

Contents

1	Introduction	1
2	Aspects of Software Measurement	15
2.1	Terminology.....	15
2.1.1	The Terms Software Measurement, Measures, Metrics, etc.	15
2.1.2	The Terms Qualitative and Quantitative Conditions	17
2.2	Classes of Software Measures.....	17
2.2.1	Classification by Fenton	17
2.2.2	Classification Derived from the Models of Software	18
2.2.3	Intra- and Inter-Modular Software Measures	18
2.2.4	Classification of Traditional Software (Complexity) Measures	19
2.2.5	Classification of Measures in Object-Oriented Programming	20
2.2.6	Other Classification Criteria.....	20
2.3	Why Software Engineering Measurement?.....	21
2.3.1	Quantitative Methods and Software Engineering.....	21
2.3.2	Increasing Entropy.....	21
2.3.3	Situation in the Object-Oriented Environment.....	21
2.3.4	Benefits of Software Measurement	22
2.3.5	Software Measurement from a Management View	23
2.4	Measurement in Physics versus Software Engineering Measurement.....	24
2.4.1	Measurement in Physics	24
2.4.2	Measurement in Software Engineering	25
2.5	Models of Software.....	27
2.5.1	Introduction in Models	27
2.5.2	Models of Programs and Software Systems	29
2.5.2.1	Definition of a Program and a Module	29
2.5.2.2	Definition of Flowgraphs.....	31
2.5.2.3	Definition of Structure Charts / Constantine Method.....	33
2.5.3	Models of Object-Oriented Programming	36

2.6	Definition of Some Basic Measures.....	36
2.6.1	Measure Lines-of-Code (LOC)	36
2.6.2	Measures of Halstead.....	37
2.6.3	Measures of McCabe	37
2.6.4	Measure of Oviedo	39
2.6.5	Measure Defect-Density	39
2.6.6	Measures of Henry et al.....	40
2.6.7	Other Measures for Structure Charts	41
2.6.8	Basic COCOMO Model	41
2.7	Problems of (Software) Measurement.....	42
2.7.1	Meaning of Numbers	42
2.7.2	Scales Types	43
2.7.3	Models behind Software Measures.....	43
2.7.4	Statistical Operations	44
2.7.5	Writing Reports	45
2.7.6	Simpson's Paradox	46
2.7.7	The Measure Defect-Density.....	47
2.7.8	Substitution of Software Components.....	47
2.7.9	Normalization of (Software) Measures	48
2.7.10	Hybrid Measures.....	49
2.7.10.1	McCabe's Measures as a Hybrid Measure	49
2.7.10.2	Single Measures Combined to Hybrid Measures	50
2.7.10.3	Summary.....	51
2.7.11	Wholeness.....	51
2.7.12	Correlation, Validation, and Prediction.....	52
2.7.12.1	Inter-Measure Correlation	52
2.7.12.2	Validation and Prediction	53
2.8	Open Questions.....	54
2.8.1	General Questions from a Measurement Theoretic View	54
2.8.2	Fenton's Topics	54
2.8.3	Questions from a Practitioner View	55
2.9	Exercises.....	56
3	History of Software Measurement.....	57
3.1	Groundwork of Software Measurement.....	57
3.2	Software Design Measurement.....	62
3.3	Cost, Effort and Size Estimation Measures.....	63
3.4	Standards in the Area of Software Measurement.....	65
3.5	Goal-Question-Metric Paradigm, User-View and Viewpoints.....	66
3.6	Measurement Theory and Software Measures.....	66

