

**Metrological certification of the algorithms and  
validation of corresponding software intended for  
measurement data processing**

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The aim of the paper is to outline the metrological aspect in the general problem of quality assurance of software used for measurement data processing. The term “validation” seems to be the most appropriate in this context.

*“Validation is confirmation through the provision of objective evidence, that the **requirements for specific intended use** or application have been fulfilled”*

We are going to discuss the following items:

1. requirements for specific intended use of software in metrology
2. general scheme for providing validation of packages for data processing, used in metrology
3. general scheme for providing validation of embedded software

The metrological requirements includes:

1. Necessity to provide accuracy estimates of the final results obtained using software and to report the results with associated uncertainties
2. Usage of the data processing algorithm in accordance with the corresponding guidelines applied in a particular field of measurement
3. Estimation of measurement uncertainty should be done within the frames of GUM

# **Validation of the packages intended for measurement data processing.**

Measurement data (initial data) :

estimates of input quantities + associated uncertainties

Reporting results:

estimates of output quantities + associated uncertainties

Hence main software should be accompanied by corresponding software for uncertainty evaluation.

Uncertainties of output quantities are caused by:

- uncertainty of input quantities
- algorithm for data processing
- algorithms for uncertainty evaluation
- realisation of above algorithms in software

Measurement Devices

$\{x_i, u_i\}_{i=1}^N$

$\{u_i\}_{i=1}^N$

$\{X_i, u_i\}_{i=1}^N$

Reference  
Data Set  
 $\{X_i\}_{i=1}^N$

Reference  
Result  
 $Y$

Software

Software for  
Uncertainty Evaluation

Law of  
Propagation  
of Uncertainty

Law of  
Propagation  
of Distributions

Final  
Result

+

Associated  
Uncertainty

$pdf(Y)$

$E(Y),$   
 $D(Y)$

$P(|E(Y) - Y| \geq \varepsilon) \leq \frac{u^2(y)}{M\varepsilon^2}?$

The following items should be pointed out:

1. Uncertainty evaluation is performed in accordance with GUM frames
2. Uncertainty caused by software itself isn't estimated separately
3. Reference data sets are used for checking that uncertainty due to software is not significant as compared with the transformed uncertainties of input data

## **Validation of embedded software.**

1. Metrological maintenance assurance of embedded software begins at the stage of measuring instrument (MI) or measuring system (MS) development

2. Algorithm for data processing is chosen in accordance with guidelines or its accuracy characteristics estimated a priori. Here the methodology of data processing algorithm certification is applicable

# Metrological Certification of Data Processing Algorithms

## Typical Data Models

### Valid Signals:

- Functions
- Time Series
- ...

+

### Noise:

- Random Noise
- Systematic Drift
- Distribution Law
- ...

## Quality Characteristics

### Accuracy

#### Type:

- Methodical
- Transformed

### Stability

#### Measure:

- Expectation
- Variance
- Limits

### Complexity

#### Way of Estimation:

- Analytical
- Approximation
- Simulation

$$I = \int_a^b y(t) dt$$

	Rectangle rule	Simpson rule
Input Data Model	$y_i = y(t_i) + \varepsilon_i \quad \varepsilon_i \in N(0, \sigma^2) \quad i = 1, \dots, m$	
Formula	$S = \frac{b-a}{m} \sum_{i=0}^{m-1} y_i$	$S = \frac{h}{3} [y_0 + 4y_1 + 2y_2 + 4y_3 + \dots + 4y_{m-1} + y_m]$
Deviation Limits	$\left  S - \int_a^b y(t) dt \right  \leq \frac{(b-a)^2}{2m} \cdot \max_{[a,b]}  y'(t) $	$\left  S - \int_a^b y(t) dt \right  \leq \frac{(b-a)^5}{90m^4} \cdot \max_{[a,b]}  y^{(4)}(t) $
Standard Deviation	$\frac{2\sigma(b-a)}{\sqrt{m}}$	$\frac{2\sqrt{2}}{3} \sigma(b-a) \sqrt{\frac{5m-1}{m^2}}$

# Validation of embedded software

3. At the stage of MI development it's possible to perform software testing using reference data sets

4. At the stage of MI usage a through check is often possible when calibrating or testing the MI

5. For complex MS a through check isn't possible as a rule. At the stage of MS operation element-to-element check should be provided for by means of internal control

## Comparable analysis of packages and embedded software validation

- Packages
- It's made at the stage of packages using in conditions specified by measurement procedure
- As a rule a posterior way on uncertainty evaluation is assumed
- GUM framework is applied directly
- Uncertainty evaluation is followed by experimental check on reference data sets
- Embedded software
- It's made at the stage of MI (MS) development
- As a rule a priority way on uncertainty evaluation is assumed
- Methodology of data processing algorithms certification is useful
- At the stage of MI (MS) through check or element-to-element check should be provided for