

Implementation and application of extended precision in Matlab

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Abstract: A multiple precision library for floating-point calculations to any number of digits has been implemented in Matlab. The library is based on the ARPREC library. One application is discussed in detail, namely the evaluation in the complex plane of special functions in regions of bad conditioning. Through the use of Matlab classes, all the basic arithmetic operations are accessible using Matlab syntax, even though the fundamental operations are coded in C++. Arithmetic supports both real and complex data to arbitrary precision. The level of the precision being used can be changed at any time. Many elementary functions are also available in Matlab syntax, although not all of them are offered for complex arguments.

Key- Words: Arbitrary precision, special functions, condition number, Lambert W function

1 Introduction

Many applications in science require high accuracy beyond that which can be obtained using IEEE double precision. Applications which benefit from increased precision include simulations, power series, and solutions of non-linear and differential equations. Recent applications to natural phenomena are contained in Boychuk *et al.* [4] and Krougly *et al.* [12], where extensive investigations of how the distribution selection for rate of spread and spotting distance will affect the spread of forest fire. Other applications are to sensitivity analysis, and stability and optimization techniques in nonlinear systems, such as closed network models (Krougly and Stanford [13]; Casale and Senozzi [7]).

The development of fundamental algorithms in IEEE double-double and quad-double floating point arithmetic was presented in Dekker (1971), Knuth (1998), Shewchuk (1997). One of the first multiple-precision packages was due to Brent (1978), and developed in Fortran 66. His package includes subroutines for evaluating elementary and special functions in multiple precision floating-point arithmetic. Brent's multiple precision package did not support complex arithmetic. Many basic properties of high-precision computations are implemented in the ARPREC software package (Borwein and Bailey, 2004; Bailey, 2002, 2005). Possibly that is the most comprehensive package in multiple-precision software. ARPREC software includes C++ and Fortran-90 modules, and can be downloaded from [1]. This package provides complex arithmetic and some com-

plex elementary functions. Another well-known library is the GMP library, but this does not support many elementary functions.

For many engineers and mathematicians, MATLAB provides a familiar and efficient problem solving environment. Standard Matlab offers only double precision accuracy, and so for applications such as those described above, it would be beneficial to implement multiple precision facilities.

We have implemented a library for high-precision numerical calculations based on the ARPREC library. We have writing interface code, defined Matlab classes, and linked to a compiled form of the ARPREC source code. Thus, we enable programs written in Matlab syntax to access the ARPREC library and compute at any set precision.

2 Special function application

We now describe a specific motivating application. The evaluation of a real-valued function has been studied in great detail. In particular the conditioning of the problem is well understood. The theory for complex-valued functions is less well developed. We are interested in evaluation of the Lambert W function.

Lambert W function plays an important role in science and mathematics [8]. It is the inverse function of $f(w) = we^w$ where $w \in \mathbb{C}$, and it is multi-valued, being denoted by $W_k(z)$, where k is the branch number. The branches of the Lambert W function can be seen in Fig. 1.

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**René Alt, Andreas Frommer, R. Baker
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Table of Contents Implementation And Application Of Extended Precision In Matlab

1. Understanding the eBook Implementation And Application Of Extended Precision In Matlab
 - The Rise of Digital Reading Implementation And Application Of Extended Precision In Matlab
 - Advantages of eBooks Over Traditional Books
2. Identifying Implementation And Application Of Extended Precision In Matlab
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Implementation And Application Of Extended Precision In Matlab
 - User-Friendly Interface
4. Exploring eBook Recommendations from Implementation And Application Of Extended Precision In Matlab
 - Personalized Recommendations

- Implementation And Application Of Extended Precision In Matlab User Reviews and Ratings
- Implementation And Application Of Extended Precision In Matlab and Bestseller Lists
- 5. Accessing Implementation And Application Of Extended Precision In Matlab Free and Paid eBooks
 - Implementation And Application Of Extended Precision In Matlab Public Domain eBooks
 - Implementation And Application Of Extended Precision In Matlab eBook Subscription Services
 - Implementation And Application Of Extended Precision In Matlab Budget-Friendly Options
- 6. Navigating Implementation And Application Of Extended Precision In Matlab eBook Formats
 - ePub, PDF, MOBI, and More
 - Implementation And Application Of Extended Precision In Matlab Compatibility with Devices
 - Implementation And Application Of Extended Precision In Matlab Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Implementation And Application Of Extended Precision In Matlab
 - Highlighting and Note-Taking Implementation And Application Of Extended Precision In Matlab
 - Interactive Elements Implementation And Application Of Extended Precision In Matlab
- 8. Staying Engaged with Implementation And Application Of Extended Precision In Matlab
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Implementation And Application Of Extended Precision In Matlab
- 9. Balancing eBooks and Physical Books Implementation And Application Of Extended Precision In Matlab
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Implementation And Application Of Extended Precision In Matlab
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Implementation And Application Of Extended Precision In Matlab
 - Setting Reading Goals Implementation And Application Of Extended Precision In Matlab
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Implementation And Application Of Extended Precision In Matlab
 - Fact-Checking eBook Content of Implementation And Application Of Extended Precision In Matlab

- Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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