3.7	European Software Measurement Projects.....	67
3.8	Software Measurement in Germany.....	68
3.9	Research in the Area of Software Measurement in North America.....	69
3.10	Research in the Area of Software Measurement in Japan.....	70
3.11	Software Measurement in Australia.....	70
3.12	Desirable Properties for Software Measures.....	71
3.13	Validation of Software Measures and Prediction Models.....	71
3.14	Software Measures in an Object-Oriented Environment.....	74
3.15	Data Dependency Measurement.....	75
3.16	Entropy Measures.....	75
3.17	Software Measures for Distributed Systems.....	75
3.18	Neuronal Networks and Software Measures.....	75
3.19	Software Measurement Tools.....	76
3.20	Software Measures and Reengineering.....	76
3.21	Software Measures and Reuse.....	77
3.22	ISO 9000-3 Standards and Software Measurement.....	78
3.23	Cognitive Processes and Measures.....	78
3.24	Current State of Software Measurement.....	79
3.25	Exercises.....	80
4	Foundations of Software Measurement I.....	81
4.1	Introduction.....	81
4.2	Objectives of Measurement Theory in the Software Measurement Area.....	83
4.3	Normative and Descriptive Approach of Measurement.....	85
4.4	What is Measurement?.....	86
4.4.1	Definition of Measurement by Roberts.....	87
4.4.2	Measurement of Software Quality Factors.....	88
4.4.3	Measurement is the Comparison of Objects.....	89
4.4.4	Basic Definitions of Measurement.....	91
4.5	Fundamental and Derived Measurement.....	95
4.5.1	Fundamental Measurement.....	95
4.5.2	Derived Measurement.....	97
4.5.3	Summary.....	99
4.6	Measurement Process.....	99

4.7	Reasons for Empirical Interpretations.....	101
4.8	Basic Concepts of Measurement Theory.....	103
4.8.1	Introduction	103
4.8.2	Numerical and Empirical Properties.....	104
4.8.3	Empirical Statement <i>Equally or More Difficult to Maintain</i>	105
4.8.4	Additive Property and Concatenation Operations	106
4.8.5	Empirical and Numerical Relational Systems	108
4.8.6	Definitions of Measures.....	109
4.8.7	Definition of a Metric	111
4.8.8	Mappings	112
4.8.9	Relations	112
4.8.10	Weak Order.....	113
4.9	Additive Homomorphism and Concatenation Operations.....	114
4.9.1	Additive Properties	114
4.9.2	Concatenation Operations in Physics	115
4.9.3	Definition of a Concatenation Operation.....	116
4.9.4	Concatenation Operations in Software Engineering	116
4.9.5	Concatenation Operation for Programs	118
4.9.6	Concatenation Operations for Structure Charts.....	120
4.9.7	Concatenation Operations for Object-Oriented Environments	121
4.9.8	Different Views of Concatenation Operations	122
4.9.9	Consequences for Software Measurement	125
4.10	Extensive Structures.....	125
4.10.1	Definitions of Extensive Structures.....	125
4.10.2	Consequences for Software Measurement	128
4.11	Scales and Scale Types.....	130
4.11.1	Scale Types and Admissible Transformations	131
4.11.2	Difference between Scale Types and Scales	132
4.11.3	How to Know the Scale Type?	132
4.11.4	Highest Scale Level?	133
4.11.5	Scale Types are not so Important?.....	133
4.11.6	Scale Types and Meaningful Statistical Operations	133
4.11.7	Scale Types and Units	134
4.11.8	Consequences for Software Measurement	135
4.12	Meaningfulness.....	135
4.12.1	Wholeness.....	135
4.12.2	Consequences for Software Measurement	139
4.13	Axiom Systems and Measurement Scales.....	139
4.13.1	Introduction and Terminology.....	139
4.13.2	Nominal Scale.....	140
4.13.3	Ordinal Scale	141
4.13.4	Interval Scale	143

