

Contents

1	Measurement Uncertainty	1
1.1	Historical review	3
1.2	Goal of this Work	5
1.3	What's new	6
2	Mathematical Concepts	9
2.1	What is a Measurement	9
2.1.1	Definitions	9
2.2	Different Approaches	13
2.2.1	Random variables	13
2.2.2	Mathematical Model	22
2.2.3	ISO Guide: First Order Approximation	27
2.2.4	Simple Rules	27
2.2.5	Monte Carlo Simulation	28
2.3	Calibration	30
2.3.1	Calibration and Measurement	30
2.3.2	Calibration Models	31
2.3.3	Computations	36
2.3.4	Measurement	43
2.3.5	Truncated SVD Solver	44
2.3.6	Numerical Comparisons and Simulations	48
2.3.7	Final remarks on Regression	54
3	M description	57
3.1	Compiling and Interpreting	58
3.2	Language M	59

3.2.1	Extended Backus-Naur Form (EBNF)	59
3.2.2	Grammar of M	61
3.2.3	Token definitions for M	63
3.2.4	Example: Grammar for Units	63
3.2.5	Complete Grammar of M	65
4	Semantics of M	69
4.1	Expression	69
4.1.1	Equation	70
4.1.2	Leaf	70
4.1.3	Units	72
4.2	Attribute List	74
4.3	Functions	75
4.3.1	Predefined Functions	78
4.4	Measurement	85
5	Implementation	93
5.1	General Architecture	93
5.2	COM Interface	95
5.3	Several Modules	99
5.3.1	SI-Units	99
5.3.2	Parser	113
5.3.3	Visitor Pattern	116
5.3.4	Drawing Cause and Effect Diagrams	122
5.3.5	The program <i>Uncertainty Manager</i>	123
6	Real Life Application	127
6.1	Certification of Bismuth content in SRM 3106	129
6.1.1	NIST SRM Program	129
6.1.2	High Performance ICP-OES	130
6.2	Measuring calcium content in spring water	136
7	Conclusion	169