Mumps Programming Language Interpreter, Compiler, and C++ Class Library User's Guide Including Sqlite Global Array Database Storage Facility

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1.1 Installation Overview

1.2 Interpreter vs Compiler

The compiler supports most of the features supported by the interpreter but not all. The compiler generates a C++ file which is subsequently compiled along with rgw Mumps run-time libraries. Compiler code is usually faster but, since both use the same database engine, database intensive programs run at about the same speed.

The compiler translates Mumps to C++. Consequently, compiled programs can be edited as C++ programs and other additional code introduced which might not be available in original Mumps.

1.3 Database options

1.3.1 Native Database Options

The native database option is fast with a minimum of overhead and it can efficiently manage very large databases however it lacks a number of features normally found on modern database systems:

1. It is sensitive to system crashes and programming errors.
2. It does a minimum of checkpointing.
3. It maintains part of the global array tree in volatile memory.

If the host system crashes or the program using the global arrays terminates unexpectedly, the contents of the entire global array database are likely to be lost.

However, in applications where speed is important and, in the event of a crash, the program can be re-run, the native database is a good choice.

The native database has two configurations:

1. The first of these is a *single user* global array facility where the global arrays are stored in one directory, usually the one in which the Mumps program is itself running. In this mode, only one *read-write*[1] Mumps program may access the global arrays in a given directory at a time although other Mumps programs may run concurrently in other directories operating on other global array data sets. This is the fastest but most restrictive option. The single user version also contains a *read-only* version that permits multiple instances of Mumps to access the database concurrently provided no version concurrent version is *read-write.*

2. The native database also has a *shared* option. In this version, multiple instances of Mumps may concurrently access the database in read-write mode. This option is slower than the single user version.

The native database is stored in the current directory in files named *key.dat* and *data.dat.* Database files created by the single user version may be used by the shared version (but not concurrently) and vice versa.

1 The native database Mumps comes in two versions: a *read-write* version which may both read and write global arrays and an *read-only* version where each Mumps program may only read the global arrays. Multiple *read-only* instances may operate concurrently on the same global array data sets.

1.3.2 Sqlite3 Database Option

If data integrity, remote and multi-user access are important, the Sqlite is better. In this option, the interpreter and compiler use Sqlite3 to store the global arrays.

While option 2 is slower than option 1, due to relational data base system overhead, using a relational database has *significant advantages* with regard to reliability and flexibility. These include:

1. All database transactions are ACID (*Atomicity, Consistency, Isolation, Durability*) compliant.
2. SQL commands such as Begin Transaction, Commit and Rollback are available.
3. The Mumps global arrays can be queried with SQL commands from non-Mumps environments.
4. SQL views of the Mumps database may be constructed.
5. The Mumps global array database can be remote and distributed.
6. Mumps programs can execute SQL commands on the server on any accessible database table.
7. Multiple concurrent Mumps programs may run at the same time.

The distribution contains scripts that will build various versions of the system. These are detailed next. You must be *root* to run these.

The scripts assume a Debian (*apt-get*) based Linux installation. If you are using a version of Linux not based on Debian, you will need to manually install and configure the required system software manually according to the procedures on your system.

Some of the scripts provided with the distribution may install system software as needed. Consequently, when using these scripts, your machine needs to have a reliable Internet connection. Also, due to Internet load factors, it is possible that software installations may take a long time or, in some cases, fail in the unlikely event that the servers from which the software to be downloaded are unavailable.

The Mumps interpreters and libraries built as a result of the scripts will be stored in ***/usr/bin, /usr/lib,*** and ***/usr/include***.

1.4 Required System Software

Building mumps requires that your system have certain software installed. For the most part, these are available through the Synaptic Package Manager or *apt-get*. The ***Build...*** scripts and the installers automatically install these if they are not present on your system.

The required software inclused the following:

1. Linux Debian based version such as Debian, Ubuntu or Mint. The Windows WSL (Windows Subsystem for Linux) implementation with Ubuntu may be used.

2. The *g++/gcc* compilers and related libraries.

3. The ***pcre*** (Perl Compatible Regular Expression) development libraries. The ***pcre*** libs should be in ***/usr/lib*** and the include files in ***/usr/include***. Be certain to install the ***pcre*** **development** libraries.

4. The *bash shell* interpreter located in ***/bin***.

5. The *GNU* ***readline*** and ***readline-dev*** packages.

6. ***autoconf***

7. The following libraries are needed for the extended precision mathematics. If they are not installed by default, you will need to do so. Be sure to install the **development** versions of the libraries:

   a) The GNU Multiple precision floating point computation library

      `http://www.mpfr.org/libmpfr-dev`

   b) The GNU Multiprecision arithmetic library development tools

      `https://gmplib.org/libgmp-dev`

1.5 Basic Software Installation

1.5.1 Installing using the Installers

Note: if you run an installer (any installer for that matter) while an Update Manager is active, the installer may report missing files, This is because the Update Manager locks the installation database until it is finished blocking your installer as a result. Retry when the Update Manager has finished.

There are now two installers (***mumps-native-single-user-amd64.deb*** and ***mumps-sqlite3-amd64.deb***) that will quickly automate the process of installing Mumps. These install a pre-compiled executable along with necessary system libraries. Instructions for running the installers is given below.

If you have a previous version installed, you may need to remove it before installing the new version. This can be done in the Synaptic package manager (package names: ***mumps-sqlite3*** or ***mumps-native-single-user***) or with the command:

sudo dpkg --remove mumps-native-single-user
or
sudo dpkg --remove mumps-sqlite3

To install, on many systems, from an explorer window, double click the downloaded ***.deb*** file.

Alternatively, in the directory containing the ***.deb*** file, do the following (there may be errors indicating missing packages. Step 2 will fix this):

sudo dpkg -i mumps-native-single-user-amd64.deb
sudo apt install -f

Or, the following:

sudo apt install gdebi
sudo gdebi mumps-native-single-user-amd64.deb

Both will install the named Mumps package and resolve dependencies. Substitute m***umps-sqlite3-amd64.deb*** for the Sqlite3 distro.

1.5.2 Installing from Source Code

Building from source code involves downloading the distro, installing required system libraries, configuring the software, and, finally, compiling and installing the software.

There are Bash script files (see below) that will perform these actions.

Because of complex configuration options, **do not use** the customary ***configure / make*** sequence. Use the scripts.

The names of these script all end in ***.script***.

1. ***ConfigureNativeMumps.script*** followed by ***BuildNativeMumps.script*** followed by ***mumps-native-single-user-amd64.deb*** using one of the methods shown above.
2. ***ConfigureSqliteMumps.script*** followed by ***BuildSqliteMumps.scrip***t followed by ***mumps-sqlite3-amd64.deb*** using one of the methods shown above.

The first set of script files (***Configure...***) install the native database version while the second set (***Build...***) compiles the code, installs a local copy of the selected version, and builds an installer (***.deb***). The ***.deb*** files are created in the source code home directory. It is they that do the actual installation. They are run as ***root.***

The ***Configure...*** scripts need only be run once. The ***Build...*** and ***.deb*** scripts need to be run every time you modify the Mumps source code or change configuration settings.

The ***Configure...*** files install the required system libraries if not already present. They use the ***apt*** command and thus ***must*** be run as ***root***. Depending on your system, they can be time consuming.

The ***apt*** tool installs required software used by Debian GNU/Linux and related distributions (such as Ubuntu and Mint). Other Linux systems use different but similar tools. These script files work only with Debian related (***apt***) systems.

The ***Build...*** scripts should ***not*** be run ***Build...*** as ***root***.

Only one database version may be installed at a time.

1.5.3 Basic Sqlite3 Database Configuration

In order for Mumps to store and retrieve global arrays in Sqlite3, there must be a pre-existing database file named ***mumps.sqlite*** which is accessible to the instance of Mumps being executed. Normally, that means the file is in the directory where you started Mumps from. Links, however, may be used if the database file is in another directory.

You may create or re-initialize ***mumps.sqlite*** with the script file:

mumps-sql-db-create.script

which is installed by the above. Options contained in ***BuildSqliteMumps.script*** can be used to set the maximum number of indices, the maximum number of characters per Mumps global array index, and the maximum number of characters that can be stored at a node. The defaults are 8, 64 and 128, respectively.

1.5.4 Sqlite3 Database Server Stored Global Arrays

While the Mumps global arrays may be stored in the Sqlite3 relational database system, with simple code changes, other RDBMS servers could also be accommodated.

There are advantages and disadvantages to storing global arrays in a relational database. The primary disadvantage is that the dynamic hierarchical nature of the Mumps database is not well suited to the tabular structure of a relational database where overall access is usually slower.

On the other hand, the Sqlite3 relational database provides flexible multi-user, robust, is fully ACID (*Atomicity, Consistency, Isolation, Durability)* compliant and provides a complete suite of transaction processing functions not otherwise available in the Mumps language definition.

A further advantage is that global array data may be interrogated and manipulated by ordinary, standard SQL commands.

By default, the Mumps interpreter maps global array references to a multi-column relational database table normally with the name ***mumps*** (this can be changed by ***BuildSqliteMumps.script***). The columns of the table are named ***a1, a2, ... a10*** and so forth. The values in the columns are: the name of the Mumps global array (in ***a1***), and indices from a global array reference (in ***a2*** through ***a9***), followed by the value stored (if any) (***a10***).

For example, the code:

```
set ^birds(1,2,3,4,5)="ducks"
```

would map to a table named *mumps* in the relational database as follows:

birds

a1	a2	a3	a4	a5	a6	a7	a8	a9	a10
birds	2	3	4	5					ducks

Where the values for ***a6*** through ***a9*** are *null*.

In most modern database systems, the *null* columns do not seriously impact speed. Alternative methods to implement trees in relational databases introduce very high levels of overhead. Further, the ***mumps*** table is indexed in Sqlite3 by global array name and the first index (first two columns) for faster access. This may be altered in ***BuildSqliteMumps.script.***

If your program instantiates array elements like the following:

```
set ^birds(1)="all"
set ^birds(1,2)="flying"
set ^birds(1,2,3)="water"
set ^birds(1,2,3,4)="large"
set ^birds(1,2,3,4,5)="ducks"
set ^birds(1,3)="flightless"
set ^birds(1,3,3)="water"
set ^birds(1,3,3,4)="large"
set ^birds(1,3,3,4,5)="penguins"
```

The relational table will look like[2]:

a1	a2	a3	a4	a5	a6	a7	a8	a9	a10
birds	1								all
birds	1	2							flying
birds	1	2	3						water
birds	1	2	3	3					large
birds	1	3	3	4	5				ducks
birds	1	3							flightless
birds	1	3	3						water
birds	1	3	3						large

2 Table row order may differ but this is not important.

```
+------+------+------+------+------+------------+-------|-------|-----------|
|birds | 1    |  3   |  3   | 5    |      |      |       |       |penguins   |
+------+------+------+------+------+------------+-------|-------|-----------|
```

Mumps access requests produce the expected results:

```
write ^birds(1)              => all
write ^birds(1,2)            => flying
write ^birds(1,2,3)          => water
write ^birds(1,2,3,4)        => large
write ^birds(1,2,3,4,5)      => ducks

write $order(^birds(1,2))     => 3
write $order(^birds(1,2,"")) => 3
```

The row-wise index duplication seen in the above is also present in other Mumps systems.

An advantage, as mentioned above, is that data stored in such a table may be queried by an ordinary SQL command such as:

```
select a10 from mumps where a1='birds' and a2='1' and a3='2';
```

which yields ***flying***.

Similarly, SQL ***views*** may be established on the ***mumps*** table to facilitate access in other ways by other SQL users.

1.6 Compilation Configure Pre-Set Options

The ***Build...*** scripts contain invocations of the ***configure*** script with the basic options pre-set. The following are the basic recommended compile configuration options. Installation (***prefix***=) is to ***local_install*** in the distro directory.

1.6.1 Single User Native Database

```
./configure \
--with-cache=262145 \
--with-hardware-math \
--with-int-32 \
--with-float-digits=6 \
--with-block=2048 \
--with-slice=0 \
--with-alarm=0
```

1.6.2 Sqlite3 Database

```
./configure \
--with-sqlite --with-dbname=mumps \
--with-slice=0 \
--with-journal-mode=MEMORY \
--with-alarm=0
```

1.7 Math Options

Arithmetic in this Mumps distribution can be performed either by hardware or by a library of extended precision software.

In extended precision mode, the precision of both floating point and integer numbers can be significantly larger than is the case with standard hardware arithmetic with minimal performance penalty.

The several Build scripts look for files ***gmp.h*** and ***mpfr.h***. If these are found, they permit the use of the extended math packages. If not found, the builds will use hardware arithmetic.

You may override this and force hardware arithmetic by modifying the scripts to add the --*with-hardware-math* option.

1.8 Numeric Configuration Options

Both extended precision and basic hardware precision are available as noted above.

In this version of Mumps, as is the case with many others, numeric values are stored in variables as character strings. When a variable participates in an arithmetic operation, the value is converted to a numeric format, the operation performed (for example, addition), and the result converted back to character string. Not only are numeric values stored in variables as strings, but also, intermediate results are in string format.

In this version of Mumps, there are several options with regard to handling numeric data. As an option, you may process numeric data either by means of builtin hardware operations or by means of extended precision software. Hardware is quicker while extended precision permits a greater range of values. The following discusses the *configure* options available.

1.8.1 Hardware Math

In hardware math mode, integer and floating point numbers are processed by your machine's arithmetic processing hardware. Floating point numbers are treated as either *long double* or *double* values and integers are treated as either signed 64-bit *long long* or signed 32-bit *long* integer values.

To enable hardware math, you must specify the following as a *configure* option:

--with-hardware-math

Integer arithmetic may be performed in *int* (32 bit) or *long long* (64 bits in the gcc compiler) mode. The default is *long long*. The *int* mode may be turned on with the *configure* option:

--with-int-32

If the above is not specified, *long long* is used. The gcc compiler implements *long long* as 64 bits. The data type *int* is implemented as 32 bits.

Floating point arithmetic may be performed in either *long double* or *double* mode. The *long double* mode may be enabled with the *configure* option:

--with-long-double

If the above is not specified, floating point arithmetic will be performed in *double* mode.

All numeric values are stored internally as strings. They are converted to binary numeric integer or floating point format just prior to an arithmetic operation and then converted back to strings.

By default, the string format of a floating point number will have with 8 digits of precision. This can be altered by *configure* using the *–with-float_digits* option (default is 8). For example, if you want 16 digits of precision, add

--with-float-digits=16

to the *configure* parameters. The number of digits specified should be consistent with the hardware data type (*double* or *long double*).

On x86 architectures, *long double* is usually implemented as an 80 bit number with a sign bit, an 15 bit exponent and 63 bit fractional part with a range of approximately 3.65×10^{-4951} to 1.18×10^{4932} while *double* is implemented as a 64 bit number.

1.8.2 Extended Precision Math

Extended precision is available through use of the GNU multiple precision arithmetic library[3] and the GNU MPFR library[4]. For integers, this means effectively unlimited precision. For floating point numbers, the exponent is 64 bits and the fraction is user specified (default of 72 bits in Mumps - this option may be set by *configure*).

Hardware arithmetic will be selected during compilation of the interpreter if (1) *configure* does ***not*** find the extended precision libraries or (2) the user affirmatively specifies the configuration option:

--with-hardware-math

If extended precision is used, the number of bits in the fraction of a floating point number can be set with:

--with-float-bits=***value***

where *value* is the number of bits. The default value is 72. The number of decimal digits for a given number of bits (nbits) is approximately:

$\log_{10}(2^{nbits})$

Thus, 72 bits corresponds to approximately 21 decimal digits.

For extended precision floating point numbers, the number of digits of precision to print is controlled by:

--with-float-digits=***value***

where *value* is the number of digits. The default is 8.

The number of digits specified should be consistent with the number of bits in the fraction. If the number of digits specified is too large, random low-order digits will appear in numbers.

If extended precision mode is in effect, integer numbers have no upper or lower bound.