4.13.5	Ratio Scale	147
4.13.6	Absolute Scale	149
4.14	Exercises.....	151
5	Foundations of Software Measurement II	157
5.1	Extensive Structures and Applications to Software Measurement.....	157
5.1.1	Introduction	157
5.1.2	Extensive Structures	158
5.1.3	Terminology	158
5.1.4	Positive and Negative Extensive Structures	159
5.1.5	Idempotency	160
5.1.6	Extensive Structure and the Measurement of Length.....	161
5.1.6.1	Weak Order of Wooden Boards	161
5.1.6.2	Non-Additive Property of Length Measurement.....	163
5.1.6.3	Measurement of Lengths and the Ratio Scale	164
5.1.6.4	Summary of Measurement of Lengths	164
5.1.7	Extensive Structure, Additive and Non-Additive Measures	165
5.1.8	Weak Order.....	166
5.1.9	Qualitative Conditions derived from Concatenation Operations	170
5.1.10	Models of Quality behind the Measures LOC, McCabe and D-INFO	180
5.1.11	Summary of the Application of the Extensive Structure to Software Measures	181
5.2	Measurement Scales and Software Measures.....	181
5.2.1	Ordinal Scale	182
5.2.2	Interval Scale	183
5.2.3	Additive Ratio Scale.....	183
5.2.4	Extensive Structure and Non-Additivity	184
5.2.5	Absolute Scale	184
5.2.5.1	Measure of McCabe as an Absolute Scale	186
5.2.5.2	Measure LOC as an Absolute Scale	187
5.2.5.3	Consequences for Software Measurement	188
5.3	Interpretation of Numbers and Hypotheses about Reality.....	189
5.4	Combination Rules and Independence Conditions.....	190
5.4.1	Combination Rules	190
5.4.2	Independence Conditions	192
5.4.3	Importance of Combination Rules and Independence Conditions ...	196
5.4.4	Hierarchy of the Independence Conditions	199
5.4.5	Consequences for Software Measurement	199
5.5	Combination Rules of Measures.....	200
5.5.1	Introduction	200
5.5.2	Additive Combination Rule.....	201

5.5.3	Additive Combination Rule Plus a Constant	203
5.5.3.1	Cyclomatic Number	204
5.5.3.2	Measure of Oviedo and Combination Rules	205
5.5.3.3	Measure Number of Modules	205
5.5.3.4	What is Counting?	206
5.5.3.5	Consequences for Software Measurement	208
5.5.4	Additivity plus/minus a Variable	209
5.5.5	Additive Combination Rule plus/minus Overlapping Variables	210
5.5.6	Maximum of Objects	211
5.5.7	Multiplication of Objects	212
5.5.8	Absolute Structure	213
5.5.9	Nested Structures more Complex than Sequences	213
5.5.10	Electrical Resistors	214
5.5.11	Negative Extensive Structure in Software Measurement	216
5.5.12	Additive, Non-Additive Ratio Scales and the Law of Pythagoras ...	217
5.5.12.1	Wholeness or Supra-Additivity	217
5.5.12.2	Measures for Supra- and Sub-Additivity	219
5.5.12.3	Consequences for Software Measurement	221
5.5.13	Density Measures	223
5.5.14	Combination Rules and Normalized Measures	224
5.5.15	No Extensive Structure but Ratio Scale	224
5.5.16	Hybrid Measures	225
5.5.17	Relativistic Speed	226
5.5.18	Hierarchy of Scale Types related to Meaningfulness of Statements	227
5.6	Calibration of Software Measures	228
5.7	Conversion Rules	230
5.8	Scale Types of Counting, Money and Time	230
5.8.1	Scale Type of Time	230
5.8.2	Scale Type of Money?	231
5.8.3	Consequences for Software Measurement	231
5.9	Normalization of Measures	231
5.9.1	Normalization by a Ratio Scale Transformation	232
5.9.2	Normalization by Bowles	232
5.9.3	Density Measures	233
5.9.3.1	Density Measures and their Properties	233
5.9.3.2	Measure Defect-Density and Consequences for Applications	235
5.9.4	Percentage Measures	237
5.9.5	Normalization by Sneed	238
5.9.6	Consequences for Software Measurement	239
5.10	The Informationflow Measure and Scale Types	239
5.11	Types of Measures	242
5.12	Alternative Axiom Systems for the Interval and Ratio Scales	247

