

Computer Algebra System Maple: A New Software Library

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Abstract. The paper represents *Maple* library containing more than **400** procedures expanding possibilities of the *Maple* package of releases **6,7** and **8**. The library is structurally organized similarly to the main *Maple* library. The process of the library installing is simple enough as a result of which the above library will be logically linked with the main *Maple* library, supporting access to software located in it equally with standard *Maple* software. The demo library is delivered free of charge at request to addresses mentioned above.

1 Introduction

Computer Algebra (also known as Symbolic Computation or Computational Algebra) has found applications in many domains of science such as mathematics, physics, chemistry, computer science, engineering, technology, computational biology, education, etc. The computer algebra systems (CAS) such as *Maple*, *Mathematica*, *Reduce*, *MuPAD*, *Magma*, *Derive*, *Macsyma*, *Axiom* and others are becoming more and more popular and now they are valuable tools for teaching, research and industry.

In a series of our books the packages such as *Reduce*, *Maple*, *MathCAD* and *Mathematica* were considered [1–4]. Our experience of approval and use in different mathematical and physical appendices of four packages *Reduce*, *Maple*, *Mathematica* and *MathCAD* enables us to consider packages *Maple* and *Mathematica* as undoubted leaders (on the basis of a generalized index) among all listed modern means of computer algebra. Meanwhile, we prefer package *Maple* due to a number of important reasons which are not considered here.

Computer algebra becomes a rather powerful and useful tool for scientists and experts from various fields. However, manifold appendices demand significant numerical calculations combined with algebraic ones. With each new release, package *Maple* meets more and more requirements. *Maple* package has been widely used not only as means of solving mathematical problems. The use of the package enabled to revise approaches to teaching subjects related to mathematics in universities by defining in many cases the methods for subject development the use of PCs to solve mathematical problems of various purposes [1–4].

Researchers use *Maple* as an essential tool when solving problems related to their investigation. The package is ideal for formulating, solving, and exploring different mathematical models. Its symbolic manipulation facilities greatly extend the range of problems which can be solved by it. Educators in high schools, colleges, and universities have revitalized traditional curricula by introducing problems and exerci-

ses which use *Maple*'s interactive mathematics and physics. Students can concentrate on important concepts rather than on tedious algebraic manipulations. Finally, engineers and experts in industries use *Maple* as an efficient tool replacing many traditional resources such as reference books, calculators, spreadsheets and programming languages. These users easily solve a wide range of mathematical problems, creating projections and consolidating their computations into professional reports.

2 A New Software Library for Maple

Meanwhile, our operational experience during 1997-2002 with the *Maple* of releases 4, 5, 6, 7 and 8 has enabled us not only to estimate its advantages compared with other similar mathematical packages, but has also revealed a series of faults and shortcomings eliminated by us. Furthermore, the *Maple* does not support a series of important enough procedures of information processing, symbolic and numeric computing, including means of access to datafiles. In view of told, we in process of the *Maple* operation have developed a lot of effective enough software (procedures and modules), by a whole series of parameters expanding opportunities of the package. This software had been organized as a library which is structurally similar to the main *Maple* library, and is provided with detailed enough Help system analogous to *Maple* Help system.

The library elements had been written on built-in *Maple* language with usage in a series of cases of means of underlying operating system MS DOS. At that, for increase of their functional efficiency a lot of special receptions of programming (including non-standard ones) had been used. Among these receptions had been used so-called method of '*disk transits*', which had been described in our books [1-4] enough in detail. In particular, the given method can be used the most advantageously in the problems, needing in a generating of *Maple* fragments executable in real-time. The essence of the given mechanism in the *Maple* environment is well illustrated in our last books [3, 4].

The presented software increases the range and efficiency of use of the package owing to the innovations in three basic directions: (1) elimination of a series of basic defects and shortcomings, (2) expanding of capabilities of a series of standard means, and (3) replenishment of the package by new means which increase the capabilities of its environment, including the means which improve the level of compatibility of releases 6, 7 and 8. The experience of use of the given software has confirmed its high operational characteristics at use of the *Maple* in numerous appendices.

As a matter of fact, the software has been developed as a self-installed Library which is analogous to the main *Maple* library. The given library is logically linked to the main *Maple* library, providing access to means contained in it similarly to standard means of the package. The given library supports the releases 6, 7 and 8; its installation provides essential increase of capabilities of the package *Maple* both for beginners and the advanced users, which use the package in various appendices.