1.9 Full List of Configure Options

The configure step as is typical contains many options. Specifying these causes modification to the source code and changes the final product. These must be set correctly. Not all combinations work.

The distribution, as noted above, contains several *bash* script files with pre-configured ***configure*** commands. For the most part, you probably don't want to write your own *configure* options except in limited cases. You may, however, want to edit the files provided to set details such as passwords and so on. This is discussed below.

The full set of options to *configure* are:

1.9.1 configure prefix=

The directory where the runtime modules will be stored. If this is not specified, the default location is in a directory named ***local_install*** in the mumps distro directory.

3 http://www.mpfr.org/
4 http://gmplib.org/manual/index.html

1.9.2 General Relational Database Options

1.9.2.1 --with-dbname=name

Default name of the Sqlite3 mumps database table name [default: ***mumps***].

1.9.2.2 --with-index_size=number

Maximum number of characters in each Sqlite3 global array index [default: 64]

1.9.2.3 --with-data_size=nbr

Maximum number of data characters stored for an Sqlite3 global array reference (final column) [default: 128]

1.9.2.4 --with-dbfile=name

Name of Sqlite's database file stored in the users directory [default: ***mumps.sqlite***]

1.9.2.5 --with-slice=value

When using Sqlite3 or the single user native database, this number should be zero.

1.9.2.6 --with-server

Compile the native database in shared (server) mode. This value should be zero for single user native and Sqlite databases. It is used with in connection with a pipe version of the global database not currently supported.

1.9.2.7 --with-alarm=value

This value should be zero for Sqlite3 and single user native modes.

1.9.2.8 --with-cache=VAL

Native global database in-memory cache size. The number is the number of blocks (see: --*with-block*) to maintain in memory.

The **only** legal values for this parameter are:

```
9
17
33
65
129
257
513
1025
2049
4097
8193
16385
32769
65537
131073
262145
524289
1048577
```

1.9.2.9 --with-block=blksize

Native global Btree block size.

The native Btree database consists of two files: the tree file (*key.dat*) containing the actual Btree and the data file (*data.dat*) containing stored data. The maximum size of the Btree file is dependent on the block size. The block sizes listed below each have a PAGE_SHIFT value and this ultimately determines the maximum file size as shown. The basic internal disk address is effectively 31 bits (signed 32 bit quantity) but, depending upon the block size, some number of bits at the low-order end of a block address are always zero. For example, if the block size is 1024, the final 10 bits of an address are always zeros. As only the significant 31 bits are stored, the true address is not 31 bits but 41 bits thus a file size of 2 terabytes is possible.

The only legal values for this parameter are:

```
1024
2048
4096
8192
16384
32768
65536
131072
262144
```

The block size determines the internal PAGE_SHIFT factor:

```
1024        →     PAGE_SHIFT 10
2048        →     PAGE_SHIFT 11
4096        →     PAGE_SHIFT 12
8192        →     PAGE_SHIFT 13
16384       →     PAGE_SHIFT 14
32768       →     PAGE_SHIFT 15
65536       →     PAGE_SHIFT 16
131072      →     PAGE_SHIFT 17
262144      →     PAGE_SHIFT 18
524288      →     PAGE_SHIFT 19
1048576     →     PAGE_SHIFT 20
2097152     →     PAGE_SHIFT 21

PAGE_SHIFT 10 corresponds to MBLOCK 1024 and a max Btree file size of 2 TB
PAGE_SHIFT 11 corresponds to MBLOCK 2048 and a max Btree file size of 4 TB
PAGE_SHIFT 12 corresponds to MBLOCK 4096 and a max Btree file size of 8 TB
PAGE_SHIFT 13 corresponds to MBLOCK 8192 and a max Btree file size of 16 TB
PAGE_SHIFT 14 corresponds to MBLOCK 16384 and a max Btree file size of 32 TB
PAGE_SHIFT 15 corresponds to MBLOCK 32768 and a max Btree file size of 64 TB
PAGE_SHIFT 16 corresponds to MBLOCK 65536 and a max Btree file size of 128 TB
```

The separate data file may grow to a max of 2**64 bytes for all settings.

1.9.2.10 --with-readonly

Native database will be read-only – only applies to the native global array facility. Multiple instances of a read-only version can be run concurrently.

1.9.3 --with-ibuf=

Maximum size of an interpreted program [default: 32000].

1.9.4 --with-strmax=

Maximum internal string size [default: 4096].

1.9.5 --with-locale=locale

Locale information [default: en_US.UTF-8].

1.9.6 --with-terminate-on-error

Halt interpreter on error [default: off]

1.9.7 --with-float-bits=val

Number of bits in an extended precision floating point fractional part (72).

1.9.8 --with-float-digits=val

Number of decimal digits to print in an extended precision floating point number (20).

1.9.9 --with-hardware-math

Use hardware arithmetic facilities.

1.9.10 --with-no-inline

Do not use inline functions.

1.9.11 --with-profile

Enable profiler (run ***gprof mumps gmon.out*** > ***stats***).

1.9.12 --with-maxglobal=val

Maximum length of a global array reference in the native database. A global reference length includes the array name, all indices, plus parentheses and commas.

2 Running a Mumps Program

2.1 Format the Global Array Sqlite3 Server

If you are using Sqlite3, be sure you have created ***mumps.sqlite*** dastabase file using the ***mumps-sql-db-create.script***. No action is needed if your are using the native database as it will create the files it requires (***key.dat*** and ***data.dat***) as needed.

2.2 Running the Mumps CLI Interpreter

To run the command line interpreter from a terminal window, type:

```
mumps
```

Any Mumps commands you enter will be executed immediately. To exit the interpreter, type **H**[alt] or *control-d.*

In interactive mode, you will be presented with a prompt (>). Any Mumps command may be typed for immediate execution (including a **goto** or **do** command with a file name reference pointing to a file to be loaded and executed).

The keyboard *up arrow* and *down arrow* keys may be used to cycle through and display commands previously entered during this session. Your may line edit previously entered commands. To execute, hit *enter.*

Command line input to the Mumps follows GNU ***readline*** conventions.

Exit the Mumps CLI. use the **Halt (h** or **H** or **halt)** command or ^**d**.

2.3 Interpreting a Mumps Program

Mumps source code programs are ASCII files that can be created by any ASCII text editor.

However, avoid using word processing editors as they may embed hidden formatting characters into the text. These will cause errors.

One way to interpret a Mumps program is to pass the name of the program as an argument to the Mumps interpreter:

mumps progname.mps

This will invoke the Mumps interpreter and pass the name of the program to it for execution. The program file passed need only be readable – execute permission is not required.

Alternatively, you may run a Mumps program source file directly by identifying the Mumps interpreter on the first source code line and making the file executable. In this case, the Mumps program will have the following as its first line:

```
#!/usr/bin/mumps
```

The pound sign (#) makes the line a comment to Mumps but **#!** is recognized by the Linux shell as introducing the name of the program (***mumps*** in this case) to receive the source file text. The default location of the Mumps interpreter is: ***/usr/bin/mumps*** .

The Mumps source file must be executable:

chmod u+x prog.mps

where ***prog.mps*** is the name of your mumps source file.

Example:

```
#!/usr/bin/mumps
      for i=1:1:10 do
      . write "Hello World ",i,!
      halt
```

You may execute the program by typing ***prog.mps*** to your terminal prompt. The program above will write ***Hello World***, followed by a number ten times.

Lines beginning (column 1) with pound sign (#) are ignored by the Mumps Interpreter and compiler.

2.4 Compiling a Program

The Mumps Compiler is invoked with the script file ***mumpsc***. This executable script will translate a Mumps program to an intermediate C++ file and compile the result using the Mumps runtime libraries. The result will be an executable binary. The intermediate C++ file is not deleted and can be inspected or edited. If available, the intermediate file is processed by ***astyle*** by default to improve readability.

The ***mumpsc*** script may be used to compile a C++ intermediate file from a previous translation from Mumps to C++. You may edit the intermediate file.

Compiled programs, in nearly all cases, **must** begin with the ***zmain*** command as the first executable command. Omitting this line will result in many errors.

You may edit the C++ file created by the Mumps Compiler and include calls to other routines. You may compile the result (the C++) file) to a binary executable using ***mumpsc***.

You should not pass a Mumps compiler generated C++ file directly to the C++ compiler because it requires libraries which the ***mumpsc*** script command automatically includes.

If you use the Mumps Compiler, you should avoid using the **xecute** command and the indirection operator (@) as these invoke the Mumps interpreter and greatly increase overhead.

3 Relational Database Functions

If Sqlite3 relational database storage of globals is enabled, the following functions and builtin variables are available in the Mumps interpreter. If the native database is in use, these, with the exception of **$zNative**, are ignored. Except as noted, a return value of zero (0) indicates success while a non-zero result indicates failure.

3.1 $zSqlite

$zsqlite with no arguments returns **true** (1) if globals are being stored in Sqlite3, **false** (0) otherwise.

3.2 $zSqlite("begin transaction")

Sends a ***BEGIN TRANSACTION;*** command to Sqlite3.

3.3 $zSqlite("commit transaction")

Sends a ***COMMIT TRANSACTION*;** command to Sqlite3.

3.4 $zSqlite("savepoint"[,*savepoint_name])*

If the second argument is omitted, send a ***SAVEPOINT default;*** command to Sqlite3. If the second argument is present, send a ***SAVEPOINT savepoint;*** command to Sqlite3 where '***savepoint***' is the value passed as the second argument. See Sqlite3 documentation for details.

3.5 $zSqlite("rollback"[,*savepoint*])

If the second argument is omitted, send a ***ROLLBACK TRANSACTION;*** to default; command to Sqlite3. If the second argument is present, send a ***ROLLBACK TRANSACTION savepoint;*** command to Sqlite3 where '***savepoint'*** is the value passed as the second argument.

3.6 $zSqlite("SQL",*sql_command)*

The SQL ***command*** will be passed to the Sqlite3 server. The result, if a single value, will be returned.

3.7 $zSqlite("pragma",*option)*

A ***PRAGMA*** command will be sent to Sqlite with *option* as its argument. If the ***PRAGMA*** results in a returned value, it will be the returned result of the function. Otherwise, the function will return 0 (success) or 1 (failure).

Some example *PRAGMA* commands:

```
s i=$zsqlite("pragma","mmap_size=20000000")
s i=$zsqlite("pragma","cache_size=-1000000")
s i=$zsqlite("pragma","journal_mode=off")
```

3.8 $zsqlOpen

Returns **true** if a connection to the SQL server is open, **false** otherwise.

3.9 $zNative

$znative returns **true** (1) if globals are being stored in the native global array. **False** (0) otherwise.

4 Implementation Notes

4.1 Source Code Format

C++ and C code were formatted using:

```
astyle -A6 -s6 *.cpp
```

C++ generated by the Mumps compiler is formatted in the same manner if ***astyle*** is available.

4.2 Modulo Operator

The modulo operator (#) returns results that are the same as the C/C++ modulo operator (%). Some Mumps documentation shows the Mumps modulo returning results that are different than what would be expected from C/C++ modulo.

4.3 Goto Command

If you use a **goto** command, all **do** command pending returns are canceled. That is if you invoke a section of code by means of a **do** and the section of code executes a **goto** command, the return to the line the **do** was on is canceled as well as any other pending returns.

You may not use a **goto** in a compiled program block.

4.4 Notes on Arithmetic Precision

See section 1.7 on page 12 for additional details.

4.4.1 $fnumber()

The builtin function **$fnumber()** only works on numbers that can be represented in a 64 bit floating point variable.

4.4.2 Exponential format numbers

All numbers represented in exponential format are treated as floating point numbers. If exponential format constants are used in expressions, they must be enclosed in quotes:

```
set i="1.23e3"*5
```

4.4.3 Arithmetic Precision

If found, Mumps will use the GNU *bignum* integer and MPFR floating point packages (this can be disabled by a ***configure*** in one of the ***Build...*** scripts).

4.4.3.1 Floating Point Precision

When using extended precision MPFR numbers, floating point values have a default fractional precision of 72 bits. This can be changed with the *--with-float-bits=val* configure option. The maximum number of printed decimal digits is, by default, 20. This can be changed with the *--with-float-digits=val* configure option. The number of meaningful decimal digits that can be printed depends upon the number of bits in the fractional part of the floating point number. More bits mean more decimal digits can be printed.

If MPFR is not present, standard hardware *double* precision is used.

4.4.3.2 Integer Precision

There is no effective limit to integer precision except string length and memory when the extended precision *bignum* package is in use. Otherwise, precision is the same as the hardware *long*.

4.4.3.3 Performance

Extended precision arithmetic results in slower performance. The amount is dependent on how much arithmetic a program does, whether it is mainly integer or floating point (floating point is slower), and, in the case of fixed length numbers, how large the numbers are. Larger numbers result in slower computations.

4.4.4 Rounding

The *$justify()* function is useful to round lengthy repeating decimal floating point numbers to a more reasonable value.

4.5 New Command

The **new** command functions differently than in the 1995 standard. The following details its behavior.

4.5.1 Runtime Symbol Table

The **new** command controls the internal run time symbol table. Upon entering a block by means of a **do** command, a new layer of the symbol table is created. Upon exit, the layer is discarded and the previous layer becomes the current layer.

When a program begins, an initial or base layer is created in the symbol table. In the absence of any **new** commands, newly created variables are stored at this base or initial layer.

When a variable is retrieved, all layers are searched beginning with the most recently created layer and progressing through to older layers until the initial layer is reached.

In the absence of any **new** commands, only the initial or base layer will contain variables.

4.5.2 Forms of the New Command

There are three forms of the **new** command based on the arguments provided. The first has no arguments, the second has a list of arguments consisting of variable names separated from one another by commas, and, finally, the third has an argument consisting of a parenthesized comma separated list of variable names. For example:

```
new
new a,b,c
new (a,b,c)
```

4.5.2.1 New Command with No Arguments

A **new** command with no arguments cause the system to copy all variables from all layers to the current layer.

Until the current block is exited, all access to any variable known at the time of the **new** command will access the copy of the variable, not the original. Upon exit from the block, the copies are deleted[5].

Any variable created whose name was not known when the **new** command was executed, will be created and stored at the lowest base layer of the symbol table and, consequently, not deleted upon exit from the block that contained the **new** command.

5 A block is any sequence of code entered as a result of a **do** command.

If a **new** command is executed in a block that invokes a block which itself executes a **new** command, the **new** command in the second block makes of copy of the invoking block's variables along with any variables created by the invoking block after executing its **new** command. If, in the symbol table stack, a vriable appears at several layers, only the most recent version will be copied.

An example is given in Figure 1. In this example, variables ***i, j,*** and ***k*** are created at the beginning of the program. The function ***test1*** is then called.

Initially, in ***test1***, the variables have the same values that they did in the main function. The variable *i* is changed. The **new** command is executed and a copy of all the variable currently known **(*i,j,k*)** is made to the current layer. The values of ***i, j,*** and ***k*** are altered the function *test2* is called.

The values of the variables on entry to ***test2*** are the same as they were in *test1*. Another **new** command is executed making another copy of the variables. These are altered and a new variable, ***y***, not previously known at any level (and thus stored at the base level) is created. Return is made to ***test1***.

In ***test1*** the values of the variable are printed and it can be seen that they have reverted to the values they had prior to entering ***test2***. Return is made to the main function.

In the main function the variables have reverted to the values they had prior to the invocation of *test1* with the exception of ***i*** which was altered in ***test1*** prior to execution of the **new** command. It retains the value it received in ***test1***.

Note also that the variable ***y*** now exists at the main function level since, when it was created in ***test1***, it was not in the group of variables copied to the symbol table level for ***test1***. Thus, it was created at the base level of the symbol table.

