Modeling in measuring devices calibration procedures.

(for discussion)

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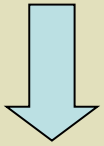
Introduction

Application of uncertainty evaluation framework to evaluation of data in calibration of measuring instruments



?

- formulating the measurement model,
- assigning the priory distributions to the input and output quantities,
- calculation of instrumental uncertainty,
- interrelation between calibration and checking compliance with the requirements

The procedure for data evaluation at calibrating MI comprises four steps:

1. constructing measurement models,

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2. calculating uncertainties of input quantities,
3. calculating uncertainty of output quantity,

4. analyzing (interpretation) the results

Classification of measurement models

measurement task	comparison	calibration	testing (control, verification)	others ?
measurement method	•direct or indirect measurements, •comparisons (substitution method,…), • ….			
field of measurement	physical model + measuring instrument model + measurement conditions			

Calibration [VIM, 2.39]

- **Calibration -** operation that, under specified conditions, in a first step establishes a ***relation between the quantity values*** with measurement uncertainties ***provided by measurement standards*** and ***corresponding indications*** **(I)** with associated measurement uncertainties and, in a second step, uses this information to establish a ***relation for obtaining a measurement result from an indication*** **(II)**.

Expression of calibration

First step

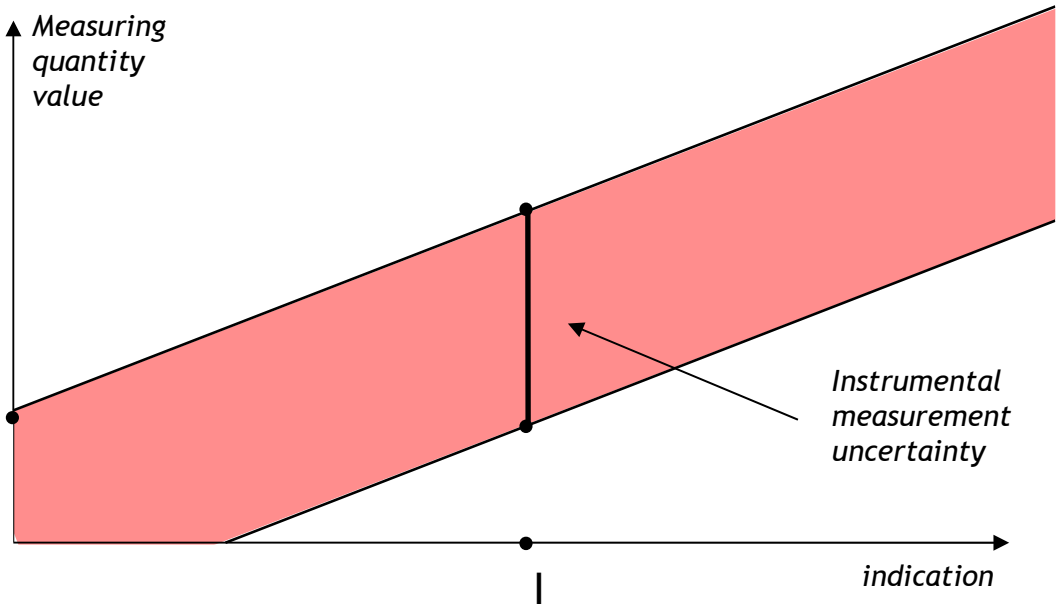
- calibration function
- calibration table

$$I = f(X)$$

Second step

- calibration diagram -graphical expression of the relation between indication and corresponding measurement result

$$X = \tilde{f}^{-1}(I)$$



First step. Modeling

- ***relation between the quantity values*** with measurement uncertainties ***provided by measurement standards*** and ***corresponding indications***