The basic attention had been given to the additional means created in process of use of the package of releases 4-8 which by a series of parameters essentially expand opportunities of the package and facilitate work with it. The considerable attention is given to the means providing package compatibility of releases 6, 7 and 8. The

experience of use of the given software has confirmed its high operational characteristics at use of the *Maple* in numerous appendices. The current version of the library contains means oriented upon the following kinds of processing:

1. Software of general destination
2. Software of operation with procedural and modular objects of the package *Maple*
3. Software of operation with numeric expressions
4. Software of operation with string and symbolic expressions
5. Software of operation with the lists, the sets and the tables
6. Software of support of data structures of a special type
7. Software of support of bit-by-bit processing of the information
8. The software expanding graphic possibilities of the package *Maple*
9. The software of expanding and improving the standard means of the *Maple*
10. Software of operation with datafiles and *Maple*-documents
 - 10.1. Software of general destination
 - 10.2. Software of operation with the *TEXT* datafiles
 - 10.3. Software of operation with the *BINARY* datafiles
 - 10.4. Software of operation with the *Maple* files
 - 10.5. Special means of operation with datafiles
11. Software of operation with user libraries
12. Software for problems solving of mathematical analysis
13. Software for problems solving of linear algebra
 - 13.1. Software of general destination
 - 13.2. Software for operation with the *rtable*-objects
14. Software for support of problems of simple statistics
 - 14.1. Software of problems solving of descriptive statistics
 - 14.2. Software of problems solving of regression analysis
 - 14.3. Software for a testing of statistical hypotheses
 - 14.4. Elements of the analysis of time (*dynamic*) series

Basic innovations of the above software can be briefly characterized in the following way. Above all, the most general procedures of operation with *Maple* package are intended for receiving information such as number of the current *Maple* release, full paths to its main subdirectories, current version of an underlying system, information about installed *Maple*-releases, etc. (group 1). Similar means are absent among the standard *Maple* software, however they appear useful enough at more advanced operation with the *Maple*.

The next group of means expands the possibilities of the *Maple* package at operation with procedures and modules. These means support kinds of processing such as converting of modules into procedures; testing of presence in files of incorrect modules; check of parameters of procedures and modules; check of activity (availability for direct use) of a procedure or module; check of type of a modular table; a converting of files of input *Maple*-format containing modules; converting of a module of the second type into the first; converting of a file of input *Maple*-format into file of internal *Maple*-format, and vice versa, etc. (group 2). The represented means provide a lot of the manifold useful operations with the procedural and modular objects of the *Maple*. They are used enough widely at advanced programming of various problems in the *Maple* environment.

Means of the third group expand the possibilities of the package at operation with numeric expressions. In particular, these means provide useful procedures such as converting of a floating-point number into a symbolic customary format, special converting of integers into lists, and vice versa, converting of an integer into symbolic format with delimiter, converting of number represented by a format {string, symbol} into fraction, etc.

The next means (group 4) expand the possibilities of the package at operation with expressions of type {string, symbol}. These means provide a series of useful procedures such as: special kinds of converting; comparison of strings or/and symbols; case sensitive pattern searching; exhaustive substitutions into strings or symbols; inversion of symbols, a strings or lists; reducing of multiplicity of entries of a symbol into a string; identification of entries of special symbols into a string; and others. In a series of cases these means simplify operation with objects of type {string, symbol}.

The fifth group represents the software which expands the possibilities of the *Maple* at operation with objects of types {list, set, table}. The list structures play an extremely important role, defining the ordered sequences of elements. Since the sixth release, a possibility of substantial expanding of operations with the list structures arises. As an example having the interesting practical appendices, we consider definition of algebra on a set of all lists having the same length. Algebraic operations the corresponding procedures provide. A series of procedures of the group supports useful kinds of processing such as: special converting of lists into sets, and vice versa; operation with rarefied lists; dynamic assignment of values to elements of a list or a set; evaluation of indices of a table over its entry; representation of a special type of the tables; special kinds of exhaustive substitutions into a list or a set; a series of important kinds of sorting of nested lists, and also many others. The given means are useful enough at operation with objects of the above types.