However, when ***y*** was altered in ***test2***, only the copy made by the **new** command in ***test2*** was altered, not the original.

```
#!/usr/bin/mumps
        set i=10
        set j=20
        set k=30
        do test1
        write "Main: expect 100 20 30 50: ",i," ",j," ",k," ",y,!
        halt

test1 write "test1: expect 10 20 30: ",i," ",j," ",k,!
      set i=100
      new
      set i=11,j=22,k=33,y=50
      do test2
      write "test1: expect 11 22 33 50 : ",i," ",j," ",k," ",y,!
      quit

test2 write "test2: expect 11 22 33 50: ",i," ",j," ",k," ",y,!
      new
      set i=12,j=23,k=34,y=55
      write "test2: expect 12 23 34 55 : ",i," ",j," ",k," ",y,!
      quit

root@AMD6 validate new01.mps

test1: expect 10 20 30: 10 20 30
test2: expect 11 22 33 50: 11 22 33 50
test2: expect 12 23 34 55 : 12 23 34 55
```

```
test1: expect 11 22 33 50 : 11 22 33 50
Main: expect 100 20 30 50: 100 20 30 50
```

Figure 1 **new** Command without Arguments

4.5.2.2 New Command with Arguments

There are two forms of the **new** command that take arguments.

The first has a list of arguments consisting of variable names separated from one another by commas:

```
new a,b,c
```

The second has an argument consisting of a parenthesized, comma separated list of variable names:

```
new (a,b,c)
```

If a variable is named in the list that does not exist, it is created in the current symbol table layer with a value of the empty string.

4.5.2.2.1New Command with Comma List of Variable Names

If the **new** command argument is a list of one or more variable names, it means that the variables listed will be copied to the current symbol table level and, eventually, discarded when the current block is exited[6].

If a variable whose name appears in the list exists at several layers in the symbol table stack, only the most recent will be copied.

Any reference to any variable not in the argument list will be satisfied by searching through the symbol table stack for the most recent instance of it. See Figure 2.

If a variable is mentioned in the argument list that does not exist, it is ignored.

```
#!/usr/bin/mumps
        set i=10
        set j=20
        set k=30
        do test1
        write "Main: expect 100 20 30 50: ",i," ",j," ",k," ",y,!
        halt

test1 write "test1: expect 10 20 30: ",i," ",j," ",k,!
      set i=100
      new i,j
      set i=11,j=22,k=33,y=50
      do test2
      write "test1: expect 11 23 34 55 : ",i," ",j," ",k," ",y,!
      quit

test2 write "test2: expect 11 22 33 50: ",i," ",j," ",k," ",y,!
      new i
      set i=12,j=23,k=34,y=55
      write "test2: expect 12 23 34 55 : ",i," ",j," ",k," ",y,!
      quit

root@AMD6 validate # new02.mps
```

6 A block is any sequence of code entered as a result of a **do** command.

```
test1: expect 10 20 30: 10 20 30
test2: expect 11 22 33 50: 11 22 33 50
test2: expect 12 23 34 55 : 12 23 34 55
test1: expect 11 23 34 55 : 11 23 34 55
Main: expect 100 20 30 50: 100 20 34 55
```

Figure 2 **new** Command with Comma List

4.5.2.2.2 New Command with Parenthesized List of Variable Names

If the **new** command argument list consists of a parenthesized list of one or more variable names, it means to make a copy of the most recent versions of all known variables except for the variable named in the list. This is similar to the no-argument version except the one or more variables known at the time of command execution will not be copied to the current symbol table layer.

When the block containing the **new** command is exited, the copies of the variables are discarded but any changes to this variables given in the argument list are not[7].

See Figure 3.

```
#!/usr/bin/mumps
        set i=10
        set j=20
        set k=30
        do test1
        write "Main: expect 11 22 30 50: ",i," ",j," ",k," ",y,!
        halt

test1 write "test1: expect 10 20 30: ",i," ",j," ",k,!
      new (i,j)
        set i=11,j=22,k=33,y=50
      do test2
      write "test1: expect 11 23 34 55 : ",i," ",j," ",k," ",y,!
        quit

test2 write "test2: expect 11 22 33 50: ",i," ",j," ",k," ",y,!
      new i
      set i=12,j=23,k=34,y=55
      write "test2: expect 12 23 34 55 : ",i," ",j," ",k," ",y,!
      quit

root@AMD6 validate # new03.mps

test1: expect 10 20 30: 10 20 30
test2: expect 11 22 33 50: 11 22 33 50
test2: expect 12 23 34 55 : 12 23 34 55
test1: expect 11 23 34 55 : 11
```

Figure 3 **new** Command with Parenthesized List

4.6 Kill Command

The **kill** command operates only on the current symbol table level.

4.7 For Command Extensions

The **for** command accepts extensions such as the following:

```
for i=$order(^a(i)) ...
```

7 Note: if one or more of the variables in the argument list are themselves copies from a lower layer but not the base layer, they will eventually be discarded.

```
for i=init:$order(^a(i)):final ...
```

In the first example, the variable ***i*** will assume all the index values of the global array in collating sequence order.

In the second, the first value of *i* will be the next higher collating sequence value of the index above *init* and subsequent values will be the values in collating sequence order of the global array up to but not including ***final***.

4.8 Break and Quit

In this version, the **break** command has a non-standard use. Originally intended as a means of interrupting a program for debugging purposes, in this implementation is is used in loop control.

A **quit** in a single line **for** terminates processing of the **for**. If there are multiple **for** commands, it terminates the nearest:

```
for i=1:1:10 write i,! if i>5 quit
      writes 1 through 6 only.


for i=1:1:10 for j=1:1:10 write j,! if j>5 quit
      writes 1 through 6 ten times.
```

A **break** may *NOT* be used in a single line **for** command. It may *ONLY* be used in an indented block that was introduced by a **do** command.

In an indented block, **quit** and **break** have special meanings:

A **quit** ends further processing of the block in which it appears and returns control to the line containing the invoking **do** at a point just after the **do**. Processing of the line containing the invoking **do** resumes. If there are more commands on the line, they are executed.

A **break** ends further processing of the block in which it appears but does not return the line containing the invoking **do**. Instead, execution moves to the line following the block which the **do** invoked.

Examples:

```
for i=1:1:10 do  write " continuing"
. write !,i
. if i>5 quit
. write " ",i
write !,"done",!

writes

      1 1 continuing
      2 2 continuing
      3 3 continuing
      4 4 continuing
      5 5 continuing
      6 continuing
      7 continuing
      8 continuing
      9 continuing
      10 continuing
      done
```

In this example, the block is invoked 10 times. After each invocation, the remainder of the line containing the **for** is executed producing the instances of the word "continuing". Each block invocation prints the value of ***i***. When the value of ***i*** is greater than 5, the block executes the **quit** command thus returning to the invoking line early. When the value if "i" is 5 or less, the full block is executed and return is made to the invoking line at block end. When the **for** command finishes execution, control is passed to the line following the **for** and "done" is printed.

```
set i=9
if i>0 do  write " continuing"
. write !,i
. if i>5 quit
. write " ",i
write !,"done",!

writes:

      9 continuing
      done
```

In this example, the block is entered, the value of "i" is printed but, because "i" is greater than 5, the **quit** is executed and control is returned to the invoking **do** and the word "continuing" is printed. Now, the line being completely executed, control passes to the line following the block and "done" is printed.

```
for i=1:1:10 do  write " mark " do  write " end of line",!
. write i
. if i>5 quit
. write "X"

writes:

      1X mark 1X end of line
      2X mark 2X end of line
      3X mark 3X end of line
      4X mark 4X end of line
      5X mark 5X end of line
      6 mark 6 end of line
      7 mark 7 end of line
      8 mark 8 end of line
      9 mark 9 end of line
      10 mark 10 end of line
```

In this example, multiple **do** commands are shown. Note the two blanks following each. Each **do** invokes the block following the line containing the **do**

On the other hand, the **break** command terminates the the block in which it is contained but execution does not return to the line containing the invoking **do** but, instead, continues with the line following the block:

```
for i=1:1:10 do  write " continuing"

. write !,i
. if i>5 break
. write " ",i
write !,"done",!

writes:

      1 1 continuing
      2 2 continuing
      3 3 continuing
      4 4 continuing
      5 5 continuing
      6
      done
```

```
set i=9
if i>0 do  write " continuing"
. write !,i
. if i>5 break
. write " ",i
write !,"done",!

writes:
9
done

for i=1:1:10 do  write " mark " do  write " end of line",!
. write i
. if i>5 break
. write "X"
write !

writes:

      1X mark 1X end of line
      2X mark 2X end of line
      3X mark 3X end of line
      4X mark 4X end of line
      5X mark 5X end of line
      6
```

In these examples, execution of the **break** can be seen to terminate the current block and move to the line following the block.

```
for i=1:1:10 do
. for j=1:1:5 do
.. write j,!
.. if j>3 break
```

The above write 1 through 4 ten times.

Note: the contents of **$test** revert to their former value when exiting an indented block by means of **break** or **quit**:

```
if 1=1 do
. write "test 1: ",$test,!
. if 1=2 write "wow",!
. else  write "not wow",!
. write "test 2: ",$test,!
write "test 3: ",$test,!

writes:

      test 1: 1
      not wow
      test 2: 0
      test 3: 1
```

If you exit a block with a **goto**, the value of **$test** is not restored.

4.9 Lock Command with SQL

Locks are not needed if you are using Sqlite3 for global array storage as SQL transaction commands can achieve the same or better effect.

When using SQL for the backend global array stores, the ***Lock*** should not be used. Instead, use the more modern native SQL transaction processing commands (*BEGIN, COMMIT, ROLLBACK*, etc.) to achieve the same effect with far greater integrity (see Section 3 on page 20).

4.10 Lock Command in Native Database Mode

The *lock* command has no effect on the single user database as there are no other users to lock datya access to.

4.11 Naked indicator

This version of Mumps does not support the naked indicator.

It was originally included in early versions of Mumps because of the binary mapping of an n-way tree which was used at the time to store the global arrays. The naked indicator was a short-hand to the interpreter to allow it to search for a global without stating at the top of the tree each time thus resulting in faster access. That is no longer the case with B-tree based access methods.

4.12 Job command

The **JOB** command results in a C/C++ ***fork()*** function to be executed thus creating a child process. The child process will attempt to execute the argument to the ***JOB*** command. The ***JOB*** command may be used in the native B-tree user mode but only one process may access the globals. The Sqlite3 version has no such restriction.

The child process must end with a ***HALT*** command or the child process will hang.

4.13 File Names Containing Directory Information

When invoking a file name containing directory information (forward slash in Linux) with the **DO** or **GOTO** commands, the file name itself **must** be enclosed in quotes. For example:

```
set x="""^/home/user/xxx.mps""" goto @x
goto @"""^/home/user/xxx.mps"""
```

Note the extra quotes. These are required.

4.14 File Names

File names should conform to variable naming conventions except that the first character of a file name may not be the percent sign (%) character. The first character must be alphabetic. File names may only contain letters, digits and the percent sign.

4.15 Array Index Collating Sequence

Array index collating sequences for both global and local array is ASCII. That is, for the *$query()* and *$order()* functions, all array indices will be presented in the same order as ASCII strings. Thus, in an array with 15 elements whose indices range from 1 to 15, the indices will be presented as:

```
1 10 11 12 13 14 15 2 3 4 5 6 7 8 9
```

You may achieve numeric ordering by storing the indices padded to left with blanks such as:

```
for i=1:1:15 set ^a($justify(i,8))=i
set i=”” for  set i=$order(^a(i)) quit:i='' write +i,” “
```

the indices will now be presented as:

```
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
```

Note the the *+i* in the **write** command has the effect of converting the string to a number with no leading blanks.

4.16 Subroutine & Function Calls

Subroutines and functions may be performed in several ways as shown in Figure 4. Values returned from functions invoked by a **do** command are ignored. In standard Mumps, the *$$* form is used only with function invocations.

Caution: be certain to include a **halt** or other exit in your program *prior* to any functions that may appear at the end of your code. If the **halt** is not present, function code will be entered and any passed variables will be undefined.

```
#!/usr/bin/mumps
# calls.mps

      set i=10
      do fcn(i)
      do fcn(5)
      do $$fcn(i)
      do $$fcn(5)
      set k=$$fcn(5)
      write "returned k=",k,!

      set i=10
      do fcn^ext.mps(i)
      do fcn^ext.mps(5)
      do $$fcn^ext.mps(i)
      do $$fcn^ext.mps(5)
      set k=$$fcn^ext.mps(5)
      write "returned k=",k,!

      do fcn^ext1.mps
      do fcn^ext1.mps
      do $$fcn^ext1.mps
      do $$fcn^ext1.mps
      set k=$$fcn^ext1.mps
      write "returned k=",k,!

      halt

fcn(x) write "in fcn(x) value passed is ",x,!
       quit x

------------------------------

#!/usr/bin/mumps
# ext.mps

fcn(x) write "in fcn(x) value passed is ",x,!
       quit x

------------------------------

#!/usr/bin/mumps
# ext1.mps

fcn    write "in fcn ext1.mps",!
       set x=22
       quit x
```

```
-----------------------------

output results:

in fcn(x) value passed is 10
in fcn(x) value passed is 5
in fcn(x) value passed is 10
in fcn(x) value passed is 5
in fcn(x) value passed is 5
returned k=5
in fcn(x) value passed is 10
in fcn(x) value passed is 5
in fcn(x) value passed is 10
in fcn(x) value passed is 5
in fcn(x) value passed is 5
returned k=5
in fcn ext1.mps
in fcn ext1.mps
in fcn ext1.mps
in fcn ext1.mps
in fcn ext1.mps
returned k=22
```

Figure 4 Subroutine/Function Calls

4.17 $Fnumber() Function

The ***$fnumber()*** is implemented via the C function ***strfmon()*** which provides much greater flexibility when dealing with differing locales and, especially, currencies. The default locale is ***en_US.UTF-8*** but this can be set with the ***configure*** option:

```
--with-locale=location-information
```

You may use **$fnumber()** with the legacy Mumps parameters or use it with a pattern parameter designed for ***strfmon()***.

If you use the ***strfmon()*** parameter option, the function takes two arguments. The first must be a number consisting of only numeric characters. The second is a character string conforming to a ***strfmon()*** pattern but preceded by an asterisk to distinguish the pattern from those used by the legacy Mumps function of the same name. The ***strfmon()*** function is well documented but here are some examples:

```
set x=12345.6789
write $fn(x,”*%!n”)     ==> 12,345.68
write $fn(x,”*%n”)      ==> $12,345.68
write $fn(x,”*%i”)      ==> USD 12,345.68
write $fn(x,”*%n3”)     ==> $12,345.683
write $fn(x,"*%20n")    ==>           $12,345.68
```

4.18 $Select() Function

All arguments of the ***$select()*** function are evaluated. In standard Mumps, they are evaluated individually until one is true or all are false.

4.19 Compiling Large Programs

When compiling[8] large programs, especially if SQL is enabled, there may be a warning about ***variable tracking*** from the gcc/g++ compiler. You may ignore this.

8 Using the compiler is not presently recommended.

4.20 Embedded Expressions

In several extended Mumps commands, the figure *&~exp~* may appear. The expression *exp* is evaluated and the result replaces the figure. For example:

```
set x=”ls -lh”
shell &~x~
```

4.21 Inline C++ Code (Compiler Only)

Lines that begin with a plus (+) sign in column 1 are inserted as-is into C++ programs. Usually, these will be lines of C++ code. For example, if you have a line of Mumps code you want to execute 1000 times, the Mumps code would be:

```
for i=1:1:1000 do
. write “abc”,!
```

This could be written as:

```
+     for(int i=0; i < 1000; i++) {
      write “abc”,!
+     }
```

The C++ *for* loop is considerably faster. Note the omission of the “.” indent.

Mumps code will not have access to the C++ variable unless you use a *declared* variable into which you place the C++ variables value:

```
      declare val
+     for(int i=0; i < 1000; i++) {
+     sprintf(val, “%s”, i);
      write val,!
+     }
```

4.22 Functions

This is the form of subroutine was originally used in Mumps. There are no parameters passed to the subroutine and the subroutine shares the same *namespace* as the calling program hence, as seen in the example in Figure 5, the values of the variables *i*, *j*, and *k* are accessible to the subroutine and any changes to them are available in the calling program.