5.12.1	Bisymmetric Structures	247
5.12.2	Ratio Scale via Ratios of Difference Structures	250
5.13	Summary of Scales and Scale Types.....	252
5.14	Scales on Programs and Scales on Flowgraphs.....	254
5.14.1	Introduction	254
5.14.2	Condition F1 (Flowgraph and Equivalence Classes of Programs)...	255
5.14.3	Condition F2	256
5.14.4	Condition F3	256
5.14.5	Condition F4.....	257
5.14.6	Consequences for Software Measurement	257
5.15	Units and Software Measurement.....	257
5.15.1	Introduction	257
5.15.2	Interval and Ratio Scales for Units.....	259
5.15.3	Requirement of Units for Software Measurement?.....	260
5.16	Framework of Software Measurement.....	261
5.16.1	Models Behind Software Measures	261
5.16.2	Measurement Theory and Software Measurement	264
5.17	Exercises.....	265
6	Measurement Theory and Object-Oriented Software Measures	273
6.1	Introduction.....	273
6.2	Object-Oriented Programming and Measurement.....	274
6.3	Classification of Object-Oriented Software Measures.....	275
6.4	Illustration of the Behavior of Object-Oriented Software Measures.....	277
6.4.1	Classes, Attributes and Methods as Sets	277
6.4.2	Measures and the Assigned Quality Model	278
6.4.3	Measures for the Depth of an Inheritance Tree	279
6.4.3.1	Examples of the Measure C-DIT.....	280
6.4.3.2	Examples of the Measure H-DIT.....	285
6.4.4	Measure Method Inheritance Factor H-MIF	286
6.4.5	Measure LCOMa	289
6.4.6	The Measure C-NAS	292
6.4.7	Measure Number of Children (C-NOC)	293
6.4.8	The Measure C-NOP	295
6.4.9	Results of our Investigation.....	296
6.5	Concatenation Operations for Object-Oriented Programs.....	298
6.5.1	The Idea behind Concatenation Operations.....	298
6.5.2	Extensive Structure and Object-Oriented Environment	301
6.5.3	Investigation of Chidamber et al.	301
6.5.4	Concatenation Operations For Methods	302

6.5.5	Concatenation Operations on the Class Level	302
6.5.5.1	Class Unification CUNI.....	302
6.5.5.2	Inheritance Relationship	303
6.5.5.3	Unification of Sibling Classes	304
6.5.5.4	Unification with a direct Subclasses.....	304
6.5.5.5	Discussion of Separate Classes.....	305
6.5.5.6	Concatenation Operation CUNI for Uses Relationships	305
6.5.5.7	Properties of the Concatenation Operation CUNI.....	306
6.5.5.8	Class Intersection CINT	306
6.5.5.9	The Empty Class.....	308
6.5.5.10	Summary.....	309
6.5.6	Concatenation Operations for Class Hierarchies.....	309
6.5.6.1	Hierarchical Aggregation HAGG.....	309
6.5.6.2	Hierarchical Generalization HGEN.....	311
6.6	Belief Structures.....	313
6.6.1	Introduction	313
6.6.2	Belief Functions.....	314
6.6.3	Motivation for the Use of Belief Structures as Measurement Structures	314
6.6.4	Kolmogoroff Axioms	315
6.6.5	Belief Functions of Dempster and Shafer.....	316
6.6.6	Qualitative Belief.....	317
6.6.7	Sets of Attributes and Methods in the Object-Oriented Environment	318
6.6.8	Axiom of Positivity	319
6.6.9	Dominance Axiom.....	319
6.6.10	Axiom of Partial Monotonicity of Qualitative Belief.....	320
6.6.10.1	Axiom of Partial Monotonicity versus Axiom of Monotonicity.....	321
6.6.10.2	Axiom of Partial Monotonicity in Physics I.....	322
6.6.10.3	Simpson's Paradox I.....	323
6.6.10.4	Axiom of Partial Monotonicity in Physics II.....	324
6.6.10.5	Simpson's Paradox II.....	325
6.6.11	DeFinetti Axioms	326
6.6.12	Importance of Partial Monotonicity for Object-Oriented Measurement	327
6.7	Modified Function of Belief and Modified Relation of Belief.....	328
6.8	Applications to Object-Oriented Measures.....	331
6.9	Ranking Properties of Object-Oriented Software Measures.....	333
6.10	Summary of Object-Oriented Software Measures.....	334
6.11	Exercises.....	335

