## **Contents**

| Pre | face                             |   |   | vii                        |  |
|-----|----------------------------------|---|---|----------------------------|--|
| Abl | orevi                            | ations  |   | xix                        |  |
| 1   | International measurement system |   |   |                            |  |
|     | 1.1                              | Princip   | ples underlying the international measurement system  | 1                          |  |
|     | 1.2                              | 2 Classification of key comparisons of national measurement standards                                       |   |                            |  |
|     | 1.3                              | Basic approaches to evaluating key comparison data  |   |                            |  |
|     | 1.4                              | Expression of the degree of equivalence of measurement standards on the basis of a mixture of distributions |   |                            |  |
|     | 1.5                              | Evalua<br>1.5.1   | ation of regional key comparison data   | 15                         |  |
|     |                                  | 1.5.2   | key comparisons Equation of linking RMO and CIPM KC. Optimization of the  | 15                         |  |
|     |                                  | 1.5.3   | algorithm of evaluating degrees of equivalence  Different principles for transforming the results of regional   | 18                         |  |
|     |                                  |   | comparisons   | 22                         |  |
|     | 1.6                              | Bayesian approach to the evaluation of systematic biases of measurement results in laboratories             |   |                            |  |
|     | 1.7                              |   | tion of measurement results in calibrating material measures easuring instruments  Formulating a measurement model  Evaluation of measurement uncertainty  Calculation of measurement uncertainty associated with a value of a material measure using Bayesian analysis  Determination of the linear calibration functions of measuring instruments | 31<br>32<br>39<br>42<br>44 |  |
|     | 1.8                              | Summ  | ary   | 51                         |  |
| 2   | Syst<br>size                     |   | reproducing physical quantities units and transferring their  | 53                         |  |
|     | 2.1                              |   | fication of reproducing physical quantities units and systems for erring their sizes (RUTS)   | 53<br>53                   |  |

|   |      | 2.1.2<br>2.1.3<br>2.1.4<br>2.1.5 | Analysis of the RUTS systems   | 55<br>74<br>77 |
|---|------|----------------------------------|--|----------------|
|   |      | 2.1.6                            | RUTS systems   | 85<br>92       |
|   | 2.2  | Physic: 2.2.1 2.2.2              | al-metrological fundamentals of constructing the RUTS systems  General ideas | 96<br>96       |
|   |      | 2.2.3<br>2.2.4<br>2.2.5          | direction for basic research   | 129            |
|   | 2.3  | Summa                            | ary  |                |
| 3 | Pote |                                  |  | 164            |
|   | 3.1  |                                  | approach to describing a measurement   | 164            |
|   |      | 3.1.1                            | Concept of a system approach to the formalized description                   |                |
|   |      | 3.1.2                            | of a measurement task  |                |
|   |      | 3.1.3                            | Measurement as a process of solving a measurement task                       |                |
|   |      | 3.1.4                            | Formalization of a measurement as a system                                   | 169            |
|   |      | 3.1.5                            | Target function of a system  |                |
|   | 3.2  |                                  |  |                |
|   | 3.3  | 3.3.1<br>3.3.2                   | Measurand and object models  |                |
|   |      | 3.3.3                            | structure  |                |
|   | 3.4  | Influen                          | ce of external measurement conditions  | 189            |
|   | 3.5  | Space-                           | time limitations   | 190            |
|   | 3.6  | Summa                            | ary  | 194            |
| 4 | Alg  | orithms                          | for evaluating the result of two or three measurements                       | 197            |
|   | 4.1  | Genera                           | ıl ideas   | 197            |
|   | 4.2  | Evalua 4.2.1 4.2.2 4.2.3         | tion problem and classical means   | 201<br>204     |
|   |      | 4.2.4                            | Geometrical interpretation of the means                                      |                |