Variables created in the subroutine in the normal manner by a **set** or **read** command, unless the subject of a **kill** command, are available to the calling routine.

Variables created in the subroutine as a result of a **new** command are destroyed upon return and are not available to the calling routine.

```
zmain
set i=10
set j=20
set k=30
write "main program: ",i," ",j," ",k,!
do test
write "main program: ",i," ",j," ",k,!
write "main program x=",x,!
write "main program $data(y)=",$data(y),!
halt
```

```
test
        write "sub-program: ",i," ",j," ",k,!
        set i=11
        set j=22
        set k=33
        set x=22
        new y
        set y=33
        quit

which produces the following output:

main program: 10 20 30
sub-program: 10 20 30
main program: 11 22 33
main program x=22
main program $data(y)=0
```

Figure 5 Local Functions

4.22.1 Call by Value

This form of subroutine call was introduced later in the evolution of Mumps. It permits parameters to be passed to the subroutine but the subroutine maintains a separate name space for values passed to it as parameters. Variables from the calling program are visible to the called program. Variables created by the called program become available to the calling program upon return (except if the are **kill**ed prior to return or created by a **new** command). and variables created in the called program are deallocated upon return and are thus not visible to the calling program. Changes to parameters passed to the called program do not change the corresponding arguments in the calling program.

```
        zmain
        set i=10
        set j=20
        set k=30
        write "main program: ",i," ",j," ",k,!
        do test(i,j,k)
        write "main program: ",i," ",j," ",k,!
        halt

test(a,b,c)
        write "sub-program: ",a," ",b," ",c,!
        set a=11
        set b=22
        set c=33
        quit

which produces the following output:

main program: 10 20 30
sub-program: 10 20 30
main program: 10 20 30
```

Figure 6 Call by Value Functions

4.22.2 Call by Reference.

Same as the above but 'call be reference' permitted. That is, changes to parameters made by the called program cause changes to the corresponding arguments in the calling program. Note the "." in front of the variables in the 'do' command that are to be passed by reference. Both call by reference and call by value arguments may be mixed in the same 'do' statement.

```
#!/usr/bin/mumps
        zmain
        set i=10
        set j=20
        set k=30
        write "main program: ",i," ",j," ",k,!
        do test(.i,.j,.k)
        write "main program: ",i," ",j," ",k,!
        halt

test(a,b,c)
        write "sub-program: ",a," ",b," ",c,!
        set a=11
        set b=22
        set c=33
        quit

which produces the following output:

main program: 10 20 30
sub-program: 10 20 30
main program: 11 22 33
```

Figure 7 Call by Reference Functions

In each of the examples, the subroutine and calling program are actually part of the same C++ function. In effect, subroutines of the type shown above as similar to the old Basic ***gosub*** facility. Functions such as shown above may also return values:

An example recursive factorial computation is shown in Figure 8.

```
#!/usr/bin/mumps
      zmain
      set i=$$factorial(5)
      write "factorial=",i,!
      halt

factorial(a)
      write "sub-program: a=",a,!
      if a<2 quit 1
      set b=$$factorial(a-1)
      write "a=",a," b=",b,!
      quit a*b

sub-program: a=5
sub-program: a=4
sub-program: a=3
sub-program: a=2
sub-program: a=1
a=2 b=1
a=3 b=2
a=4 b=6
a=5 b=24
factorial=120
```

Figure 8 Function Return Values

5 Shell Commands

The **shell** command passes the remainder of the line to a shell for execution (**sh** in Linux). Shell output will appear on **stdout**. The command sets **$test** to false if the *fork()* fails, true otherwise.

5.1 shell/p

The **shell/p** form passes the remainder of the line to a shell for execution but opens a pipe **from** the shell **to** Mumps unit number 6. All **stdout** output from the shell is directed to unit number 6 and can be read with any of the input commands or functions in association with the **use** command.

5.2 shell/g

The **shell/g** form passes the remainder of the line to a shell for execution (**sh** in Linux) and opens an output pipe **from** the Mumps program **to** the shell as Mumps unit number 6. Data **written** to this unit becomes **stdin** to the shell. Output from the shell is written to **stdout**. Remember to **close** unit number 6 to signal end-of-file to the shell.

5.3 shell

With no qualifier, the **shell** command passes the remainder of the command line to a shell. Input or output from the shell come from or go to **stdin** or **stdout**, respectively.

5.3.1 Epression Substitution

In all cases, the remainder of the command line is scanned for **&~...~** expressions. The expression between **&~** and ~ is evaluated and the result replaces the **&~...~** expression.

For example:

```
shell sort dictionary.tmp | uniq -c | sort -nr > dictionary.s
```

The Linux shell created will do the following:

1. The file *dictionary.tmp,* a collection of words, will be sorted by **sort** and the output piped to **uniq**
2. **uniq** counts duplicate entries and pipes its output consisting of a count and a word to **sort**
3. **sort** sorts the result numerically by number of duplicates in reverse order and writes its output to *dictionary.s*.

```
shell/p sort dictionary.tmp | uniq -c | sort -nr
open 1:"dictionary.s,new"
for  do
. use 6
. read line
. if '$test break
. use 1
. write line,!
close 1
```

Figure 9 Shell Command Example

The above does the same but the output will be presented to Mumps unit 6 which reads and writes the result to the file named dictionary.s

6 Added Commands

6.1 Database *expr*

By default, Native databse file *key.dat* and *data.dat* are stored in the directory current when a program is invoked.

The **database** command may be used to set the name of the files to be used to store the native global arrays. The expression will be evaluated and the resulting name will become the name, suffixed *.key* and *.dat,* of the files in which the native global arrays are stored. The expression may contain directory information. For example:

```
database "/home/user/data/mumps"
```

will cause the system to access files:

```
/home/user/data/mumps.key
/home/user/data/mumps.dat
```

This command ***must*** be issued prior to any attempt to access the global arrays. It only works with the native B-tree database option.

6.2 Zhalt return_code

The **zhalt** command will terminate the current program with a return error code given by its argument. Example:

```
if a=0 zhalt 99
```

The value of **$?** in the BASH environment will be 99.

6.3 Declare

The Declare command is ignored by the interpreter.

In the compiler, is can be used to establish one or more variables as declared C++ variables rather than variables stored in the Mumps run time symbol table. Consequently, access to these variables is about twice as fast.

Declared variables may only be scaler variables. The may not, at present, be subscripted.

Declared variable names may conflict with exiting internal compiler variables. In which case, select a different name for your scaler vairable.

Example:

```
zmain
declare dclx,dclx1
for dclx=0:1:1000 set dclx1=dclx write dclx1,!
```

7 Z Functions and System Variables

$zfunctions are extensions added by the implementor and not covered by the standard. Thus, many if not all of the following M2 extensions may not be supported or supported differently in other implementations. Likewise, there are implementer defined system variables which may be queried and, in some cases, set.

M2 implementation note: you may add new **$z** functions by modifying the function **zfcn()** located in the source file *bifs.cpp.in*

7.1 System Variables

7.1.1 $zProgram

Returns a string with the name of the currently executing program.

7.2 Bash Functions

7.2.1 $zbasename(arg1[,arg2])

Returns a result equivalent of the Bash function *basename*

```
$zbasename(“/home/jsmith/base.wiki”) yields base.wiki
$zbasename(“/home/jsmith/”) yields jsmith
$zbasename(“/”) yields /

$zbasename(“/home/jsmith/base.wiki”,”.wiki”) yields base
$zbasename(“/home/jsmith/base.wikia”,”ki”) yields base.wi
$zbasename(“/home/jsmith/base.wiki”,”base.wiki”) yields base.wiki
```

7.2.2 $zfiletest(arg1,arg2)

Performs a Bash style check on a file name. The first argument is the name of a file and the second is a parameter that determines the type for file check. If the check condition is *true*, a one (1) is returned, zero (0) otherwise. The following are legal values for the second argument:

```
-a True if FILE exists.
-b True if FILE exists and is a block-special file.
-c True if FILE exists and is a character-special file.
-d True if FILE exists and is a directory.
-e True if FILE exists.
-f True if FILE exists and is a regular file.
-g True if FILE exists and its SGID bit is set.
-h True if FILE exists and is a symbolic link.
-k True if FILE exists and its sticky bit is set.
-p True if FILE exists and is a named pipe (FIFO).
-r True if FILE exists and is readable.
-s True if FILE exists and has a size greater than zero.
-t True if file descriptor FD is open and refers to a terminal.
-u True if FILE exists and its SUID (set user ID) bit is set.
-w True if FILE exists and is writable.
-x True if FILE exists and is executable.
-O True if FILE exists and is owned by the effective user ID.
-G True if FILE exists and is owned by the effective group ID.
-L True if FILE exists and is a symbolic link.
-N True if FILE exists and has been modified since it was last read.
-S True if FILE exists and is a socket.
```

7.3 Math Functions

The following C/C++ math functions are available in M2. Their arguments and return values are the same as the correspondingly named C++ functions.

7.3.1 **$zabs(arg)** absolute value

Function returns the absolute value of its numeric argument.

7.3.2 **$zacos(arg)** arc cosine

Computes the inverse cosine (arc cosine) of the input value. Arguments must be in the range -1 to 1.

7.3.3 **$zasin(arg)** Arc sine

Computes the inverse sine (arc sine) of the argument **arg**. Arguments must be in the range -1 to 1.

7.3.4 **$atan(arg)** Arc tangent

Computes the inverse tangent (arc tangent) of the input value.

7.3.5 **$zcos(arg)** Cosine

Computes the cosine of the argument **arg**. Angles are specified in radians.

7.3.6 **$zexp(arg)** Exponential

Calculates the exponential of **arg**, that is, ***e*** raised to the power *arg* (where ***e*** is the base of the natural system of logarithms, approximately 2.71828).

7.3.7 **$zexp2(arg)** Exponential base 2

Calculates 2 raised to the power *arg*.

7.3.8 **$zexp10(arg)** Exponential base 10

Calculates 10 raised to the power *arg*.

7.3.9 **$zlog(arg)** Natural log

Returns the natural logarithm of **arg**, that is, its logarithm base ***e*** (where e is the base of the natural system of logarithms, 2.71828...).

7.3.10 **$zlog2(arg)** Base 2 log

Returns the base 2 logarithm of ***arg***.

7.3.11 **$zlog10(arg)** Base 10 log

Returns the base 10 logarithm of **arg**.

7.3.12 **$zpow(arg1,arg2)** Power function

Calculates **arg1** raised to the exponent **arg2**.

7.3.13 **$zsqrt(*arg*)** Square root

Function returns the square root of its numeric argument.

7.3.14 **$zsin(arg)** Sine function

Computes the sine of the argument **arg**. Angles are specified in radians.

7.3.15 $ztan(arg) Tangent function

Computes the tangent of **arg**.

7.4 Date functions

7.4.1 $zdate(or $zd) formatted date string

Function returns the system date and time in standard system printable format. This includes: day of week, month, day of month, time (hour:minute:second), and year (4 digits).

7.4.2 $zd1 numeric internal date

Returns the number of seconds since January 1, 1970 - a standard used in Linux. This number may be used to accurately correlate events.

7.4.3 $zd2(*InternalDate*) date conversion

Translates the Linux time from $ZD1 into standard system printable format. The argument is a Linux format time value.

7.4.4 $zd3(*Year,Month,Day*) Julian date

Returns the day of the year (Julian date) for the Gregorian date argument.

7.4.5 $zd4(*Year,DayOfYear*) Julian to Gregorian

Returns the Gregorian date for the Julian date argument.

7.4.6 $zd5(*Year, Month, Day*) comma listed date

Returns a string consisting of the year, a comma, the day of year, and the number of days since Sunday (Monday is 1).

7.4.7 $zd6 hour:minute

Returns a string consisting of the hour, a colon, and the minute.

7.4.8 $zd7 hyphenated date

Returns a string consisting of the year, hyphen, month, hyphen, and day of month. If an argument is given in the form of the number of seconds since Jan 1, 1970, the result returned will reflect the argument date.

7.4.9 $zd8 hyphenated date with time

Returns a string consisting of the year, hyphen, month, hyphen, and day of month, comma, and time in HH:MM format. If an argument is given in the form of the number of seconds since Jan 1, 1970, the result returned will reflect the argument date.

7.5 Special Purpose Functions

The following special purpose functions are available:

7.5.1 $zb(arg) remove blanks

Function returns a string in which all leading blanks have been removed and all multiple blanks have been replaced by single blanks. See also **$zNoBlanks()**. Figure 10 gives examples.

```
#!/usr/bin/mumps
 set a="   abc   xyz     123    "
 write $zb(a),"***",!
```

```
output:

abc xyz 123 ***

                                    Figure 10 $Zb() Examples
```

7.5.2 $zchdir(directory_path) change directory

Function changes the current directory to the path specified. If the operation succeeds, a zero is returned. If it fails, -1 is returned.

7.5.3 $zCurrentFile Current Mumps File

Returns the name of the currently executing Mumps program file (if any) ar blank.

7.5.4 $zdump[(filename)] dump global arrays

Function dumps the globals to a sequential ASCII file in the current directory. If an argument is given, it is taken as the name of the file to which the globals will be written. If the argument is omitted, a file name is constructed from the system date of the form **number.dmp** where **number** is the value of the C++ **time()** function at the time of the dump.

The dump file is a pure ASCII text file. Each entry in the global array is represented by two lines. The first line is the global array reference and the second line is the store value. In the global array reference, parentheses and commas are replaced by the "~" character. Thus, if you wish to use this facility, you may not include the "~" character in a global array index.

The function **$zrestore()** reloads the global arrays from a dump file (see below).

$zdump and **$zrestore** do not work when SQL is used for the global array store.

7.5.5 $zrestore[(arg)] restore globals

Function restores the globals from a dump file produced by **$zdump**. If an argument is given, it is taken as the name of the dump file otherwise, the default name **dump** is used.

$zdump and **$zrestore** do not work when SQL is used for the global array store.

7.5.6 $zfile(*arg*) file exists test

Function returns a zero or one indicating if the file given as the argument exists.

7.5.7 $zflush flush Btree buffers

Function flushes all modified native global array handler buffers to disk. The function should only be used with the native globals. After flushing, all updates to the btree file system have been committed. In cases where the internal buffers are very large, this function may take several seconds to execute. The function returns the empty string. Flushing the buffers is a precaution against system failure which would otherwise result in corruption of the global arrays.

7.5.8 $zgetenv(*arg*) get environment variable

Returns the contents of the environment variable specified as *arg* or the empty string if the variable is not found.

7.5.9 $zhtml(*arg*) encode HTML string

Function encodes its argument in the form necessary to be a cgi-bin parameter. That is, alphabetics remain unchanged, blanks become plus signs and all other characters become hexadecimal values, preceded by a percent sign.

7.5.10 $zhit global array cache hit ratio

Function calculates and returns the native global array cache hit ratio. This number ranges between zero and one. A value of one indicates all requests were satisfied from the cache while a value of zero indicates no requests were satisfied from the cache. Calling this function resets the hit ratio to zero. A higher value for the hit ratio indicates better database performance.

7.5.11 $zlower(string) convert to lower case

Function returns the input string with alphabetics converted to lower case.

7.5.12 $znormal(*arg1*[,arg2]) word normalization

Function converts the word passed as argument 1 to lower case and removes any embedded punctuation. If a second argument is given, the word is truncated to the length specified by this argument. If no second argument is given, words are truncated to 25 characters if their length exceeds 25 characters.

7.5.13 $zNoBlanks(arg*)* remove all blanks

Returns ***arg*** with all blanks removed. See also: **$zb**.

7.5.14 $zpad(arg1,arg2) left justify with padding

Function left justifies the first argument in a string whose length is given by the second argument, padding to the right with blanks.