7	Desirable Properties of Software Measures	339
7.1	Introduction.....	339
7.2	Required Properties by Bache.....	340
7.3	Required Properties of Measures by Conte et al.....	344
7.4	Size Measures.....	349
7.5	Validation Criteria of IEEE Standard 1061 for Software Measures.....	352
7.6	Required Properties of Software Complexity Measures by Basili and Reiter.....	354
7.7	Desirable Attributes of Effective Measures by Ejiogu.....	355
7.8	Required Properties of Software Complexity Measures by Fenton.....	358
7.9	Required Properties of Jones.....	360
7.10	Required Properties of Software Complexity Measures by Kearney et al.....	364
7.11	Required Properties for Software Measures by Shepperd and Ince.....	366
7.12	Weyuker's Properties.....	368
7.12.1	Weyuker's Property 1 (Basic Assumption of a Measure).....	370
7.12.2	Weyuker's Property 2 (Finitely many Identifiers)	370
7.12.3	Weyuker's Property 3 (Equivalence Classes)	371
7.12.4	Weyuker's Property 4 (Same Functionality, but different Complexity)	371
7.12.5	Weyuker's Property 5 (Weak Positivity)	371
7.12.6	Weyuker's Property 6 (Rejection of the Weakest Independence Condition C1)	373
7.12.7	Weyuker's Property 7 (Weak Commutativity).....	375
7.12.8	Weyuker's Property 8 (Renaming).....	377
7.12.9	Weyuker's Property 9 (Wholeness).....	377
7.12.9.1	Measures for Wholeness.....	379
7.12.9.2	Morascas et al. Argumentations	382
7.12.9.3	Ratio Scale Measure without the Extensive Structure.....	383
7.12.9.4	Measure LOC and Wholeness	383
7.12.10	Are Weyuker's Properties Compatible?	384
7.12.11	Weyuker's Properties and Cherniavsky's Comments	385
7.12.12	Wholeness, but no Ratio Scale	385
7.12.13	Weyuker's Property 9 and the Law of Pythagoras	388
7.12.14	Weyuker's Statements and the Existential Quantifiers	389
7.12.15	Summary of Weyuker's Properties.....	390
7.13	Required Properties by Lakshmanan et al.....	391
7.14	Desired Properties by Watts.....	395

7.15	Summary of Desirable Properties.....	397
7.16	Zuse's Requirements for Software Measures.....	399
7.17	Ordinal or Ratio Scales for Software Measurement?.....	402
7.18	Exercises.....	404
8	Validation of Software Measures and Prediction Models.....	407
8.1	Introduction.....	407
8.2	Terminology.....	408
8.3	Misunderstanding of Validation and Prediction.....	408
8.3.1	Valid Measure.....	408
8.3.2	Validation of Simple Versus Complicated Measures.....	410
8.3.3	Views in Validating Measures.....	412
8.4	Some Results of Prediction Experiments in Literature.....	412
8.4.1	LOC and Prediction.....	412
8.4.2	Prediction and Errors.....	413
8.4.3	Prediction and Effort of Software Development.....	416
8.5	Internal and External Attributes.....	417
8.6	Correlation Coefficients and Prediction I.....	420
8.6.1	Definition of the Pearson Correlation Coefficient.....	420
8.6.2	Correlation between Variables.....	421
8.6.3	Other Effects of Correlation.....	423
8.6.4	Software Measures and Time-Based Variables.....	424
8.6.5	Misinterpretation of the Pearson Correlation Coefficient.....	426
8.6.6	Summary.....	427
8.7	Internal Validation of Software Measures.....	428
8.7.1	Internal Validation of the Measures LOC and McCabe as Ordinal Scales.....	430
8.7.2	Internal Validation of the Measures LOC and McCabe as Ratio Scales.....	431
8.7.2.1	Internal Validation of MCC-V2 and LOC as Absolute Scales.....	432
8.7.2.2	Summary of the Internal Validation of the Measures of McCabe and LOC.....	433
8.7.3	Internal Validation and Consequences for Software Measurement.....	434
8.8	External Validation of Software Measures.....	435
8.8.1	External Validation of the Measure LOC.....	436
8.8.2	Properties of the External Variable Costs of Maintenance.....	437
8.8.2.1	Weak Order for Costs of Maintenance.....	438
8.8.2.2	Positivity for Costs of Maintenance.....	439
8.8.2.3	Independence Conditions C1-C2 for Costs of Maintenance.....	440
8.8.2.4	Substitution Property for Costs of Maintenance.....	441