$$I = f(X)$$

Error

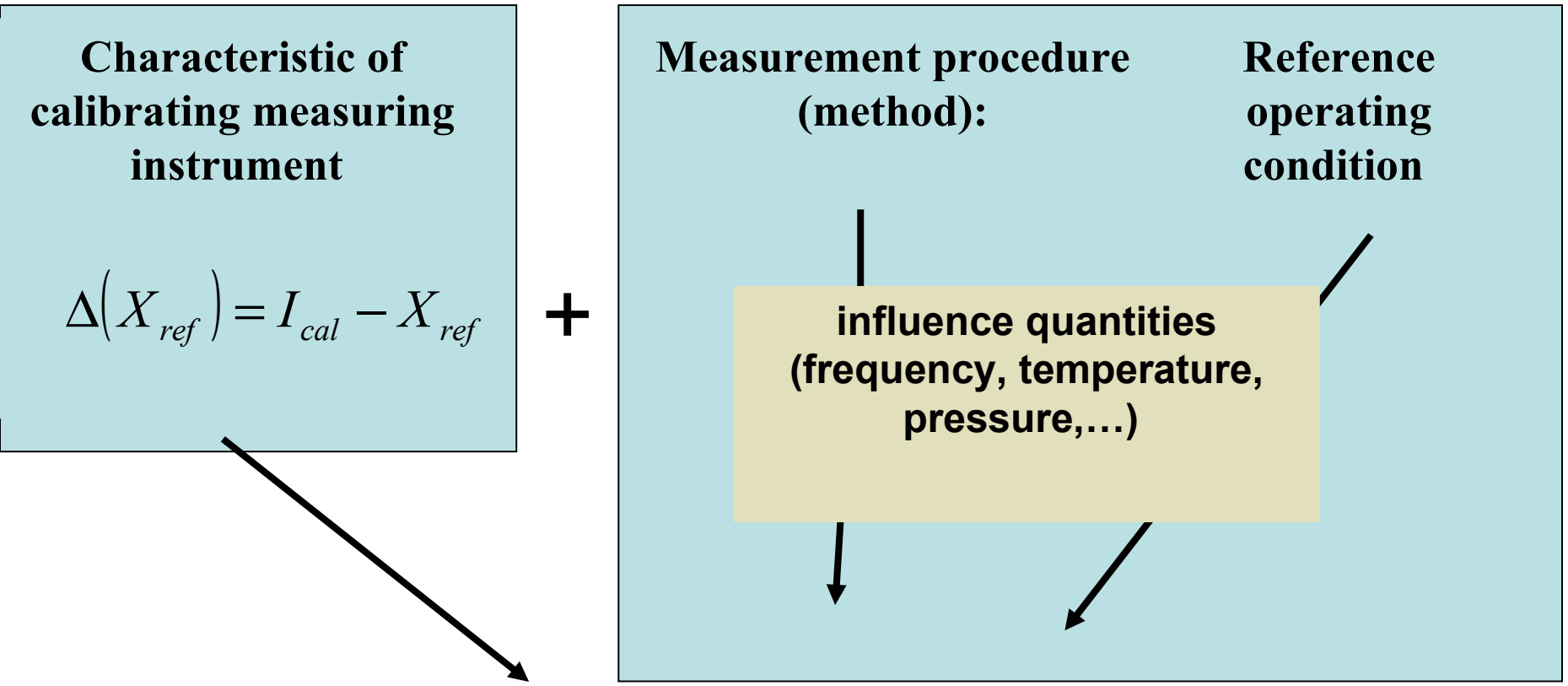
$$\Delta(X_{ref}) = I_{cal} - X_{ref}$$

Calibration coefficient

$$k = \frac{I_{cal}}{X_{ref}}$$

others

Measurement model



$$\Delta(X_{ref}) = I_{cal} - X_{ref} + G(Z_1,\ldots,Z_k)$$

Evaluating measurement uncertainty

prior information measurement results

$$I, X_{ref}, Z_1, \ldots, Z_k$$

input quantities' values + associated uncertainties

Error (instrumental bias)