7.5.15 $zseek(arg)

Function takes one argument (a positive integer) which is a byte offset in the currently active (use) file. The command moves the file pointer to that location in the file. **$zseek()** may only be used on files opened with **old** attribute. Figure 11 gives examples.

```
#!/usr/bin/mumps
 open 1:"tdb,new"
 for j=1:1:1000 do
 . use 1
 . set i=$ztell
 . set ^a(j)=i
 . write "**** ",j,!

 close 1
 open 1:"tdb,old"
 for j="":$order(^a(j)):"" do
 . use 1
 . set i=$zseek(^a(j))
 . read a
 . use 5
 . write a,!

output:

**** 1
**** 10
**** 100
**** 1000
**** 101
**** 102
**** 103
**** 104
**** 105
**** 106
**** 107
```

```
**** 108
**** 109
**** 11
**** 110
**** 111
...
```

Figure 11 $Zseek() Examples

7.5.16 $zsrand(arg)

Seed the random number generator. The value passed as the argument will seed the internal random number generator. If the random number generator is re-seeded with the same seed, the sequence of random numbers produced by **$random** will be the same. The value passed must be a positive integer.

7.5.17 $zstem(arg)

Returns an word English word stem of the argument. This function attempts to remove common endings from words and return a root stem.

7.5.18 $zsystem(arg)

Executes "arg" in a system shell. Returns -1 (fork failed) or the return code of the execution of the argument. See also the **shell** command.

7.5.19 $ztell

Function returns the byte offset in the currently open file. Similar to the C++ **ftello** function. Note: The offset returned is for the file most recently made the default i/o file by the **use** command. **$ztell** may be used on either a file opened as **new, old** or **append**. (See example under **$zseek** above)

7.5.20 $zu(expression)

Function returns 1 if the expression is numeric, 0 otherwise.

7.5.21 $zwi(arg)

Function loads an internal buffer with the string given as the argument. The alphabetic characters of the argument are converted to lower case. The contents of this buffer are returned by the **$zwn** and **$zwp** functions. Figure 12 gives examples.

7.5.22 **$zwn** extract words from buffer

Function returns successive words from the internal buffer delimited by blanks. When no more words remain, it returns an empty string (string of length zero). Returned words are converted to lower case. See **$zwi**.

7.5.23 $zwp extract words from buffer

Function returns successive words from an internal buffer delimited by blanks and punctuation characters. When no more words remain, it returns an empty string (string of length 0). Returned words are converted to lower case. See **$zwi**.

7.5.24 **$zws(string)** initialize internal buffer

Initializes the parse buffer but does not convert "string" to lower case as is the case with **$zwi**

```
#!/usr/bin/mumps
 set i="now, is the time, for all good"
 set %=$zwi(i)
 for w=$zwp write w,!
 write "-------",!
 set %=$zwi(i)
```

```
7  for w=$zwn write w,!

output:

     now
     ,
     is
     the
     time
     ,
     for
     all
     good
     -------
     now,
     is
     the
     time,
     for
     all
     good
```

Figure 12 $Zwi() Examples

7.5.25 Scan Functions

7.5.25.1.1 $zzScan

7.5.25.1.2 $zzScanAlnum

7.5.25.1.3 $zzInput(var)

The functions return the next word in the current input stream delimited by white space. Words are restricted to a maximum length of 1023. Successive calls return successive words. When there are no more input words, an empty string is returned and **$test** is set to *false*.

If only part of a line is scanned as a result of these functions, a subsequent **read** command will begin at the white space following the last word returned.

If scanning input from stdin (i/o unit 5), you may signal end of file with a *control-d* on a separate line by itself. This will result terminate the scan and **$test** will be set to false.

$zzScan returns all words delimited by whitespace with no conversion. Words may contain any *printable* ASCII character.

$zzScanAlnum processes words before returning them according to the following rules:

- If a word begins with a number or punctuation, it is not returned.
- Non alpha-numeric characters are removed.
- Alpha characters are converted to lower case.

Both functions will advance to additional lines as needed. If a word exceeds 1023 bytes, the results are undefined. See Figure 13 for an example.

```
for the input line:

now -- __ ?? !@#$%^&*()_+= IS 2for the time for
```

```
     for  set i=$zzScan quit:'$test  write i,!

output:

     now
     --
     __
     ??
     !@#$%^&*()_+=
     IS
     2for
     the
     time
     for

     for  set i=$zzScanAlnum quit:'$test  write i,!

output:

     now
     the
     time
     for
```

Figure 13 Scan Functions Examples

$zzInput(var) reads an entire input line, converts all characters to lower case, separates the words, removes punctuation (as defined by the C *ispunct()* function except hyphen), and stores the words into a numerically indexed array whose name is the value of the variable or constant passed as the argument. The function returns the number of elements in the array. A return of zero indicates no input was obtained (end of file). As the array created by the function could be quite large, you should probably **kill** it when no it is longer needed. The maximum line length permitted is twice the system parameter *MAX_STR* (9,000 bytes by default).

7.6 Vector and Matrix Functions

7.6.1 $zzAvg(vector)

Computes and returns the average of the numeric values in the vector. For example, see Figure 14.

```
#!/usr/bin/mumps
 for i=1:1:10 set ^a(99,i)=i
 set i=$zzAvg(^a(99))
 write "average=",i,!
```

Figure 14 $zzAvg() Example

The above writes 5.5

7.6.2 $zzCentroid(gblMatrix,gblRef)

A centroid vector *gblRef* is calculated for the invoking two dimensional global array *gblMatrix*. The centroid vector is the average value for each for each column of the matrix. Any previous contents of the global array named to receive the centroid vector are lost. The global array *gblMatrix* must contain at least two dimensions. See Figure 15 for an example. The matrix must be a top level global array.

```
#!/usr/bin/mumps
 for i=0:1:10 do
 . for j=1:1:10 do
 .. set ^A(i,j)=5
 set %=$zzCentroid(^A,^B)
```

```
 for i=1:1:10 write ^B(i),!

output:

5
5
5
5
5
5
5
5
5
5
```

Figure 15 $zzCentroid() Example

7.6.3 $zzCount(gblVector)

Counts the number of nodes that contain a value in the global array reference and any descendants. For example, see Figure 9.

```
#!/usr/bin/mumps
 kill ^a
 for i=1:1:10 set ^a(99,i)=i
 set i=$zzCount(^a(99))
 write "count=",i,!

writes: count=10
```

Figure 16 $zzCount() Example

7.6.4 $zzMax(gbl)

Computes and returns the maximum numeric value in the vector and any descendants. See Figure 17 for an example.

```
#!/usr/bin/mumps
 for i=1:1:10 set ^a(99,i)=i
 set i=$zzMax(^a(99))
 write "max=",i,!

output:

10
```

Figure 17 $zzMax() Example

The above writes the largest value stored in the vector.

7.6.5 $zzMin(gbl)

Returns the minimum numeric value stored in the vector and any descendants. See Figure 18 for an example.

```
#/usr/bin/mumps
 for i=1:1:10 set ^a(99,i)=i*2
 set i=$zzMin(^a(99))
 write "min=",i,!
```

```
output:

2

                              Figure 18 $zzMin() Example
```

7.6.6 $zzMultiply(gbl1,gbl2,gbl3)

Multiplies the first and second matrix leaving the result in the third. The ordinary rules of algebra apply. Figure 22 gives an example. The arguments *gbl1* and *gbl2* must be top level, two dimensional arrays.

7.6.7 $zzSum(gblVector)

Computes and returns the sum of the numeric values stored in the vector. For example, see Figure 23.

7.6.8 $zzTranspose(gblMatrix1,gblMatrix2)

Transposes the first global array matrix leaving the result in the second. For example, see Figure 24. the argument *gblMatrix1* must be a top level, two dimensional array.

7.7 Text Processing Functions

The following functions are used in connection with experiments in information storage and retrieval.

7.7.1 Similarity Functions

7.7.1.1 $zzCosine(gbl1,gbl2)

7.7.1.2 $zzSim1(gbl1,gbl2)

7.7.1.3 $zzDice(gbl1,gbl2)

7.7.1.4 $zzJaccard(gbl1,gbl2)

These compute the Cosine, Sim1, Dice and Jaccard similarity coefficients between document vectors given as the first and second arguments. Both arguments are numeric global array vectors. The formulae are given in Figure 19 and an example in code is given in Figure 20. The formulae calculate the similarities between two global array vector *gbl1* and global array vector *gbl2*. The vectors need not be of equal length. Missing elements are interpreted as zero. The vectors should be top level vectors.

$$Simularity_{Dice}(i,j)=\frac{2\sum_{k=1}^{k=t} Term_{ik}\cdot Term_{jk}}{\sum_{k=1}^{k=t} Term_{ik}+\sum Term_{jk}}$$

$$Simularity_{Jaccard}(i,j)=\frac{\sum_{k=1}^{k=t} Term_{ik}\cdot Term_{jk}}{\sum_{k=1}^{k=t} Term_{ik}+\sum Term_{jk}-\sum_{k=1}^{k=t}(Term_{ik}\cdot Term_{jk})}$$

$$Simularity_{Cosine}(i,j)=\frac{\sum_{k=1}^{k=t} Term_{ik}\cdot Term_{jk}}{\sqrt{\sum_{k=1}^{k=t} Term_{ik}^2\cdot\sum Term_{jk}^2}}$$

$$Simularity_{\text{¿}1}(i,j)=\sum_{k=1}^{k=t} Term_{ik}\cdot Term_{jk}$$

Figure 19 Similarity Formulae

```
#!/usr/bin/mumps
 kill ^A
 kill ^B

 set ^A("1")=3
 set ^A("2")=2
 set ^A("3")=1
 set ^A("4")=0
 set ^A("5")=0
 set ^A("6")=0
 set ^A("7")=1
 set ^A("8")=1

 set ^B("1")=1
 set ^B("2")=1
 set ^B("3")=1
 set ^B("4")=0
 set ^B("5")=0
 set ^B("6")=1
 set ^B("7")=0
 set ^B("8")=0

 write "Cosine=",$zzCosine(^A,^B),!
 write "Sim1=",$zzSim1(^A,^B),!
 write "Dice=",$zzDice(^A,^B),!
 write "Jaccard=",$zzJaccard(^A,^B),!
```

output:

```
Cosine=0.75
Sim1=6
Dice=1
Jaccard=1
```

Figure 20 Similarity Functions

7.7.2 $zzBMGSearch(arg1,arg2)

Boyer-Moore-Gosper Function returns the number of non-overlapping occurrences of *arg1* in *arg2*.

These functions, were obtained from

```
ftp://ftp.uu.net/usenet/comp.sources.unix/volume5/bmgsubs.Z
```

and were written by Jeffrey Mogul (Stanford University), based on code written by James A. Woods (NASA Ames, an agency of the U.S. Government) and are thus believed to be in the public domain. Figure 21 gives an example.

```
#!/usr/bin/mumps
 set key=”now”
 set str=”now is the now of the now in the know”
 write $zBMGSearch(key,str),!
```

output:

```
4
```

Figure 21 $zzBMGSearch() Example

7.7.3 $zPerlMatch(string,pattern)

Applies the Perl **pattern** to **string** and returns 1 if the pattern fits and 0 otherwise. The **$zPerlMatch** function has the side effect of creating variables in the local symbol table to hold backreferences, the equivalent concept of **$1**, **$2**, **$3**, ... in Perl. Up to nine backreferences are currently supported, and can be accessed through the same naming scheme as Perl (**$1** through **$9**). These variables remain defined up to a subsequent call to **$zPerlMatch**, at which point they are replaced by the backreferences captured from that invocation. Undefined backreferences are cleared between invocations; that is, if a match operation captured five backreferences, then $6 through $9 will contain the empty string. Figure 25 contains examples (long lines wrapped).

```
#/usr/bin/mumps
 set ^d("1","1")=2
 set ^d("1","2")=3
 set ^d("2","1")=1
 set ^d("2","2")=-1
 set ^d("3","1")=0
 set ^d("3","2")=4
 set ^e("1","1")=5
 set ^e("1","2")=-2
 set ^e("1","3")=4
 set ^e("1","4")=7
 set ^e("2","1")=-6
 set ^e("2","2")=1
 set ^e("2","3")=-3
 set ^e("2","4")=0
 set %=$zzMultiply(^d,^e,^f)
 for i="":$order(^f(i)):"" do
 . for j="":$order(^f(i,j)):"" do
 .. write i," ",j," ",^f(i,j),!
```

output:

```
1 1 -8
1 2 -1
1 3 -1
1 4 14
2 1 11
2 2 -3
2 3 7
2 4 7
3 1 -24
3 2 4
3 3 -12
3 4 0
```

Figure 22 $zzMultiply() Example

```
#!/usr/bin/mumps
 for i=1:1:10 set ^a(99,i)=i
 set i=$zzSum(^a(99))
 write "sum=",i,!
```

output:

```
55
```

Figure 23 $zzSum() Example

```
#!/usr/bin/mumps
 kill ^f

 set ^d("1","1")=2
 set ^d("1","2")=3
 set ^d("2","1")=4
 set ^d("2","2")=0

 set %=$zzTranspose(^d,^f)

 for i="":$order(^f(i)):"" do
 . for j="":$order(^f(i,j)):"" do
 .. write i," ",j," ",^f(i,j),!
```

output:

```
    1 1 2
    1 2 4
    2 1 3
    2 2 0
```

Figure 24 $zzTranspose() Example

```
#!/usr/bin/mumps
 write "Please enter a telephone number:",!
  read phonenum

  set p="^(1-)?(\(?\d{3}\)?)?(-| )?\d{3}-?\d{4}$"
  if $zperlmatch(phonenum,p) do
  . write "+++ This looks like a phone number.",!
  . write "The area code is: ",$2,!
  else  do
  . write "--- This didn't look like a phone number.",!
```

output:

```
Please enter a telephone number:
(123) 456-7890
+++ This looks like a phone number.
The area code is: (123)

Please enter a telephone number:
(123) 456-7890
+++ This looks like a phone number.
```

Figure 25 $zPerlMatch() Example

7.7.4 $zReplace(string,pattern,replacement)

The regular expression in *pattern* is evaluated on *string* and, if there is a match, the matching section is replaced by *replacement*. Figure 26 contains an example. In the first part, the word 'is' is replaced by 'IS'. In the second part, a match is sought for any content between two sets of matching brackets ([[...]]). The matched section is in back reference **$2**. This is then used as a pattern to be replaced.

7.7.5 $zShred(string,length)

7.7.6 $zShredQuery(string,length)

The **$zShred()** function segments the input argument **string** into fragments of **length** size upon successive calls. The function returns a string of length zero when there are no more fragments of size **length** remaining (thus, short fragments at the end of a string are not returned).

$zShred copies the input string to an internal buffer upon the first call. Subsequent calls retrieve from this buffer. When the buffer is consumed, the function will copy the contents of the next string submitted to the buffer. Figure 27 contains an example.

```
#!/usr/bin/mumps
 set a="now is the time for all"
 set a=$zReplace(a,"is","IS")
 write a,!

 set a="[[now is the time]]"
 if $zPerlMatch(a,"(\[\[)(.*)(\]\])") do
 . set a=$zReplace(a,$2,"ABC")
 . write a,!

output:

now IS the time for all
[[ABC]]
```

Figure 26 $zReplace() Example

```
#!/usr/bin/mumps
 set a="now is the time for all good men to "
 set a=a_"come to the aid of the party"
 for  do  quit:j=""
 . set j=$zShred(a,5)
 . if j="" quit
 . write j,!

output:

     nowis
     theti
```

```
    mefor
    allgo
    odmen
    tocom
    etoth
    eaido
    fthep
```

Figure 27 $zShred() Example

The **$zShredQuery** function segments **length** shifted copies of the input **string** into fragments of size **length** upon successive calls. That is, the function first returns all the fragments of size length of the **string** in the same manner as **$zShred**. However, it then shifts the starting point of the input string to the right by one and returns all the fragments of size length relative to the shifted starting point. If repeatedly called, it repeats this process a total of **length** times. When there are no more combinations, the empty string is returned as shown in Figure 28.

```
#!/usr/bin/mumps
 set a="now is the time for all good men to come to "
 set a=a_"the aid of the party"
 for  do  quit:j=""
 . set j=$zShredQuery(a,5)
 . if j="" quit
 . write j,!

output:
```

```
     nowis                        tothe                        goodm
     theti                        aidof                        entoc
     mefor                        thepa                        ometo
     allgo                        wisth                        theai
     odmen                        etime                        dofth
     tocom                        foral                        epart
     etoth                        lgood                        isthe
     eaido                        mento                        timef
     fthep                        comet                        orall
     owist                        othea                        goodm
     hetim                        idoft                        entoc
     efora                        hepar                        ometo
     llgoo                        isthe                        theai
     dment                        timef                        dofth
     ocome                        orall                        epart
```

Figure 28 $ShredQuery() Example

7.7.7 $zzSoundex(s1)

Returns the Soundex code for the argument string as follows:

1. All letters are converted to lower case;
2. Non-alphabetic characters are removed;
3. Adjacent duplicate letters are replaced by a single occurrence;
4. The first letter is retained;
5. The letters b, f, p, and v are replaced by the number 1;
6. The letters c, g, j, k, q, s, x, and z are replaced by the number 2;
7. The letters d and t are replaced by the number 3;
8. The letter l is replaced by the number 4;
9. The letters m and n are replaced by the letter 5;

10. the letter r is replaced by the number 6;
11. The is truncated to four characters.