The sixth group contains the expanded means of work with the data structures such as the *stack*, *queue*, *priqueue*, etc. Along with standard data structures of types {stack, queue, heap, priqueue}, the new *dirax*-type maintained by module *DIRAX* had been defined. The module supports data structure of direct access of *dirax* type, which by a series of parameters essentially expands data structures of types {stack, heap, queue}. The data structures of the *dirax* type are founded on list organization, however allow to address itself immediately to its elements according to their addresses (numbers). Moreover, in contrast to structures of type {stack, queue}, the *dirax* structure is precisely identified by *ispd* index; a reception, used in the module, allows easily to define precise classification of data structures of type {stack, queue, heap, dirax}. At the same time, the *DIRAX* module ensures the effective solution of problems of shared use of data structures of all above-mentioned types. Furthermore, means of testing of the above data structures types have been essentially precised, because the standard means have some inaccuracies.

In the seventh group the software which supports bit-by-bit information processing in environment of the *Maple* is represented. The package does not possess means of the similar type. The software offered by us is represented by six useful procedures such as: *Bit*, *Bit1*, *xbyte*, *xbyte1*, *xNB* and *xpack*. These procedures serve for bit-by-bit information processing, i.e. the user has a possibility to operate with strings or symbols on the level of separate bits composing them.

The eighth group contains 60 procedures which expand and improve the standard means of the *Maple* of releases 6, 7 and 8. The package does not possess means of the similar type and their availability in a series of cases essentially expands possibilities of the package and simplifies operation with it. These means are used enough widely both at operation with *Maple* in interactive mode and at programming of various problems in its environment. In particular, the changes touched the *assign* procedure which is one of the reasons of incompatibility of releases 6, 7 and 8. The given problem has appeared rather essential at translating of software created in environment of the 6th release, into environment of the 7th and 8th release. The incompatibility problem of the last three releases of the *Maple* is considered in detail in our books [1–4]. The procedures represented in the group both eliminate the above problem of incompatibility of releases and enlarge the possibilities of the standard function *assign* by allowing, in particular, to assign a sequences of expressions to variables.

The subgroup of procedures *Save*, *Save1*, *Save2* and *Read1* fulfills a much wider set of functions, than built-in functions ‘*save*’ and ‘*read*’, eliminating a series of essential shortcomings of the last. Along with that, the standard procedures ‘*convert*’ and ‘*type*’ have been essentially expanded and precised. In particular, a series of important types of data structures and expressions had been defined. So, new types for files, directories, paths to files, bytes have been determined, etc. The mechanism of types is very powerful facility of the *Maple*, therefore its further expanding is topical enough in my opinion. The other procedures of the ninth group also represent undoubted interest at programming of various problems in the *Maple* environment, both by simplifying the programming and by making it by more clear.

The ninth group contains the software expanding graphic possibilities of the *Maple*. The package does not possess means of the similar type. The software is represented by 12 useful procedures having undoubted applied interest.

Being the programming language in the package environment, oriented, first of all, onto symbolical calculations, the *Maple*-language has the relatively limited opportunities at operation with the data which are located in external memory. And in this plan the *Maple*-language essentially yields to traditional programming languages such as C, Cobol, Fortran, PL/1, Pascal, ADA, Basic, etc. At the same time, the *Maple* language, oriented, first of all, onto the solution of problems of mathematical character, gives a set of means for access to datafiles which can entirely satisfy a wide enough audience of users of physical and mathematical appendices of the package. The tenth group contains a lot of additional means of access to datafiles which essentially expand opportunities of the package in the given direction.

In particular, the subgroup from 50 procedures supports a series of important functions of access to datafiles, namely: operations with drives and volumes of external memory, operations with directories and files, renaming of directories and files, change of attributes of a directory and a file, check of properties of a directory or a file, and many other procedures, which support a multitude of useful functions of operation with elements of a PC’s file system.

The next four subgroups contain means supporting a number of useful functions of work with datafiles of types *TEXT* and *BINARY*, with *Maple* files of other types, and a lot of means for special datafiles processing. In particular, means of these subgroups provide procedures such as: effective handling of situation “*end of BINARY file*”, methods of organization of direct access to *TEXT* files, an extracting of correct email-

addresses out of a *txt*-file, a coding/decoding of a *TEXT* file, useful restructurings of the *TEXT* files, and many others.

