More Accurate Computation: Methods and Software

[Track Proposal to SAC 2006, Dijon, France.]

Philippe Langlois
DALI Research Project
University of Perpignan, France
langlois@univ-perp.fr.

Siegfried M. Rump
Inst. f. Informatik III
Technical University Hamburg-Harburg,
Germany
rump@tu-harburg.de.

ABSTRACT
We propose to organize at SAC 2006 a track that focuses on today and tomorrow methods and software to go further than the precision currently available on our computers. How to manage the need for more accurate results without suffering from an impractical over-cost?

This track aims to gather applied computer scientists, computer engineers and application developers together with researchers on numerical software quality to exhibit the current state of the art on the need and the solutions to reach both accuracy, reliability and performance in software.

Categories and Subject Descriptors
G.4 [Mathematics of Computation]: Mathematical Software; G.1.0 [Numerical Analysis]: General; D.2.7 [Software Engineering]: Software Verification; B.2.4 [Hardware]: High-Speed Arithmetic; J.2 [Computer Applications]: Engineering

General Terms
Algorithms, Design, Languages, Performance, Reliability, Standardization

Keywords
Floating Point, IEEE-754 Standard

1. RATIONALE
The current standard for floating point computation, the IEEE-754 standard, provides about 16 decimal digits precision. When applied to ill-conditioned problems, numerical software loses significant digits and may not be able to return the accuracy prescribed by the user. Such loss of precision may have unforeseeable effects, both quantitative (inaccurate digits) and qualitative (instability, non-convergence, inexact branching tests). Computational geometry, number theory, robotics, scientific computing are examples of classic fields of such need.

Several alternatives to provide more accurate results using this fixed precision arithmetic are offered to applied computer scientists and engineers. New hardware facilities (as the fused multiply-add instruction) may yield new algorithms being both more accurate and efficient. A second way to improve the accuracy is to rewrite the algorithm taking into account (low-level) properties of finite precision arithmetic. Such re-writing is both difficult to design and may be restricted to specific algorithms. Algorithms that compute the accurate results of the sum or the dot product of floating point numbers illustrate such kind of development being still in progress since the 60's; references are numerous, e.g., see [5, ch.4] for entries. Re-writing is even sometimes restricted to a specific data structure; let us cite for example the classic Bjork and Pereira algorithm to solve Vandermonde linear systems. Nevertheless, recent research results prove that error-free transformations are useful tools to design new algorithms being both accurate and fast in terms of flops and also in terms of measured computing time [9].

On the other hand, software simulation of extended precision is the more general and used approach to satisfy accuracy constraints and even the dynamic control of this accuracy. Extended precision can be of arbitrary or fixed length, and existing libraries can be generic or application oriented (e.g., in computational geometry). These libraries differ from the way multiprecision numbers are represented and implemented. Examples of well known multiprecision libraries are GMP, MPFR, ARPREC, MPFUN, LIDIA, CGAL.

When high performance is wanted to implement the extended precision and fixed-length extra accurate arithmetic, it is necessary to use floating point numbers and operators as much as possible. Fixed-length expansions such “double-double” or “quad-double” libraries [2, 1, 4] are actual and effective solutions to simulate twice or four times the IEEE-754 double precision [6]. For example a quad-double number is an unvaluated sum of four IEEE double precision numbers and its associated arithmetic provides at least 212 bits of significand. Since these fixed-length expansions benefit from both the speed and the portability the IEEE floating-
point standard ensure, they are currently embedded in major developments such for example within the new extended and mixed precision BLAS [8]. A new algorithm for precise evaluation of dot products being 40% faster than XBLAS is presented in [9].

An important field that also need accurate computation is the evaluation of elementary transcendental functions. Recently a french team developed a library that use extended precision to compute elementary functions with correct rounding [3].

This track completes tracks about reliable computation presented at SAC’04 and SAC’05. Reliable computing benefits from extended precision libraries. Using adaptable extended precision provides a solution to the well-known overestimation of interval computation, e.g., MPFI couples interval arithmetic and multiprecision computation with MPFR. Sometimes, it is difficult or not necessary to increase the accuracy but only to known rigorous error bounds for the computed result. A Matlab toolbox INTLAB for computing rigorous error bounds for certain numerical problems is presented in [7]. Computing such rigorous bound can be very difficult. A common way to do this is to keep track of the intermediate errors of computations, for example using interval arithmetic. Another method can be to use a rigorous Wilkinson running error analysis as done in [9].

Related Conference Events: This track will propose to computer scientists and engineers an ACM event in Europe about Mathematical Software within the more general scientific frame provided by the SAC Conferences. The proposed track focuses on a topic (accurate computation) which is both present for numerical software researchers and applied computer scientists. Such focus completes the classic presentations more dedicated to specialists encountered in the main related conferences we list hereafter.

- IEEE ARITH Symposium: June 2005, Cape Cod (USA) and next in 2007;
- IMACS-GAMM SCAN’04, Fukuoka (Japan); next in 2006;
- Real Numbers and Computers: RNC’04, Dagstuhl (Germany); next in Nov-Dec 2006 at Nancy (France).

2. ORGANIZATION

Email diffusion via the following email lists and web pages (the list will be extended).

- A Web Page dedicated to this track is located at http://webdali.univ-perp.fr/MAC.
- NA-Digest on http://www.netlib.org/na-net/ dedicated to the worldwide community of numerical analysts and related researchers.

3. SHORT CV OF THE TRACK CHAIRS

Ph. Langlois is Professor of Computer Science at University of Perpignan. His research are devoted to improve the accuracy and the reliability of numerical software. More information is available at URL: http://webdali.univ-perp.fr/~langlois.

S.M. Rump is Professor Dr. at Technical University Hamburg - Harburg. His research concerns numerical linear algebra, interval arithmetic and self-validating algorithms. More information is available at URL: http://www.ti3.tu-harburg.de/.

4. REFERENCES