8.8.2.5	Package Depiction for Costs of Maintenance.....	441
8.8.2.6	Weak Commutativity for Costs of Maintenance	442
8.8.2.7	Weak Monotonicity and Monotonicity for Costs of Maintenance	443
8.8.2.8	Archimedean Axiom for Costs of Maintenance	444
8.8.2.9	Wholeness for Costs of Maintenance	445
8.8.2.10	Additivity for Costs of Maintenance	446
8.8.3	Evaluation of the Twelve Properties of Costs of Maintenance	446
8.8.4	Properties of the Measure LOC	449
8.8.5	Measure LOC, External Variable Costs of Maintenance and the Function f	449
8.8.6	Consequences for Software Measurement	452
8.9	Prediction - Theorems and Proofs.....	452
8.9.1	Definition of Prediction	453
8.9.2	Prediction Models and Wholeness	454
8.9.3	Prediction Models in Physics	455
8.9.4	Theorems for Validation of Measures and Prediction Models.....	455
8.9.4.1	Introduction	455
8.9.4.2	Theorems	456
8.10	Relationship of Complexity and Effort in Time.....	464
8.11	Validation of the Measure Information Flow.....	465
8.12	Correlation Coefficients and Prediction II.....	466
8.12.1	Correlation is a Comparison of Empirical and Numerical Properties	467
8.12.2	Inter-Measure Correlation	468
8.12.3	High Correlation Related to a Valid Measure	469
8.13	Simple Measures for Prediction?.....	470
8.13.1	Properties of Simple Measures	470
8.13.2	Halstead Measures and Prediction.....	471
8.14	Software Quality Attributes Derived from External Variables.....	472
8.15	Summary of Validation and Prediction.....	473
8.16	Exercises.....	474
9	Applications of Software Measures.....	479
9.1	Introduction.....	479
9.2	Application of Software Measures to Real Existing Software Systems....	480
9.2.1	Introduction	481
9.2.2	The Investigation	481
9.2.3	The used Software Measures	482
9.2.4	The Experiment	483

9.2.5	Summary of the Investigation.....	484
9.3	The Software Life-Cycle and Software Measurement.....	485
9.4	ISO 9000-3 Norm and Software Measurement.....	487
9.4.1	Introduction	487
9.4.2	Measures and ISO9000-3	488
9.4.2.1	Design Phase.....	488
9.4.2.2	Coding Phase	488
9.4.2.3	Fault and Change Rates	489
9.4.2.4	Project Monitor Measures	489
9.4.3	Summary of Measurement and Topics of the ISO9000-3 Standard.....	490
9.5	Mostly Used Measures in Industry.....	491
9.6	The Function-Point Method.....	491
9.6.1	Introduction	492
9.6.2	Definition of the Function-Point Method	493
9.6.3	Measurement Theoretic Discussion of the Function Point Method	496
9.6.3.1	The Extensive Structure and the Function-Point Method	496
9.6.3.2	Technical Complexity Factor	500
9.6.4	Function-Point Method as a Prediction Model.....	501
9.6.5	Function-Point Method as a Size Measure	502
9.6.6	Strengths and Weaknesses of the Function Point Method	503
9.6.7	Why is the Function-Point Method so Successful?.....	504
9.7	The COCOMO Models and Deviations.....	505
9.7.1	Definitions of the Various COCOMO Models.....	505
9.7.2	Measurement Theoretic Discussion of the various COCOMO Models.....	507
9.7.2.1	Relational System of the COCOMO Model.....	507
9.7.2.2	Concatenation Operation and Combination Rule (Ratio Scale).....	508
9.7.2.3	COCOMO Model and Software Measurement	510
9.7.3	Modified COCOMO Models.....	512
9.7.4	Transformations of the COCOMO Model.....	512
9.7.5	Scale Types and the COCOMO Model	514
9.7.6	Strengths and Weaknesses of the COCOMO Model.....	514
9.8	Maintainability Characteristics of a Final Product.....	515
9.8.1	Introduction	515
9.8.2	Design and Implementation Characteristics	516
9.8.2.1	Entire System Analysis.....	516
9.8.2.2	Component Analysis.....	517
9.8.2.3	Data Flow Analysis	519
9.8.3	Coupling between Modules.....	520
9.8.4	Cohesion	524
9.8.5	Modularization.....	525