The *Maple* package of releases 6, 7 and 8 have a number of means for creation of mechanisms of operation with the user libraries (structurally analogous to the main *Maple* library) of procedures and modules, allowing in the *Maple* environment to use them at a level of access, analogous for built-in means of the package. The procedures, represented by the eleventh group, allow to substantially simplify operation with user libraries. So, the basic procedure *User_pflm* ensures making and update of user's libraries structurally analogous to main *Maple* library, with their subsequent logical linking with the main library, what ensures access to functional means, contained in them, at a level of the built-in package means. At that, at the procedure call it is enough to indicate only a set or a list of names of the saved means and a name of sub-directory for the created library. Along with that, this group contains a number of means for support of the simplest ways of creation of the user procedures libraries and organization of access to them. User libraries, created in such a way, have the organization, more simple, than the main *Maple* library. In a series of cases such libraries are the more simple in use.

For interactive making or updating of Help database of the user's library the *Maple* gives means of the *Help*-group of the Graphical User Interface (GUI), namely: two functions 'Save to Database' and 'Remove Topic'. However, in view of a series of differences of releases 6, 7 and 8 the *helpman* procedure providing automatic up-date of the user's Help database on the basis of the beforehand prepared *mws*-files had been created. At that, it is necessary to note one important circumstance. In some cases by a chain of functions "Help -> Save to Database" of the *Maple*'s GUI, a putting into user Help database of a *Mapl*-worksheet is not guaranteed (at registering it in the corresponding index file *Maple.ind*), whereas the procedure *helpman* is free of this defect.

Having created own library of procedures with use of the above procedure *User_pflm*, or in a different way, quite naturally arises a problem of its optimization, in particular, with the purpose of a frequency revealing of use of means, contained in it, and basic computer resources used by them. In this context the problem of optimization of the user libraries is a rather important. For these purposes a rather useful appears the procedure *StatLib(L)*, providing gathering of the basic statistics on the indicated *L* library and the return it for the subsequent analysis. Along with that, the group contains means for support of various useful procedures for operation with the user libraries of different organization, including means for restoration of the damaged libraries.

At last, means of groups 12-14 support a series of useful enough procedures for problems solving in analysis, linear algebra and simple statistics. In particular, these means provide a series of very useful procedures for operation with *rtable*-objects, for special sorting of numeric objects of types {*array*, *matrix*, *Matrix*}, for construction of linear and quadratic regression models, for hypotheses testing and analysis of time series. The detailed description of all means composing the above library is represented in our monograph [4]. The means, represented by the given library, relieved a lot of the questions which have arisen in discussions of members of the *Maple User Group* and outlined a series of interesting ways of subsequent development of the library.

3 Structural Library Organization

The library is structurally similar to the main *Maple* library, is supplied with the advanced Help-system about means located in it and is logically linked to the main *Maple* library, providing access to means contained in it similarly to the package means. For the library no more than 6 MB of free space on hard disk is demanded. The library is located in separate subdirectory of *LIB*-directory with the main *Maple* library. The library subdirectory contains three files *Maple.hdb*, *Maple.ind*, *Maple.lib* (analogously to the main *Maple* library), and also special file *Maple_U.cmd* which contains all history of updating of the library since its creating.

The simple guide describes installation of library at presence on the personal computer of the installed *Maple* package of releases 6, 7 and/or 8. The library admits two levels of installation, namely: (1) implantation into a *Maple* environment of the fully-prepared library of the corresponding release (6, 7 or 8) with posterior linking of it with the main *Maple* library, and (2) execution in *Maple* environment of a special *mws*-file with definitions of the library members with posterior adding of Help database into the library installed in this way.

The library Help system gives the detailed enough description of all means contained in the library with the most typical examples of their use, including analysis of erroneous and especial situations, which can arise at their execution. In one's turn, the monograph [4] represents the detailed description of the software contained in the library, including source texts of the procedures.

The library delivery includes the source texts of all procedures and modules. That allows not only easily to immerse them into the *Maple* environment of releases 6, 7 and 8 on many computer platforms, but also to use as an useful enough illustrative material at mastering of the advanced programming in the package environment. Many of the software, represented here, use useful enough methods in the practical respect and also receptions of programming (including and non-standard ones) in the package environment, conditioning to them as the applied, and educational interest.

The library is designed for the broad audience of experts, teachers, post-graduates and students of the natural-science professions which use in own professional work the *Maple* package of releases 6, 7 or 8 on Windows platform. The library is delivered as shareware software on the basis of separate request by email indicated above; for the more detailed acquaintance with the library its demo can be requested.

References

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