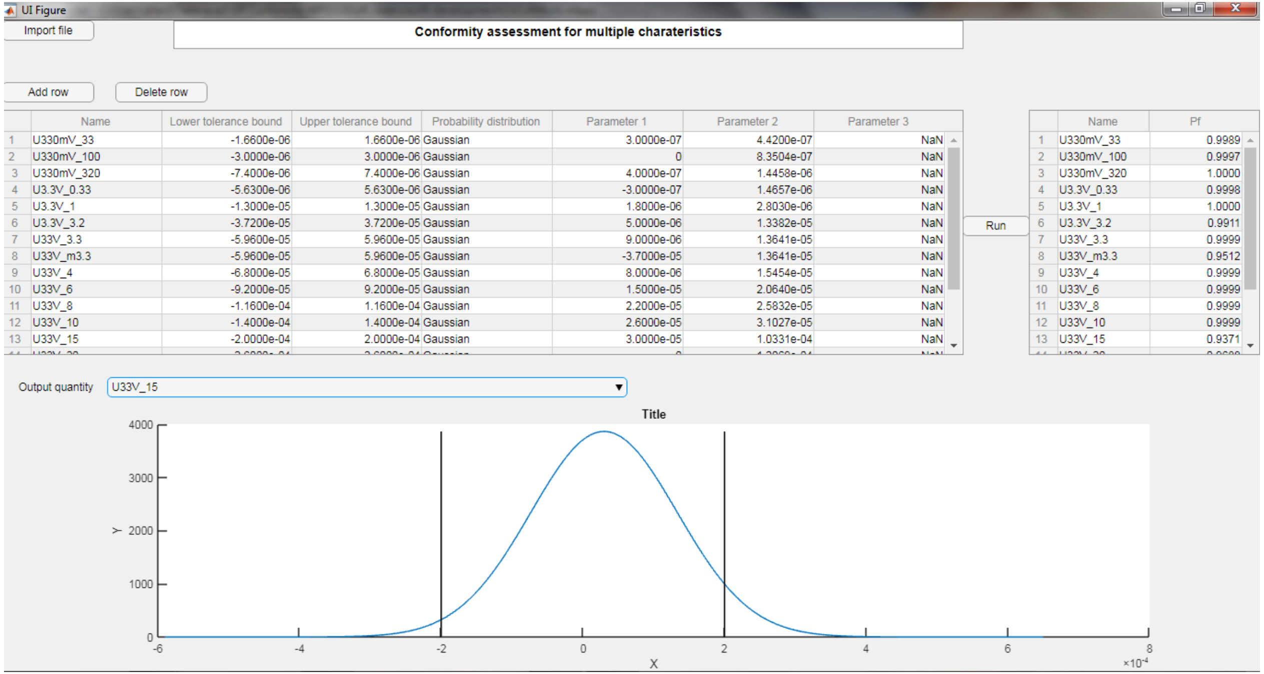
Feedback from CASoft's primary supporter

- Typical calibration operations include multiple measurements for a single item (Ex : calibration of a multimeter)
  - Voltage calibration… for different voltage levels…
  - Resistance calibration… for different resistance levels…
  - Current calibration… for different current levels…
  - 126 measurement results are considered for deciding whether the multimeter is conforming or not.
- Current practice in the laboratory does not consider any prior distribution
  - Need for a simplified tool for calculating conformance probabilities quickly for each individual quantity of interest.

CASOFT FUNCTIONALITIES

Conformance probability for multiple quantities of interest

- Restricted choice of PDFs (Gaussian, t Student)
- No prior knowledge
- Calculation of the conformance probability up to 300 components



CASOFT DETAILS

Coming soon !

- A first release of CASoft is expected by early February 2020
- A freely available software, developed as a standalone application using Matlab
    - No purchase of any Matlab license is required
    - Available on www.lne.fr/en
    - In English

CONCLUSION

- Support for Impact Project (LNE-NPL-RISE)

- Objective : Facilitate the uptake of JCGM106 by the community by:
  - Development of software
  - Communication activities

- Important dialog with Trescal, primary supporter of the project, to get the feedback from « real life » in conformity assessment

- The simplified version of CASoft is an important step between current practice in laboratories and a full bayesian framework as described in JCGM106:2012.

Thank you for your attention

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States