7.7.8 $zSmithWaterman(s1,s2,algn,mat,gap,noMatch,match)

Computes the Smith Waterman score between two strings. Result returned is the highest alignment score achieved. String lengths are limited by **STR_MAX** in the interpreter. If you compare very long strings (>100,000 characters), you may exceed stack space. This can be increased under Linux with the command:

```
ulimit -s unlimited
```

Figure 29 gives an example.

```
#!/usr/bin/mumps
 set s1="now is the time"
 set s2="now  i th  time"
 set i=$zSmithWaterman(s1,s2,1,0,-1,-1,2)
 write "score=",i,!

output:

   1 now- is the time 16
     ::: :: ::: :::::
   1 now  i- th  time 16

score=23
```

Figure 29 $zSmithWaterman() Example

Parameters:

If *algn* is zero, no printout of alignments is produced. If *algn* is not zero, a summary of the alternative alignments will be printed.

If *mat* is zero, intermediate matrices will not be printed.

The parameters *gap*, *noMatch* and *match* are the gap and mismatch penalties (negative integers) and the match reward (a positive integer).

If insufficient memory is available, a segmentation violation will be raised. Try increasing your stack size.

7.7.9 $zzIDF(global,doccount)

Calculates the Inverse Document Frequency score of words contained in the argument *global*. The parameter *doccount* is the total number of documents. The index of each element of the *global* vector is a word and the value stored is the number of times the word occurs in the collection. Figure 30 gives and example. The vector argument *global* must be a top level array.

```
#!/usr/bin/mumps
 set ^a("now")=2
 set ^a("is")=5
 set ^a("the")=6
 set ^a("time")=3
 set j=4
 set %=$zzIDF(^a,j)
 for i="":$order(^a(i)):"" write i," ",^a(i),!
```

```
output:

is 0.7
now 2.0
the 0.4
time 1.4
```

Figure 30 $zzIDF() Example

7.7.10 Correlation Functions

7.7.10.1 $zzTermCorrelate(global1,global2)

Calculates the Term-Term co-occurrence matrix for the Document-Term matrix in *global1*. The result is placed in *global2*.

A Term-Term matrix has terms (words) as the indices of its rows and columns. A Term-Term matrix gives, for each position, the degree to which the term corresponding to the row is similar to the term corresponding to the column. The diagonal, which is the degree a term is related to itself, is ignored. Both operands must be top level arrays.

In both the doc-doc and term-term matrices, the upper and lower diagonal matrices are mirror images of one another. Figure 31 gives an example. The order of words in the output will depend upon which data base facility is in use and what it's collating settings are. The Native global array handler collates according to ASCII-7.

```
#!/usr/bin/mumps
 kill ^A,^B

 set ^A("1","computer")=5
 set ^A("1","data")=2
 set ^A("1","program")=6
 set ^A("1","disk")=3
 set ^A("1","laptop")=7
 set ^A("1","monitor")=1

 set ^A("2","computer")=5
 set ^A("2","printer")=2
 set ^A("2","program")=6
 set ^A("2","memory")=3
 set ^A("2","laptop")=7
 set ^A("2","language")=1

 set ^A("3","computer")=5
 set ^A("3","printer")=2
 set ^A("3","disk")=6
 set ^A("3","memory")=3
 set ^A("3","laptop")=7
 set ^A("3","USB")=1

 set %=$zzTermCorrelate(^A,^B)

 for i="":$order(^B(i)):"" do
 . write i,!
 . for j="":$order(^B(i,j)):"" do
 .. write ?10,j," ",^B(i,j),!
```

output:

```
USB
        computer 1
        disk 1
        laptop 1
        memory 1
        printer 1
computer
        USB 1
        data 1
        disk 2
        language 1
        laptop 3
        memory 2
        monitor 1
        printer 2
        program 2
data
        computer 1
        disk 1
        laptop 1
        monitor 1
        program 1
disk
        USB 1
        computer 2
        data 1
        laptop 2
        memory 1
        monitor 1
        printer 1
        program 1
language
        computer 1
        laptop 1
        memory 1
        printer 1
        program 1
laptop
        USB 1
        computer 3
        data 1
        disk 2
        language 1
        memory 2
        monitor 1
        printer 2
        program 2
memory
        USB 1
        computer 2
        disk 1
        language 1
        laptop 2
        printer 2
        program 1
monitor
        computer 1
        data 1
        disk 1
        laptop 1
        program 1
printer
        USB 1
        computer 2
        disk 1
        language 1
        laptop 2
        memory 2
        program 1
program
        computer 2
        data 1
        disk 1
        language 1
        laptop 2
        memory 1
        monitor 1
        printer 1
```

Figure 31 $zTermCorrelate() Example

7.7.10.2 $zzDocCorrelate(gblref1,gblref2,mthd,thrshld)

A square Document-Document matrix *gblref2* is calculated from the Document-Term matrix *gblref1* according to method *mthd* (Cosine, Sim1, Dice, Jaccard). The value of elements in the Document-Document matrix will not exceed threshold (*thrshld*) and the cells associated with coresponding document numbers will not exist.

A Document-Document matrix has document id's as its row and column indices. A cell in the matrix indicates the degree to which the row document is related to the column document. The diagonal is ignored. Figure 32 gives an example.

7.7.11 Stop and Synonym Functions

7.7.11.1 $zStopInit(arg)

7.7.11.2 $zStopLookup(word)

7.7.11.3 $zSynInit(fileName)

7.7.11.4 $zSynLookup(word)

A call to **$zStopInit(file_name)** will open and load a file of stop words into a C++ container. The file should consist of one word per line. If the file cannot be opened or there is insufficient memory to hold the list of words, the program will halt with an error message. **$zStopInit()** converts all words to lower case.

```
#!/usr/bin/mumps
 kill ^A,^B

 set ^A("1","computer")=5
 set ^A("1","data")=2
 set ^A("1","program")=6
 set ^A("1","disk")=3
```

```
set ^A("1","laptop")=7
set ^A("1","monitor")=1

set ^A("2","computer")=5
set ^A("2","printer")=2
set ^A("2","program")=6
set ^A("2","memory")=3
set ^A("2","laptop")=7
set ^A("2","language")=1

set ^A("3","computer")=5
set ^A("3","printer")=2
set ^A("3","disk")=6
set ^A("3","memory")=3
set ^A("3","laptop")=7
set ^A("3","USB")=1

set %=$zzDocCorrelate(^A,^B,"Cosine",.5)

for i="":$order(^B(i)):"" do
. write i,!
. for j="":$order(^B(i,j)):"" do
.. write ?10,j," ",^B(i,j),!

output:

1
         2 0.887096774193548
         3 0.741935483870968
2
         1 0.887096774193548
         3 0.701612903225806
3
         1 0.741935483870968
         2 0.701612903225806
```

Figure 32 $zDocCorrelate()Example

A call to **$zStopLookup(word)** will return 1 if *word* is in the stop list, 0 otherwise. Words presented to **$zStopLookup(word)** should be in lower case.

$SynInit() opens a synonym file. The file should consist of two or more words per line separated by from one another by one blank. The words are treated as synonyms with the first word on each line as the primary synonym. The primary synonym may be a code or category number. This word or code will be returned if any of the remaining words are passed as arguments to **$SynLookup()**. Figure 33 gives an example.

7.8 SQL functions

These functions are peculiar to this implementation..'

```
Assume that the file “stop” contains the word “and”

 set %=$zStopInit("stop")
 if $zStopLookup("and") write "yes",!

Writes yes

Assume that the file “synonyms” contains a line with the text:
```

```
compression compressions compress compressed compresses

 set %=$zSynInit("synonyms")
 write $zSynLookup("compressions"),!

output:

compression
```

Figure 33 Stop List Functions

7.8.1 $zsqlOpen

Returns *true* if a connection to the SQL server is open, *false* otherwise.

7.8.2 $zNative

$znative returns true if globals are being stored in the native global array.

7.8.3 $zSqlite[command[,option]]

$zsqlite with no arguments returns 1 if globals are being stored in Sqlite3, 0 otherwise.

7.8.3.1 $zSqlite("begin transaction")

Send a *BEGIN TRANSACTION;* command to Sqlite.

7.8.3.2 $zSqlite("commit transaction")

Send a *COMMIT TRANSACTION* ;command to Sqlite.

7.8.3.3 $zSqlite("savepoint"[,*savepoint*])

If the second argument is omitted, send a *SAVEPOINT default;* command to Sqlite.
If the second argument is present, send a *SAVEPOINT savepoint;* command to Sqlite where '*savepoint*' is the value passed as the second argument.

7.8.3.4 $zSqlite("rollback"[,*savepoint*])

If the second argument is omitted, send a *ROLLBACK TRANSACTION to default;* command to Sqlite.
If the second argument is present, send a *ROLLBACK TRANSACTION to savepoint;* command to Sqlite where '*savepoint*' is the value passed as the second argument.

7.8.3.5 $zSqlite("pragma",*option)*

A PRAGMA command will be sent to Sqlite with *option* as its argument. If the *PRAGMA* results in a returned value, it will be the returned result of the finction. Otherwise, the function will return 1 (success) or 1 (failure).

8 GTK Desktop GUI Apps

Several simplified GTK functions are included. These will alow you to create desktop GUI applications. These are functions that control GTK widgets in a graphical application.

8.1 Glade GUI Design Tool

The open source program *Glade* allows the user to design the layout of a desktop GUI app by dragging and dropping GUI widgets (buttons, text boxes, etc.) onto a canvas. Figure 34 gives an example that includes several widget types.

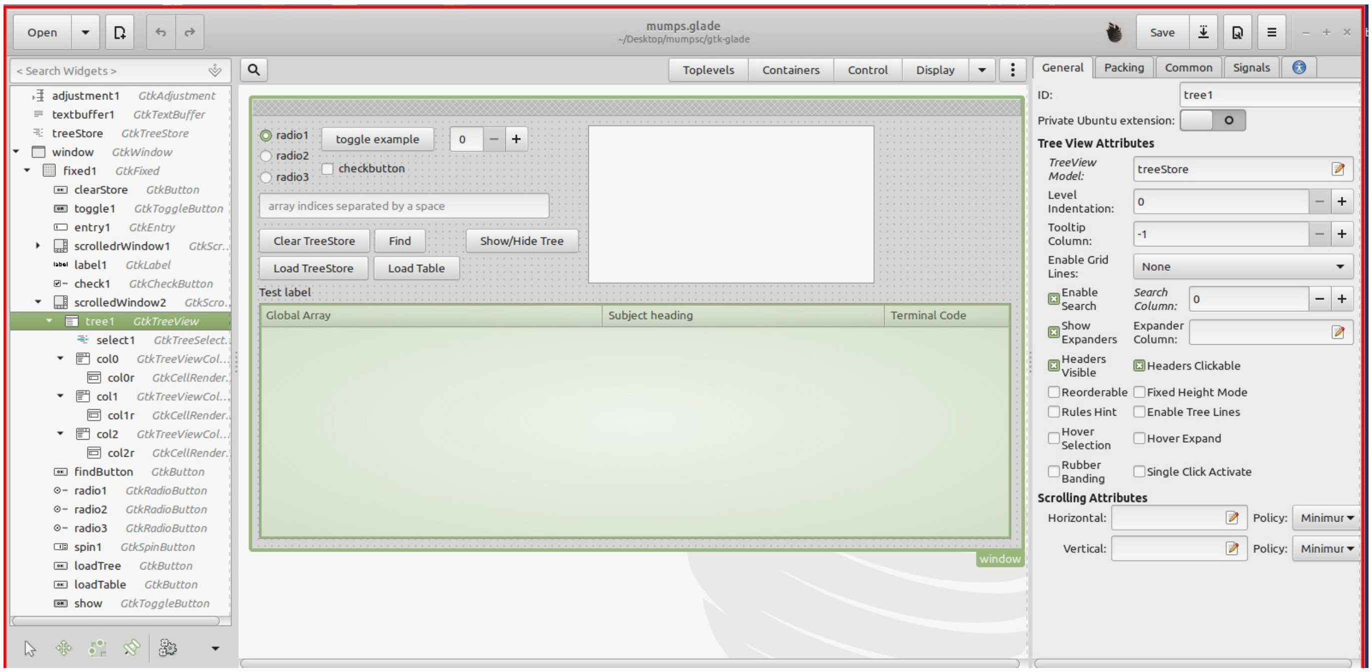

Figure 34 Glade Canvas

When you save a Glade canvas it appears in your directory as a file with the *.glade* extension. This is an XML file giving the details on your design.

Included with the Mumps distribution in the directory *gtk-glade* is a script file named *appBuild,script* and a Mumps program named *extractWidgets.mps*. The script file:

1. runs the Mumps file which reads the file *.glade* file from above and builds several files;
2. compiles (using the Mumps compiler) the file *gtk.mps* which includes the files from the previous step and creates an executable named *gtk* which will render the GUI application on the screen.

Among the files created by *extractWidgets.mps* are several files containing Mumps programs to service the actions to be performed by interacting with the on-screen GUI. There will be a file for each signal defined for each widget. The files will have names of the form:

on.widgetName.clicked.mps

where *widgetName* is the name of the widget as given in the *ID* field in the glade app and *clicked* is a signal established for that widget. The file will be invoked if the action associated with the signal is detected (for example, a button is clicked).