+ associated uncertainty

+

prior information about error - maximum permissible measurement error (MPE)

prior distribution of input quantities and MI error

checking consistency of relevant information

posterior distribution of MI error , its best estimate and associated uncertainty

$$\hat{\Delta}(x_{ref}), u(\hat{\Delta}(x_{ref}))$$

The relation for obtaining a measurement result from MI indication: some practical solutions:

- **Correction for systematic bias:**

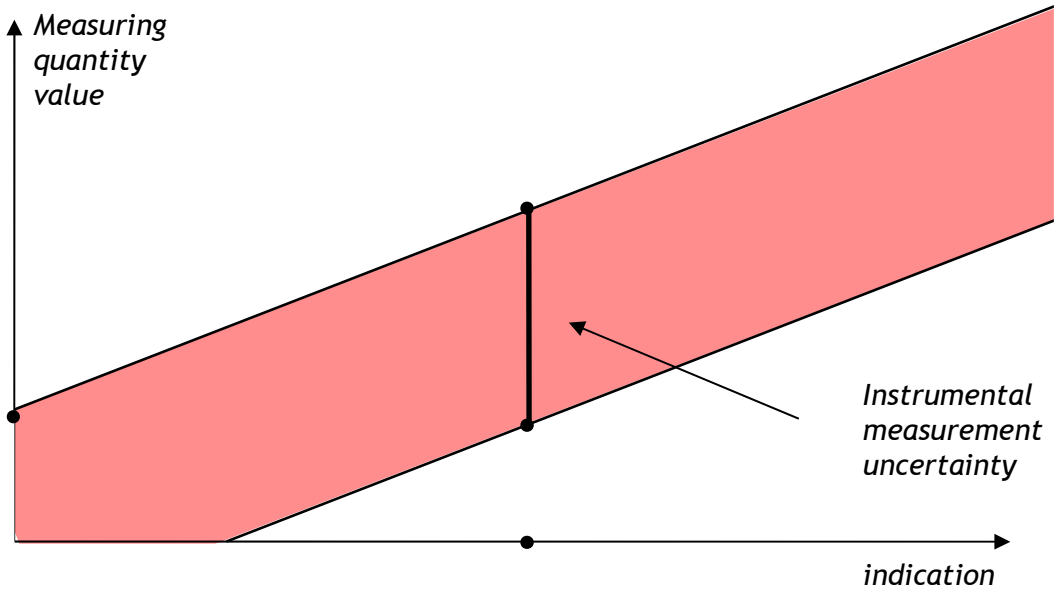
$$I^{correct}{}_{cal} = I_{cal} - \Delta\left(X_{ref}\right)$$

$$u_{inst}\left(x(t)\right) = u\left(\Delta\left(x_{ref}\right)\right)$$

- **Without correction:**

$$u_{inst} = \sqrt{\Delta^2\left(X_{ref}\right) + u^2\left(\Delta\left(x_{ref}\right)\right)}$$

