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For Comments Only

Draft Indian Standard

Determination and use of Straight-Line Calibration Functions

ICS 03.120.30

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NATIONAL FOREWORD

(Formal clauses to be added later on)

The text of the International Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standard. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

In this adopted standard, reference appears to an International Standard for which Indian Standard also exists. The corresponding Indian Standard, which is to be substituted in its place, is listed below along with its degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO/IEC Guide 99:2007, International vocabulary of metrology | Basic and general concepts and associated terms (VIM)	IS/ISO/IEC Guide 99:2007, International vocabulary of metrology - Basic and general concepts and associated terms (VIM)	Identical

In this adopted standard, references appear to certain International Standards for which no Indian Standards exist. The technical committee have reviewed the provisions of the following International standards referred in this standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
ISO/IEC Guide 98-3:2008	Uncertainty of measurement | Part 3: Guide to the expression of uncertainty in measure-ment (GUM:1995)

Annexes A to G are informative only.

Note: The technical content of the document is not available on website. For details, please refer the corresponding ISO/TS 28037: 2010 or kindly contact:

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Scope

This Technical Specification is concerned with linear, that is, straight-line, calibration functions that describe the relationship between two variables X and Y, namely, functions of the form $Y = A + BX$. Although many of the principles apply to more general types of calibration function, the approaches described exploit the simple form of the straight-line calibration function wherever possible.

Values of the parameters A and B, are determined on the basis of measured data points $(xi; yi)$, $i = 1,\ldots,m$. Various cases are considered relating to the nature of the uncertainties associated with these data. No assumption is made that the errors relating to the yi are homoscedastic (having equal variance), and similarly for the xi when the errors are not negligible.

Estimates of the parameters A and B are determined using least squares methods. The emphasis of this Technical Specification is on choosing the least squares method most appropriate for the type of measurement data, in particular methods that reflect the associated uncertainties. The most general type of covariance matrix associated with the measurement data is treated, but important special cases that lead to simpler calculations are described in detail.

For all cases considered, methods for validating the use of the straight-line calibration functions and for evaluating the uncertainties and covariance associated with the parameter estimates are given.

The Technical Specification also describes the use of the calibration function parameter estimates and their associated uncertainties and covariance to predict a value of X and its associated standard uncertainty given a measured value of Y and its associated standard uncertainty.

NOTE 1 The Technical Specification does not give a general treatment of outliers in measurement data, although the validation tests given can be used as a basis for identifying discrepant data.

NOTE 2 The Technical Specification describes a method to evaluate the uncertainties associated with the measurement data in the case that those uncertainties are known only up to a scale factor (Annex E).

Introduction

Calibration is an essential part of many measurement procedures and often involves fitting to measured data a calibration function that best describes the relationship of one variable to another. This Technical Specification considers straight-line calibration functions that describe a dependent variable Y as a function of an independent variable X. The straight-line relationship depends on the intercept A and the slope B of the line. A and B are referred to as the parameters of the line. The purpose of a calibration procedure is to determine estimates a and b of A and B for a particular measuring system under consideration on the basis of measurement data $(xi; yi)$, $i = 1,\ldots,m$, provided by the measuring system. The measurement data have associated uncertainty, which means there will be uncertainty associated with a and b. This Technical Specification describes how a and b can be determined given the data and the associated uncertainty information. It also provides a means for evaluating the uncertainties associated with these estimates. The treatment of uncertainty in this Technical Specification is carried out in a manner consistent with ISO/IEC Guide 98-3:2008, “Guide to the expression of uncertainty in measurement” (GUM).

Given the uncertainty information associated with the measurement data, an appropriate method can be specified to determine estimates of the calibration function parameters. This uncertainty information may include quantified covariance effects, relating to dependencies among some or all of the quantities involved.

Once the straight-line model has been fitted to the data, it is necessary to determine whether or not the model and data are consistent with each other. In cases of consistency, the model so obtained can validly be used to predict a value x of the variable X corresponding to a measured value y of the variable Y provided by the same measuring system. It can also be used to evaluate the uncertainties associated with the calibration function parameters and the uncertainty associated with the predicted value x.

The determination and use of a straight-line calibration function can therefore be considered to consist of five steps:

1. Obtaining uncertainty and covariance information associated with the measurement data - although dependent on the particular area of measurement, examples are provided within this Technical Specification;
2. Providing best estimates of the straight-line parameters;
3. Validating the model, both in terms of the functional form (does the data reflect a straight-line relationship?) and statistically (is the spread of the data consistent with their associated uncertainties?) using a chi-squared test;
4. Obtaining the standard uncertainties and covariance associated with the estimate of the straight-line parameters.
5. Using the calibration function for prediction, that is, determining an estimate x of the X-variable and its associated uncertainty corresponding to a measured value y of the Y-variable and its associated uncertainty.

The above steps are shown diagrammatically in Figure 1.