8.2 GTK Example

8.2.1 Glade Design Tool

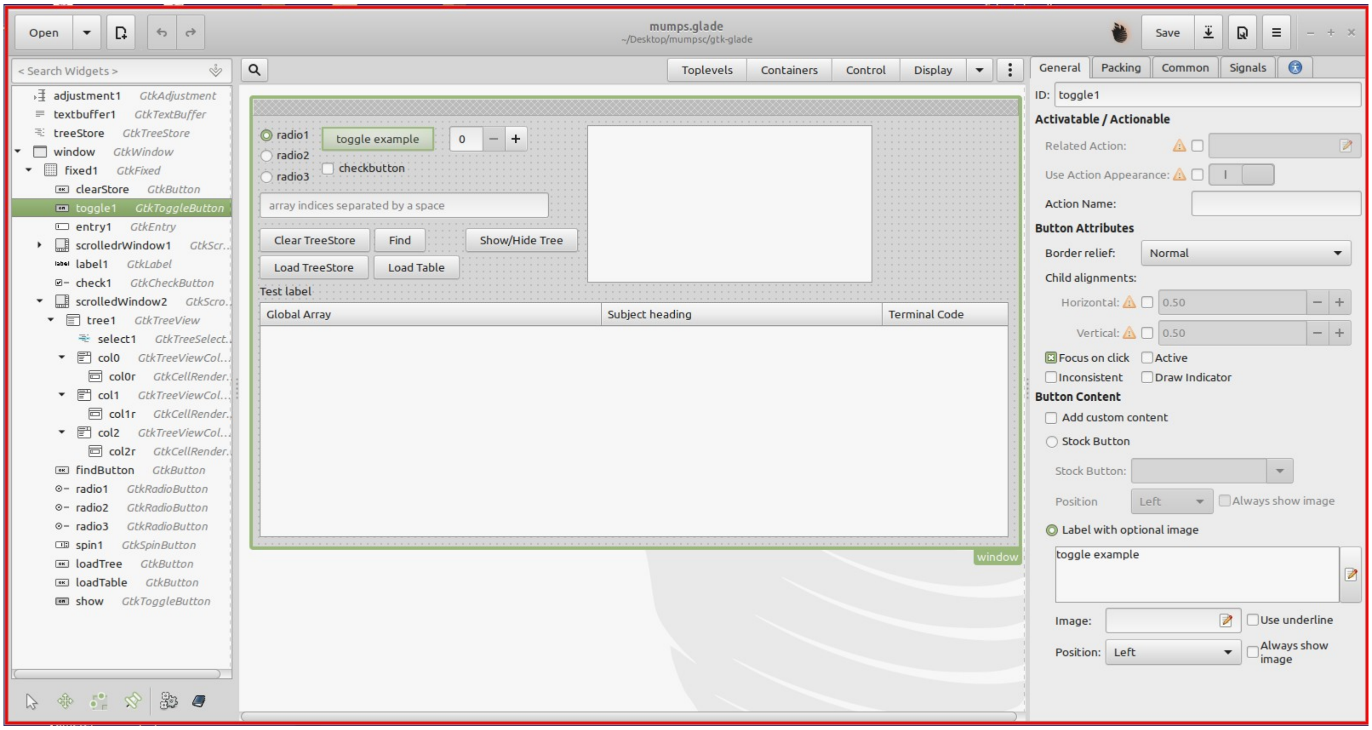

Figure 35 Toggle Button Screen 1

In Figure 35 you see the a Glade layout page. The center panel is the layout for the on-screen app that is being built. The various entities (widgets) have been dragged and dropped into their positions from widgets available in dropdown menus shown at the top named Toplevel, Containers, Control, and Display.

The leftmost panel contains the user assigned names (IDs) of the widgets along with an indication of their data types.

Some widgets are nested within others according to the display hierarchy. This, the GtkToggleButton named toggle1 is contained within the GtkFixed container named fixed1 which in turn is contained within the GtkWindow named window.

The rightmost panel contains tabs which show options for a selected widget. In this case, the selected widget is the toggle1 button which is highlighted in green in upper left of center panel and also as a row in panel one.

As can be seen in panels 1 and 3, the ID of the widget is toggle1 (user assigned), The widget is a GtkToggleButton (as seen in panel 1).

The text displayed in the button is set in panel 3 under *Label with Optional Image*. No image is assigned in this case.

Except for assigning the ID name of the widget and entering the text to appear in the button, the remainder of the options are defaults which are suitable for most ordinary applications.

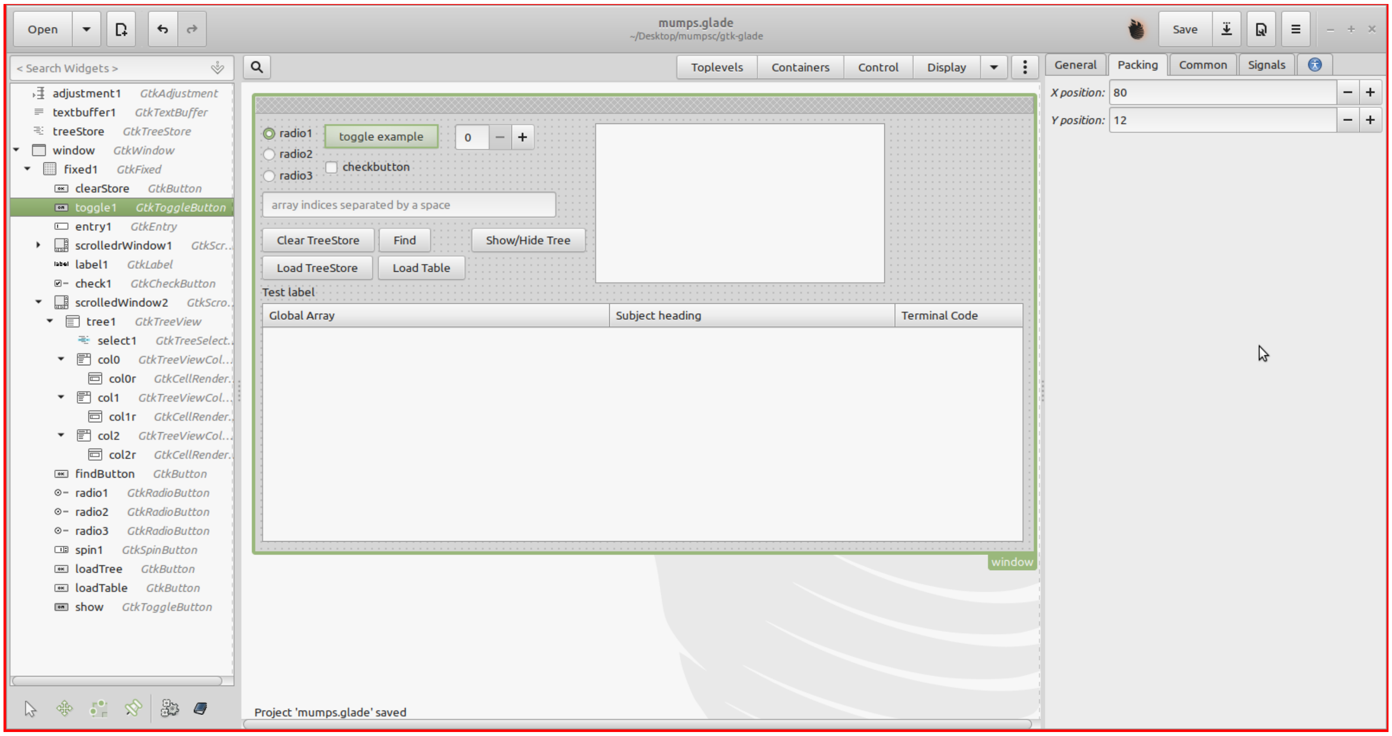

Figure 36 Toggle Button Screen 2

In Figure 36 the second tab of panel 3 has been selected. This panel determines the location of the widget within the window. Changing these numbers moves the widget accordingly.

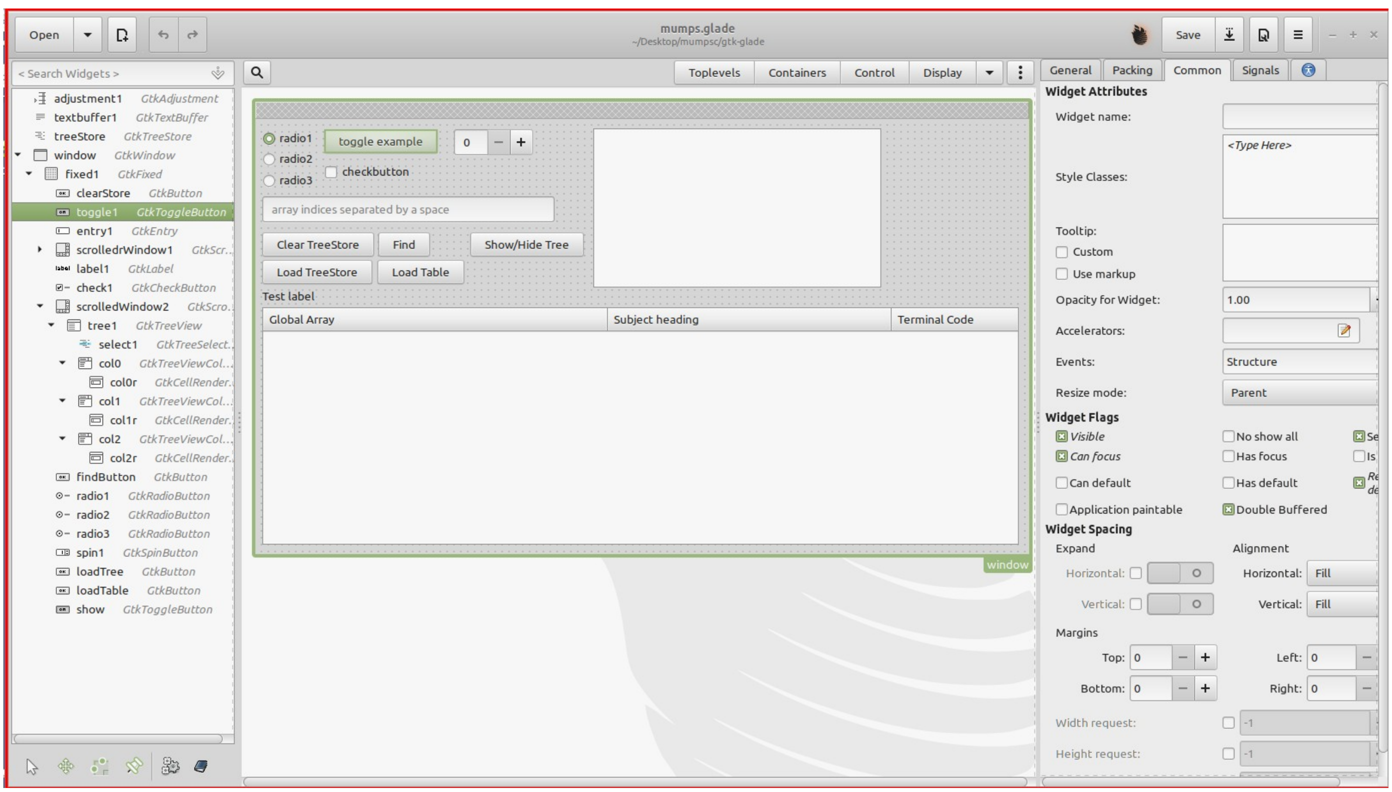

Figure 37 Toggle Button Screen 3

In the third tab of panel 3 are many adjustments all of which are defaults except for the height and width settings. These determine the size of the button. The height and width request boxes have been unchecked which causes the button to be sized to fit the contained text.

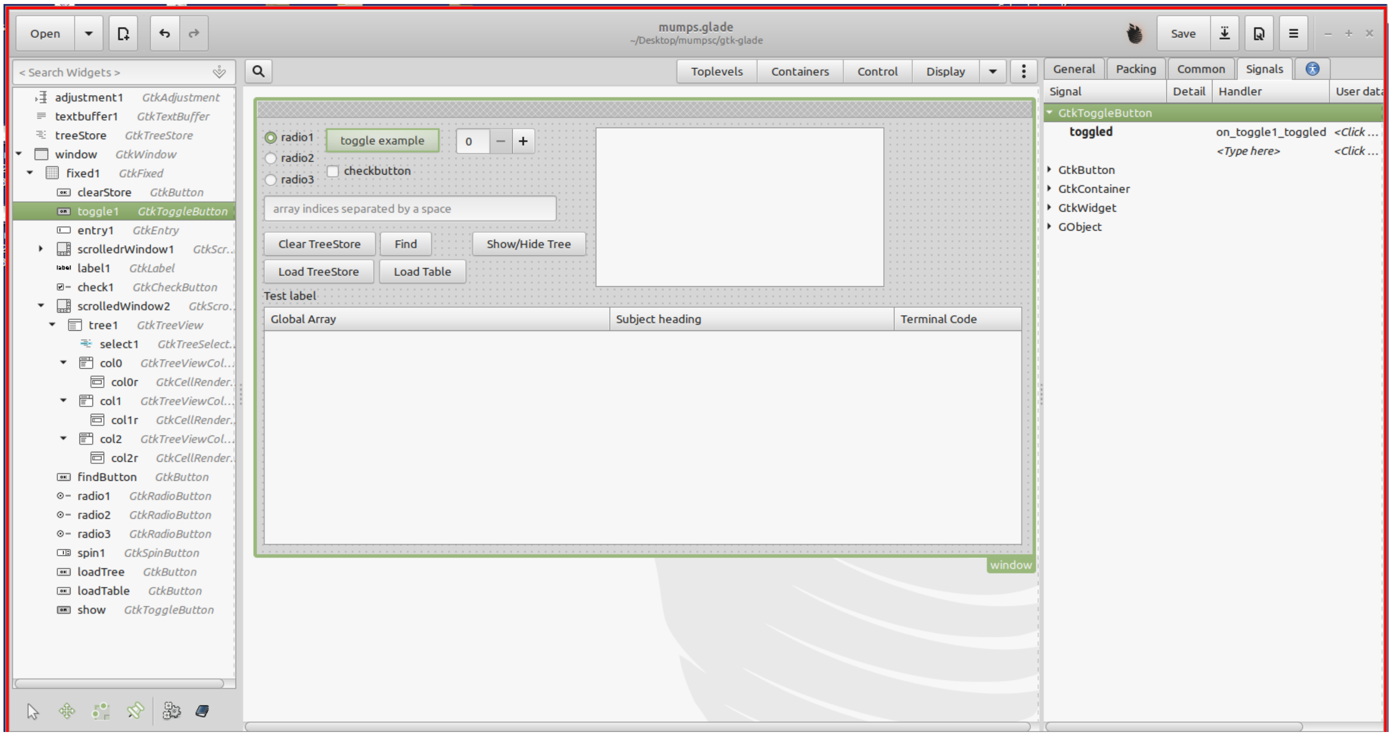

Figure 38 Toggle Button Screen 4

In Figure 38 we see the last tab of panel 3. This is the panel where you select the signals to be emitted for actions on the widget. Since this is a toggle button, the primary action is to click the button using the left button on your mouse. This action can emit a toggled signal.

If you want your program to process this signal, you enter the name of the routine to be called should the signal emit. In this case, the function named *on_toggle1_toggled* will be called if the button is clicked. The GTK GUI manager will cause the button to appear depressed or not depressed after successive clicks. Your function can determine the state of the button by using a system function.

When you save a Glade layout, it is saved as an XML file with the extension *.glade*.

8.2.2 Building A Mumps App from The Glade XML File

The disk representation of a Glade design is a XML file. For purposes of building a Mumps program from this file, the file needs to be named *mumps.glade*.

In the above we highlighted the toggl1 toggle button. The Glade XML for that button looks like:

```
<child>
  <object class="GtkToggleButton" id="toggle1">
    <property name="label" translatable="yes">toggle example</property>
    <property name="visible">True</property>
    <property name="can_focus">True</property>
    <property name="receives_default">True</property>
    <signal name="toggled" handler="on_toggle1_toggled" swapped="no"/>
  </object>
  <packing>
    <property name="x">80</property>
    <property name="y">12</property>
```

```
    </packing>
  </child>
```

The above is a fragment of the larger Glade file which is 299 lines in length. The XML tells us that the name of the widget (toggle1), its data type (GtkToggleButton), its label contents (toggle example), any signals it emits (toggled) and the name of the signal handlers (on_toggle1_toggled). It also gives the location of the button on the app window and other information concerning its appearance and performance.

The distro program *extractWidgets.mps* reads the XML file and generates files that are used to compile and service an application. These are:

8.2.2.1 gtk1.h

This file contains C declarations for all the widgets defined in the XML file. It also includes the relevant GTK header files. In the case of the toggle one widget, the line:

```
GtkToggleButton *toggle1;
```

appears, among others.

8.2.2.2 gtk2.h

This file contains code that will invoke a Mumps signal handler (see below) for each signal emitted for a widget. In the case of the toggle1 widget, this code looks like:

```
toggle1=GTK_TOGGLE_BUTTON(gtk_builder_get_object(builder,"toggle1"));
{ char tmp[128]; sprintf(tmp,"%p", toggle1);
 SymPut("toggle1",tmp); fprintf(f," set toggle1=\"%s\"\n",tmp); }
```

The above code fragment which will be compiled into the base program *gtk.mps* builds the internal data structure and screen representation associated with the widget by means of *gtk_builder_object().* This function reads the *mumps.glade* XML file information for the parameter *toggle1.* The function returns a pointer to the object which is stored in the GtkToggleButton pointer *toggle1* (the names of the widgets and the internal pointers as usually the same, both are *toggle1* in this case).