Step II. Modeling

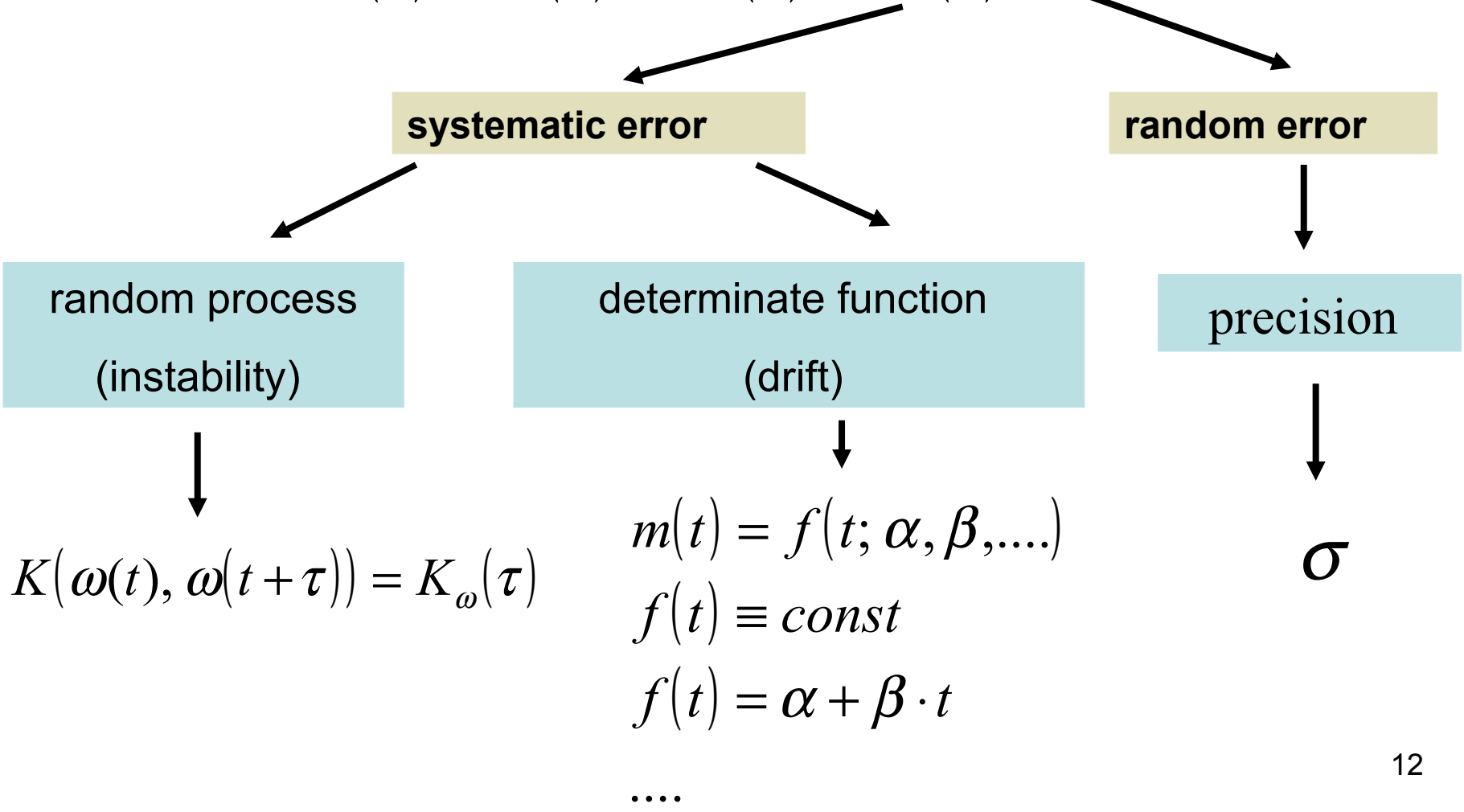


$$u_{instr}(x)$$

$$\hat{\Delta}(t), u\left(\hat{\Delta}(t)\right) \quad ? \quad x(t+\tau), u_{inst}\left(x(t+\tau)\right)$$

Measuring instrument error modeling

$$\Delta(t) = I(t) - X(t) = \omega(t) + \varepsilon$$



prior information

I

- maximum permissible measurement error (MPE) θ
- precision (SD) σ
- results of previous calibration

II

results of calibration

$$\hat{\Delta}\left(x_{ref}, t_0\right), u\left(\hat{\Delta}\left(x_{ref}, t_0\right)\right)$$

III

investigation of stability of MI error

Analysis and interpretation of all available information

"evaluation approach":

$$p\left(\omega(t+\tau) \mid \omega(t)\right) = \frac{p\left(\omega(t+\tau), \omega(t)\right)}{p\left(\omega(t)\right)}$$

estimate of MI error and associated uncertainty

$$E\left(\omega(t+\tau) \mid \omega(t)\right), D\left(\omega(t+\tau) \mid \omega(t)\right)$$

"checking approach":

???

$$\Delta(t_0) < \theta$$

$$u_{inst} = \frac{\theta}{\sqrt{3}}$$