Towards reliable implementation of digital filters

In this thesis we develop approaches for improvement of the numerical behavior of digital filters with focus on the impact of accuracy of the computations. This work is done in the context of a reliable hardware/software code generator for Linear Time-Invariant (LTI) digital filters, in particular with Infinite Impulse Response (IIR). With this work we consider problems related to the implementation of LTI filters in Fixed-Point arithmetic while taking into account finite precision of the computations necessary for the transformation from filter to code. This point is important in the context of filters used in embedded critical systems such as autonomous vehicles. We provide a new methodology for the error analysis when linear filter algorithms are investigated from a computer arithmetic aspect. In the heart of this methodology lies the reliable evaluation of the Worst-Case Peak Gain measure of a filter, which is the $l_1$ norm of its impulse response. The proposed error analysis is based on a combination of techniques such as rigorous Floating-Point error analysis, interval arithmetic and multiple precision implementations. This thesis also investigates the problematic of compromise between hardware cost (e.g. area) and the precision of computations during the implementation on FPGA. We provide basic brick algorithms for an automatic solution of this problem. Finally, we integrate our approaches into an open-source unifying framework to enable automatic and reliable implementation of any LTI digital filter algorithm.