The main aim of this Technical Specification is to consider steps 2 to 5. Therefore, as part of step 1, before using this Technical Specification, the user will need to provide standard uncertainties, and covariances if relevant, associated with the measured Y-values and, as appropriate, those associated with the measured X-values. Account should be taken of the principles of the GUM in evaluating these uncertainties on the basis of a measurement model that is specific to the area of concern.

ISO 11095:1996 [14] is concerned with linear calibration using reference materials. It differs from this Technical Specification in the ways given in Table 1.

The numerical methods given are based on reference [6].

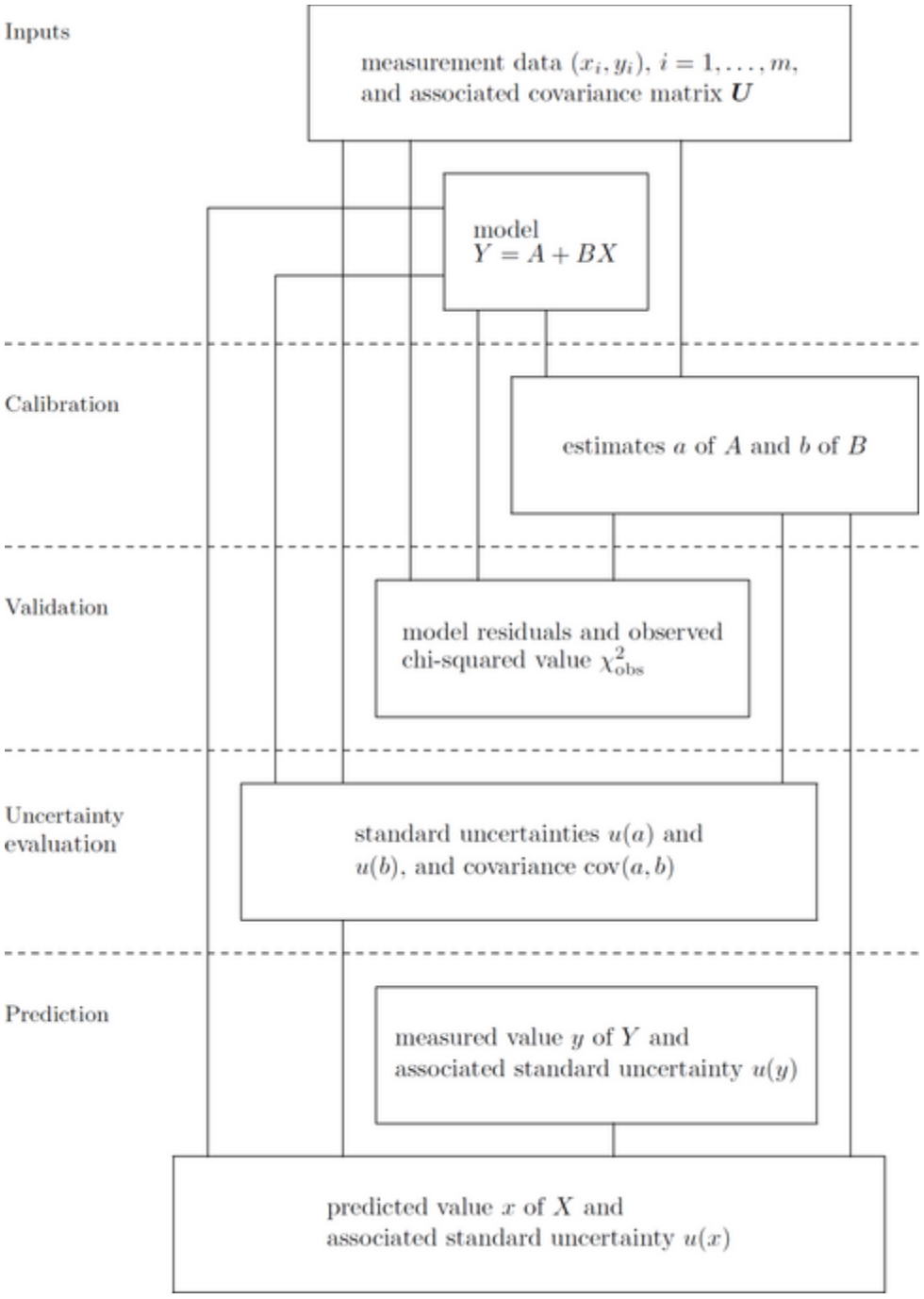

Figure 1 — Summary of the steps in the determination and use of straight-line calibration functions

Table 1 — Differences between ISO 11095:1996 and ISO/TS 28037:2010

Feature	ISO 11095:1996	ISO/TS 28037:2010
Specifically addresses reference materials	Yes	More general
X-values assumed to be known exactly	Yes	More general uncertainty information
All measured values obtained independently	Yes	More general uncertainty information

Feature	ISO 11095:1996	ISO/TS 28037:2010
Terminology aligned with GUM	No	Yes
Types of uncertainty structure treated	Two	Five, including the most general case
Only uncertainty associated with random errors	Yes	More general uncertainty information
Consistency test	ANOVA	Chi-squared
Uncertainty associated with predictions	Ad hoc	GUM compatible