|     | 4.2.5<br>4.2.6<br>4.2.7                               | Relations of the means  | . 229  |
|-----|---|---|--|
| 4.3 | Algorit<br>4.3.1<br>4.3.2                             | thms of optimal evaluation  | . 245  |
| 4.4 | Heurist 4.4.1 4.4.2 4.4.3 4.4.4                       | tic methods for obtaining estimates  Principles of heuristic evaluation  Linear and quasi-linear estimates  Difference quasi-linear estimates  Heuristic means for $n = 2$  | . 258<br>. 263<br>. 266  |
| 4.5 | 4.5.1<br>4.5.2<br>4.5.3                               | Structural means  | . 283<br>. 285<br>. 289  |
|     |   | , , , , , , , , , , , , , , , , , , ,   |  |
| 4.6 | Applic 4.6.1 4.6.2 4.6.3 4.6.4                        | Digital filters with finite memory  | . 309<br>. 311<br>. 314  |
| 4.7 | Summ  | ary   | . 319  |
|     | rologica  | al traceability of measurement results (illustrated by an   |  |
|     |   |   | 321  |
| 5.1 |   |   | . 321  |
| 5.2 |   |   | . 323  |
|     | 5.2.2   | features of MRI as an object of metrological investigations Main sources of distortions of measurement information signals in magnetic channels, and methods of their   |  |
|     | 5.2.3   |   |  |
| 5.3 |   | -   | . 340<br>. 340   |
|     | 4.4<br>4.5<br>4.6<br>4.7<br>Met<br>exai<br>5.1<br>5.2 | 4.2.6 4.2.7 4.3 Algorit 4.3.1 4.3.2 4.4 Heuris 4.4.1 4.4.2 4.4.3 4.4.4 4.5 Structu 4.5.1 4.5.2 4.5.3 4.5.4 4.6 Applic 4.6.1 4.6.2 4.6.3 4.6.4 4.7 Summ Metrologic example of 5.1 Genera 5.2 Precise signals 5.2.1 5.2.2 5.2.3 5.3 Metho 5.3.1 | <ul> <li>4.2.6 Inverse problems in the theory of means</li> <li>4.2.7 Weighted means</li> <li>4.3 Algorithms of optimal evaluation</li> <li>4.3.1 Probability approach</li> <li>4.3.2 Deterministic approach</li> <li>4.4 Heuristic methods for obtaining estimates</li> <li>4.4.1 Principles of heuristic evaluation</li> <li>4.4.2 Linear and quasi-linear estimates</li> <li>4.4.3 Difference quasi-linear estimates</li> <li>4.4.4 Heuristic means for n = 2</li> <li>4.5 Structural and diagnostic methods for obtaining estimates</li> <li>4.5.1 Structural means</li> <li>4.5.2 Use of redundant variables to increase evaluation accuracy</li> <li>4.5.3 Application of diagnostic algorithms for screening a part of measurements</li> <li>4.5.4 Systematization and analysis of evaluation algorithms</li> <li>4.6 Application of means for filtering problems</li> <li>4.6.1 Digital filters with finite memory</li> <li>4.6.2 Median filters</li> <li>4.6.3 Diagnostic filters</li> <li>4.6.4 Example of filtering navigational information</li> <li>4.7 Summary</li> <li>Metrological traceability of measurement results (illustrated by an example of magnetic recording instruments)</li> <li>5.1 General ideas</li> <li>5.2 Precise magnetic recording instruments (MRI) of analog electrical signals as a part of measuring systems; MRI metrological traceability</li> <li>5.2.1 Application of recording/reproducing electrical signals on magnetic carriers in measurement technique and specific features of MRI as an object of metrological investigations</li> <li>5.2.2 Main sources of distortions of measurement information signals in magnetic channels, and methods of their measurements</li> <li>5.2.3 Problems of the metrological traceability of MRI</li> <li>5.3 Methods of determining MRI metrological characteristics</li> <li>5.3.1 Problems in developing metrological traceability systems</li> </ul> |

|      | 5.3.3                    | Methods for experimental evaluation of the basic error of measurement information signals registration in MRI |                |
|------|--------------------------|---|----------------|
|      | 524                      | channels  | . 367          |
|      | 5.3.4                    | Methods for determining the dynamic characteristics of MRI channels   | . 375          |
| •    | 5.3.5                    | Methods for determining the nonlinear distortions and oscillations of a signal time delay in MRI channels     |                |
| 5.4  |                          | are implementation of the methods for determining MRI ogical characteristics                                  |                |
| 5.5  | Summ                     | ary   |                |
| Vali |                          | of software used in metrology   | 425            |
| 6.1  |                          | al ideas  | . 425          |
| 6.2  | Tasks                    | of the metrological validation of software (MVS) used in ogy  | . 428<br>. 428 |
| 6.3  |                          | aches to evaluating precision parameters of software used in ogy  | . 446          |
|      | 6.3.2                    | measurement result  |                |
| 6.4  | Requir<br>6.4.1          | General requirements for measuring instruments with regard  |                |
|      | 6.4.2<br>6.4.3           | to the application of software  | . 472          |
| 6.5  |                          | pproval Documentation for type approval Requirements for the approval procedure Verification                  | . 492<br>. 494 |
| 6.6  | Assess<br>6.6.1<br>6.6.2 | Brief review  | . 495          |
|      |                          | OIML Document D 31  | . 497          |

| Contents |
|----------|
|----------|

| χV | 1 | 1 |
|----|---|---|
|    | • | • |

|              |      | 6.6.3 | Definition of risk classes according to the WELMEC Guide 7.2 | 500 |
|--------------|------|-------|--|-----|
|              |      | 6.6.4 | Determination of severity degrees of software tests          |     |
|              |      |       | in Russia  | 502 |
| 6            | 5.7  | Summa | ary  | 504 |
| Bibliography |      |       | 512  |     |
| Index        | ndex |       |  | 545 |