The string value of the pointer is stored in the Mumps symbol table (*SymPut()*) and a string containing the Mumps command or the form: *set toggle1=0x123456* is written to the file gtk4.mps.

8.2.2.3 gtk3.h

This file contains the basic signal handlers (written in C) which are used to invoke the corresponding Mumps programs which will actuall handle the signal. The code for the toggle1 widget looks like:

```
extern "C" void on_toggle1_toggled(GtkWidget *w)
{struct MSV * Ptr = AllocSV(); char tmp[512];
sprintf(tmp,"set widget=\"%p\" g ^on.toggle1.toggled.mps",w);
Interpret((const char *) tmp, Ptr); free(Ptr);}
```

This fragment establishes the signal handler (*on_toggle1_toggled()*), creates an instance of the Mumps state vector (MSV *Ptr), creates a string consisting of Mumps *set* and *goto* (g) *commands* with the string value of the widget *w* as the right hand side of the *set* command.

The subject of the goto command is a file named ^*on.toggle1.clicked.mps* which will contain the Mumps code to process the signal.

Next, it then invokes the mumps interpreter (*Interpret()*) which executes the commands in *tmp*.

The first line specifies that the calling conventions for this function will follow C language rules. This is because the Mumps interpreter is actually a collection of C++ programs and the basic GTK library is written in C.

8.2.2.4 gtk4.h

This file is created when the actual application is run. It writes, for each widget, a Mumps set command that establishes the address of the data structure for the widget. In the case of the toggle1 example, this looks like:

```
set toggle1="0x55ab6337e230"
```

When the Mumps signal handler is invoked, the file containing this information will be run by the signal handler thus giving the signal handler the memory references of all widgets in the application.

8.2.2.5 gtk.mps

This is the main routine that is compiled by the Mumps compiler. It will start the GTK GUI system. It looks like:

```
# Jan 30, 2022
+ #include "gtk1.h"
        zmain
+ #include "gtk2.h"
        do ^gtk4.h
+ gtk_main();
        write "Goodbye!",!
        zexit
+ #include "gtk3.h"
```

The lines that begin with a plus sign are passed directly to the C++ compiler. The function *gtk_main()* passes control to the GTK runtime routines. Return is only made upon program termination.

The first #include brings in the global widget declarations (in C++). The second #include incorporates all the builder calls which create the widgets on the screen and their associated data structured. The third #include brings in the C++ signal handlers for all signals used by the widgets.

8.2.2.6 on.toggle1.toggled.mps

The actual Mumps signal handler created by *extractWidgets.mps*, named *on.toggle1.toggled.mps* looks like:

```
#!/usr/bin/mumps

#       Mumps GTK Signal Handler

 do ^gtk4.h
 write "on.toggle1.toggled.mps"," ",widget,!
 write $z~mdh~toggle~button~get~active(toggle1),!
```

The function *$z~mdh~toggle~button~get~active(toggle1)* returns 0 or 1 depending if the button is not depressed or depressed. In this case of the function, it's Mumps reference (toggle1) was used but the variable *widget* is also present which contains a pointer to the data structure of the widget (toggle1 in this case) which emitted the signal.

You're on your own from here.

8.3 MDH Functions

8.3.1 $z~mdh~toggle~button~get~active(ToggleButtonReference)

Returns 0 if the button is inactive, 1 if active

8.3.2 $z~mdh~toggle~button~set~active(ToggleButtonReference,intVal)

Sets the button to active if intVal is 1, inactive if the value is 0.

8.3.3 $z~mdh~dialog~new~with~buttons(ParentWindowRef,dialog)

Raises a Gtk Dialog window displaying the contents of *dialog* with buttons **Yes** and **No**. Returns 1 if **Yes** is clicked; 0 if **No** is clicked; and -1 if the box is dismissed.

8.3.4 $z~mdh~entry~get~text(EntryReference)

Returns the current string contents of the referenced Entry box.

8.3.5 $z~mdh~entry~set~text(EntryReference,value)

Sets the contents of the named entry box to *value*.

8.3.6 $z~mdh~text~buffer~set~text(TextBufferReference,string)

Sets the contents of the referenced text buffer to the value of string.

8.3.7 $z~mdh~label~set~text(LabelReference,string)

Sets the text contents of the label referenced to string. Triggers a value changed signal.

8.3.8 $z~mdh~tree~selection~get~selected(TreeModelReference,column)

Returns value in designated column of referenced TreeModel.

8.3.9 $z~mdh~tree~store~clear(TreeStoreReference)

Clears (deletes) the contents of the referenced TreeStore.

8.3.10 $z~mdh~tree~level~add(TreeStoreReference,treeDepth,index,data[,...])

Add index at tree level treeeDepth to column 1 of TreeStore. Add additional data items in successive columns.

8.3.11 $z~mdh~spin~button~get~value(SpinButtonReference)

Returns the current value of the referenced SpinButton.

8.3.12 $z~mdh~spin~button~set~value(SpinButtonReference,number)

Sets the current value of the referenced spin button to number.

8.3.13 $z~mdh~widget~hide(widgetReference)

Hides the widget from view.

8.3.14 $z~mdh~widget~show(widgetReference)

Displays (un-hides) the widget.

9 Pattern Matching

9.1 Mumps 95 Pattern Matching

Author: Matthew Lockner

Mumps 95 compliant pattern matching (the '?' operator) is implemented in this compiler/interpreter as given by the following grammar:

```
pattern         ::= {pattern_atom}
pattern_atom    ::= count pattern_element
count           ::= int | '.' | '.' int | int '.' | int '.' int
pattern_element ::= pattern_code {pattern_code} | string | alternation
pattern_code    ::= 'A' | 'C' | 'E' | 'L' | 'N' | 'P' | 'U'
alternation     ::= '(' pattern_atom {',' pattern_atom} ')'
```

The largest difference between the current and previous standard is the introduction of the alternation construct, an extension that works as in other popular regular expressions implementations. It allows for one of many possible pattern fragments to match a given portion of subject text.

A string literal must be quoted. Also note that alternations are only allowed to contain pattern atoms and not full patterns; while this is a possible shortcoming, it is in accordance with the standard. It is a trivial matter to extend alternations to the ability to contain full patterns, and this may be implemented upon sufficient demand.

Pattern matching is supported by the Perl-Compatible Regular Expressions library (PCRE). Mumps patterns are translated via a recursive-descent parser in the Mumps library into a form consistent with Perl regular expressions, where PCRE then does the actual work of matching. Internally, much of this translation is simple character-level transliteration (substituting '`|`' for the comma in alternation lists, for example). Pattern code sequences are supported using the POSIX character classes supported in PCRE and are mostly intuitive, with the possible exception of '`E`', which is substituted with `[[:print][:cntrl:]]`. Currently, this construct should cover the ASCII 7-bit character set (lower ASCII).

Due to the heavy string-handling requirements of the pattern translation process, this module uses a separate set of string-handling functions built on top of the C standard string functions, using no dynamic memory allocation and fixed-length buffers for all operations whose length is given by the constant STR_MAX in *sysparms.h*. If an operation overflows during the execution of a Mumps compiled binary, a diagnostic is output to *stderr* and the program terminates. If such termination occurs too frequently, simply increase the value of STR_MAX.

9.2 Using Perl Regular Expressions

Author: Matthew Lockner

In addition to Mumps 95 pattern matching using the '?' operator, it is also possible to perform pattern matching against Perl regular expressions via the *perlmatch* function. Support for this functionality is provided by the Perl-Compatible Regular Expressions library (PCRE), which supports a majority of the functionality found in Perl's regular expression engine.

The *perlmatch* function works in a somewhat similar fashion to the '?' operator. It is provided with a subject string and a Perl pattern against which to match the subject. The result of the function is boolean and may be used in boolean expression contexts such as the "If" statement.

Some subtleties that differ significantly from Mumps pattern matching should be noted:

1. A Mumps match expects that the pattern will match against the entire subject string, in that successful matching implies that no characters are left unmatched even if the pattern matched

against an initial segment of the subject string. Using *perlmatch*, it is sufficient that the entire Perl pattern matches an initial segment of the subject string to return a successful match.

2. The *perlmatch* function has the side effect of creating variables in the local symbol table to hold *backreferences*, the equivalent concept of $1, $2, $3, ... in Perl. Up to nine backreferences are currently supported, and can be accessed through the same naming scheme as Perl ($1 through $9). These variables remain defined up to a subsequent call to *perlmatch* , at which point they are replaced by the backreferences captured from that invocation. Undefined backreferences are cleared between invocations; that is, if a match operation captured five backreferences, then $6 through $9 will contain the null string.

Examples

This program asks the user to input a telephone number. If the data entered looks like a valid telephone number, it extracts and prints the area code portion using a backreference; otherwise, it prints a failure message and exits.

```
Write "Please enter a telephone number:",!
Read phonenum

If $$^perlmatch(phonenum,"^(1-)?(\(?\d{3}\)?)?(-| )?\d{3}-?\d{4}$") Do
. Write "+++ This looks like a phone number.",!
. Write "The area code is: ",$2,!
Else  Do
. Write "--- This didn't look like a phone number.",!
```

The output of several sample runs of the program follows:

```
Please enter a telephone number:
1-123-555-4567
+++ This looks like a phone number.
The area code is: 123


Please enter a telephone number:
(123)-555-1234
+++ This looks like a phone number.
The area code is: (123)


Please enter a telephone number:
(123) 555-0987
+++ This looks like a phone number.
The area code is: (123)
```

As in Perl, sections of the regular expression contained in parentheses define what is contained in the backreferences following a match operation. The backreference variables are named in a left-to-right order with respect to the expression, meaning that $1 is assigned the portion matched against the leftmost parenthesized section of the regular expression, with further references assigned names in increasing order. For a much more in-depth treatment of the subject of Perl regular expressions, refer to the *perlre* manpage distributed with the Perl language (also widely available online).

10 Mumps Compiler

Included in the distribution package is a compiler for the Mumps language and the Multi-Dimensional and Hierarchical library (MDH).

The compiler translates Mumps source code to C++ then compiles the C++ file to an executable binary.

The MDH toolkit consists of a collection of class libraries and other software that facilitates Mumps style coding in C++. It supports global arrays, Mumps-style string operations and functions.

There is a companion document entitled ***MDHiUsersGuide.pdf*** which provides additional details on the MDH package.

10.1 How to Compile and Run a Mumps or MDH Program.

In order to be compiled, programs written in Mumps must have the extension ***.mps.*** Programs written for the interpreter, however, may have any extension however ***.mps*** is preferred. MDH programs written in C++ must have the ***.cpp*** extension.

When you compile a Mumps program, a C++ translation of your program is created and written to the disk with the same name but with the ***.cpp*** extension. The C++ translation is then compiled and linked with run-time libraries to build an executable binary.

You may compile a Mumps program or MDH C++ program by using the executable script ***mumpsc***. To compile a Mumps or MDH C++ program using the script, type:

```
mumpsc myprog.mps
```

If the name of the file presented as an argument to ***mumpsc*** has the extension ***.mps***, the script will first translate the Mumps to C++ and then compile the result and link the output of the C++ compiler with standard Mumps libraries.

If the name of the file presented as an argument to ***mumpsc*** has the extension ***.cpp***, the script will compile the C++ program with the Mumps libraries.

The program that translates Mumps to C++ is named ***mumps2c***. You may run this program standalone:

```
mumps2c myprog.mps
```

The result will be a file named *myprog.cpp.* You may edit or modify this file and then compile it to binary executable with the ***mumpsc*** script.

Both ordinary C++ programs that use the MDH class libraries and C++ programs created by the Mumps compiler make use of the same compile and runtime libraries. The ***mumpsc*** script passes these to the ***gpp*** compiler. Use of the ***gpp*** compiler without these will result in errors.

10.2 Compiler Error Messages

Generally speaking, in most cases you will receive syntax error messages from the Mumps compiler that will identify the error and the line number in the original Mumps program containing the error.

However, in some cases, an error may not be detected by the Mumps compiler but, instead, by the C++ compiler.

Consequently, if you get C++ error messages, the line number on the error message will refer to the line number in the C++ translation of your Mumps program. To link this to a line number in your Mumps program, look into the generated ***.cpp*** file at the line number given by the C++ error message and then back track to the nearest prior commented Mumps source line - this shows the original in your Mumps programs that caused the problem.

For example, if you get a message from the C++ compiler saying that you have an error at line 1234 in the C++ module, open the C++ file and move to line 1234. At that location you may see something like:

```
/*===========================================================================*
svPtr->LineNumber=4; //       write "the sum is: ",total,!
/*===========================================================================*/
       if (svPtr->out_file[svPtr->io]==NULL) ErrorMessage("Write to input file",svPtr->LineNumber);
       svPtr->hor[svPtr->io]+=fprintf(svPtr->out_file[svPtr->io],"%s","the sum is: ");
       if (sym_(SYMGET,(unsigned char *) "total",(unsigned char *) tmp0,svPtr)==NULL)
            VariableNotFound(svPtr->LineNumber);
       svPtr->hor[svPtr->io]+=fprintf(svPtr->out_file[svPtr->io],"%s",tmp0);
       fprintf(svPtr->out_file[svPtr->io],"\n"); svPtr->hor[svPtr->io]=0; svPtr->ver[svPtr->io]++;
```

Figure 39 Example C++ Code

Note that each original line of Mumps code and its line number in the original Mumps file appear in a comment prior to the C++ translation of the line. Note that the translation of a line of Mumps code may result in multiple lines of C++ code.

Generally speaking, you may receive C++ error messages if you reference non-existent labels or subroutines, or incorrectly specify indented do blocks (see below).

10.3 Global Array Storage in Compiled Programs

Global arrays will be stored in Sqlite3 or the native Btree database depending on which script you used to build the interpreter. Global arrays created by compiled programs are interchangeable with global arrays created by the interpreter.

10.4 Compiler Implementation Overview

The compiled modules, exclusive of database access, execute faster than the same code executing on the interpreter. However, programs will large amounts of database or I/O activity will run at about the same speed.

One advantage of full compilation is interoperability with other languages and with the host operating system. Programs written in C++ have full access to all system features and can be manually edited to improve performance.

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```

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Programs written with the MDH may call upon the Perl Compatible Regular Expression Library. In some cases, this library is distributed with the Mumps Compiler. The PCRE Library is not covered by the GNU GPL/LGPL Licenses but, rather, by the license shownn below. The following is the PCRE license:

```
PCRE LICENCE
------------
PCRE is a library of functions to support regular expressions whose syntax
and semantics are as close as possible to those of the Perl 5 language.
Written by: Philip Hazel
University of Cambridge Computing Service,
Cambridge, England. Phone: +44 1223 334714.
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restrictions:
1. This software is distributed in the hope that it will be useful,
   but WITHOUT ANY WARRANTY; without even the implied warranty of
   MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
2. The origin of this software must not be misrepresented, either by
   explicit claim or by omission. In practice, this means that if you use
   PCRE in software which you distribute to others, commercially or
   otherwise, you must put a sentence like this
     Regular expression support is provided by the PCRE library package,
     which is open source software, written by Philip Hazel, and copyright
     by the University of Cambridge, England.
   somewhere reasonably visible in your documentation and in any relevant
```

```
   files or online help data or similar. A reference to the ftp site for
   the source, that is, to
     ftp://ftp.csx.cam.ac.uk/pub/software/programming/pcre/
   should also be given in the documentation.
3. Altered versions must be plainly marked as such, and must not be
   misrepresented as being the original software.
4. If PCRE is embedded in any software that is released under the GNU
   General Purpose Licence (GPL), or Lesser General Purpose Licence (LGPL),
   then the terms of that licence shall supersede any condition above with
   which it is incompatible.
The documentation for PCRE, supplied in the "doc" directory, is distributed
under the same terms as the software itself.
End
```

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