# Chapter 7

# Conclusion

MEASUREMENT uncertainty evaluation is not an art for a few gifted persons only. Rather it is sumptuous or even tedious work that can be executed in a very mechanical way. Having it done by a computer system therefore seems like a sensible approach. We have shown with the MUSAC-tool that such a system is indeed very feasible. The effort of evaluating and assessing measurement uncertainty can be facilitated and automated in various ways.

- Assistance in the collection of all relevant influences, i.e. the data repository indicates to the user many potential influences thereby minimizing the possibility of overlooking important influences.

- The presence of a mathematical model for a particular measurement procedure is often very illustrative.

- The MUSAC-system offers various ways of evaluating the model and displaying the results of given evaluations.

- The M-language constitutes a new tool for metrologists. The latter can play various scenarios for a given measurement procedure and quickly gain understanding of the influences.

## Problems with and without solutions

During the development of the MUSAC-system we encountered problems such as finding the right regression method for first order estimation or whether or not Berkson's Model is correct, that turned out to be part of an open field of research. Our experiments showed that Berkson's Model is most likely correct, but there are arguments for both XIP-FIT and for P-FIT when dealing with first order estimation. Even more controversial is the discussion about what regression method should be applied with the Monte Carlo Simulation. Interestingly enough the Monte Carlo Simulation poses another problem which is a current research topic with statisticians: *Copula*, generation of multivariate distributions with given marginal distributions and perhaps additional constraints such as given covariance matrix.

The MUSAC-system combines many solutions to questions that were open when the project started: It was not at all clear whether the measurement procedure description language M was feasible and/or sensible in any way. It was unclear how (if at all) we should visualize a measurement procedure and how the user of the MUSAC-system should be guided through the process of measurement uncertainty evaluation. The MUSAC-system is available as a software named *Uncertainty Manager*. It gives neat evidence that this problem is solved to a very satisfactory degree.

People in metrological fields are not accustomed to *models for measurement procedure*. Therefore the model, i.e. the formula describing the entire measurement procedure is difficult to formulate and it was questionable whether M was powerful enough to accomplish this for the range of measurements performed in Analytical Chemistry. We have succeeded in formulating models for several classes of measurement procedures in that metrological field. Still, it is very well possible that metrological specialists in other fields will need additional features in M to be able to formulate their specific measurements. Anyhow, we surely observe that having a model for a measurement procedure together with its various evaluation results offers a new point of view on measurement procedures. This approach can certainly be generalized to other processes. Therefore, it could be very worthwhile to elaborate and refine the M-language. We imagine the use of M in order to model business processes, production lines, money flows or similar processes. Once a process is expressed in M, the MUSAC-system can perform an uncertainty evaluation which is tantamount to doing a *sensitivity*

*analysis* on the modeled process. M could open up the insight on processes in a very practical way.

Apart from these conceptual solutions offered, the MUSAC-system unites a number of technical solutions for computer science problems. Without going into details we list them here to give an oversight of the range of questions that arose while programming the MUSAC-system and the calculator module in particular: There were issues to be solved with memory management for the Monte Carlo Simulations as well as for the AST representations. Some few aspects of symbolical computing such as handling of SI-Units and construction of derivations were touched. The field of symbolical computing is a large subdivision of general computer science. It was never the intention to invent yet another symbolical mathematics tool. Rather the knowledge about the vast complexity of symbolical algorithms served in the MUSAC-system as an argument to refrain from trying to implement certain features like symbolical simplification of M-expressions. There were a number of numerical computing issues such as the proper application of Kahan's summation trick and the entire application of Berkson's Model. And last but not least the design and the implementation of a new language is always a challenging task despite well developed techniques.

If you are still reading, dear inclined reader, I thank you for your attention.