9.9	Basic Measures for Structure Charts.....	526
9.9.1	Representation of a Structure Chart in an Adjacency Matrix.....	526
9.9.2	Simple Software Design Measures.....	528
9.10	The Measure Information Flow of Henry and Kafura.....	530
9.11	Measures of Bowles.....	531
9.11.1	Factors of Complexity of an Individual Module.....	531
9.11.2	Measures at the System Level.....	532
9.11.3	Aggregated System Complexity.....	533
9.11.4	Examples Calculated with the System MDS.....	534
9.11.5	Measure of Bowles and Stamp Coupling.....	539
9.11.6	Discussion of the Measures of Bowles from a Measurement Theoretic View.....	539
9.11.7	Summary.....	541
9.12	Measures for the Coding Phase.....	541
9.12.1	Introduction.....	541
9.12.2	Measures of McCabe.....	542
9.12.2.1	The Many Purposes of McCabe's Measures.....	544
9.12.2.2	Measurement Theoretic Investigation.....	545
9.12.3	Measures of Halstead.....	546
9.12.4	Set of Measures Analyzing the Structure and Size.....	548
9.12.5	Relationship of McCabe Measures and LOC.....	549
9.12.6	The Number Ten for McCabe's Measures.....	550
9.12.7	The DATRIX-Measures.....	551
9.12.8	Measure for Source Code Analysis.....	555
9.13	Measures for Cohesion.....	556
9.13.1	Introduction.....	556
9.13.2	Weiser's View.....	556
9.13.3	Measures of Bieman, Ott, and Thuss.....	557
9.13.4	Other Measures for Cohesion.....	561
9.14	Measures for the Testing Phase.....	561
9.15	Measures for the Software Maintenance Phase.....	564
9.15.1	List of Maintenance Measures.....	564
9.15.2	Number of Defects Found after Release.....	564
9.15.3	Number of Changes or Change Requests.....	565
9.15.4	Time to Identify and Correct Defects.....	565
9.15.5	Defect-Density.....	565
9.15.6	Mean-Time-To-Failures.....	566
9.15.7	Software Maturity Index.....	566
9.15.8	Summary.....	567
9.16	Document Quality.....	567
9.17	Measure for Object-Oriented Programming.....	567

9.17.1	Overview of Object-Oriented Software Measures	567
9.17.2	Detailed Description of Object-Oriented Software Measures	574
9.18	Summary of Software Measurement in the Software Life-Cycle.....	576
9.19	Exercises.....	577
10	Afterword	581
11	Solutions of Exercises	583
11.1	Solutions for Chapter 2.....	583
11.2	Solutions for Chapter 3.....	585
11.3	Solutions for Chapter 4.....	586
11.4	Solutions for Chapter 5.....	594
11.5	Solutions for Chapter 6.....	606
11.6	Solutions for Chapter 7.....	609
11.7	Solutions for Chapter 8.....	612
11.8	Solutions for Chapter 9.....	617
12	Glossary of Terms and Terms used as Synonyms	623
12.1	Terms used as Synonyms.....	623
12.2	Glossary of Terms.....	624
Attachment I:	The System ZD-MIS	671
Attachment II:	Proof of the Equivalence of Extensive Structures	673
Attachment III:	Proof of the Theorems of Chapter 8	677
Attachment IV:	Proof of the Theorems of Chapter 5	683
Attachment V:	Notations and Used Symbols.....	689
Attachment VI:	Axioms Systems	693
Definitions	699
Theorems	702

Contents	XXIX
Exercises.....	703
References to Literature	707
Name Index	737
Subject Index.....	745