Modern Computer Arithmetic

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This installment of Computer's series highlighting the work published in IEEE Computer Society journals comes from IEEE Transactions on Computers.

A 2009 *IEEE Transactions on Computers* (*TC*) guest editorial called computer arithmetic "the mother of all computer research and application topics." Today, one might question what computer arithmetic still offers in terms of advancing scientific research; after all, multiplication and addition haven't changed. The answer is surprisingly easy: new architectures, processors, problems, application domains, and so forth all require computations and are open to new challenges for computer arithmetic. Big data crunching, exascale computing, low-power constraints, and decimal precision are just a few domains in which advances are implicitly pushing for rapid, deep reshaping of the traditional computer-arithmetic framework. *TC* (www.computer.org/web/tc) has long published regular submissions as well as special sections on this topic, including one scheduled for 2017. Here, we focus on three recently published papers.

In "Parallel Reproducible Summation," James Demmel and Hong Diep Nguyen (*IEEE Trans. Computers*, vol. 64, no. 7, 2015, pp. 2060–2070) address result reproducibility in cases where it's a requirement. They present a technique for floating-point reproducible addition that doesn't depend on the order in which operations are performed, which makes it appropriate for massively parallel environments.

Mioara Joldeş and her colleagues deal with manipulation of floating-point expansions in "Arithmetic Algorithms for Extended Precision Using Floating-Point Expansions" (*IEEE Trans. Computers*, vol. 65, no. 4, 2016, pp. 1197–1210). Such expansions, which are unevaluated sums of a few floating-point numbers, might be used when one temporarily needs to represent numerical values with a higher precision than that offered by the available floating-point format. The authors introduce and prove new algorithms for dividing and square-rooting floating-point expansions, as well as for "normalizing" such expansions.

In "On the Design of Approximate Restoring Dividers for Error-Tolerant Applications" (*IEEE Trans. Computers*, vol. 65, no. 8, 2016, pp. 2522–2533), Linbin Chen and his colleagues propose several approximate restoring-divider designs. Their simulation results show that, compared with nonrestoring division schemes, their designs had superior delay, power dissipation, circuit complexity, and error tolerance. Most striking, the approximate designs offer better error tolerance "for quotient-oriented applications (image processing) than remainder-oriented applications (modulo operations)."

These papers are a small but representative view of trends in computer arithmetic. However, computer arithmetic also bridges the gap between architecture and application design—and thus will continue to advance in vibrant directions, provided it maintains strong connections with technology and advanced research.

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