Developer's manual for
Ox™ 7

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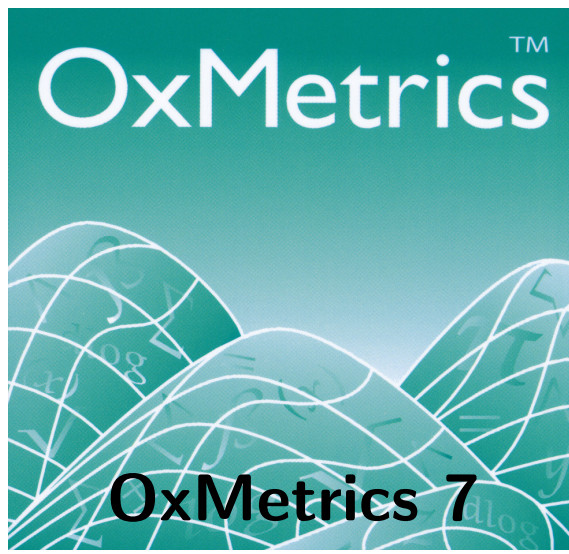

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Ox$^{\textbf{TM}}$ **7**

Developer's manual

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Chapter D1

Introduction

Ox is an open system to which you can add functions written in other languages. It is also possible to control Ox from another programming environment such as Visual C++. The interface to the Ox dynamic link library is based on the C language. Most, if not all, other languages provide a mechanism to interface in a manner similar to the C language. For example, under Windows, the Ox interface is very similar to interfacing with the Windows API.

Extending Ox requires an understanding of the innards of Ox, a decent knowledge of C, as well as the right tools. In addition, extending Ox is simpler on some platforms than others. Thus, it is unavoidable that writing Ox extensions is somewhat more complex than writing plain Ox code. However, there could be reasons for extending Ox, e.g. when you need the speed of raw C or FORTRAN code, or to add a user-friendly interface in Java, say. Another case is to write a wrapper to use a function from another library.

When you port some Ox code to C for reasons of speed, make sure that the function takes up a significant part of the time it takes to run the program and that it actually will be a faster in C than in Ox! This chapter gives many examples that could provide a start for your coding effort.

When you write your own C functions to link to Ox, memory management inside the C code is your responsibility. So care is required: any errors can bring down the Ox program, or, worse, lead to erroneous outcomes.

The main platforms for Ox are Windows, Linux and OS X, and the foreign language interface is available on each platform. A dynamic link library has the `.so` extension under Linux and OS X, while under Windows it is `.dll`.

Chapter D4 documents the C functions available to interface with Ox. This includes the C mathematical functions exported by the Ox DLL: any program could use Ox as a function library by making direct calls to the Ox DLL.

An easy way to create an interface for an Ox program is using OxPack and the OxMetrics front-end. This only requires coding in Ox, and is documented in Chapter D5.

D1.1 The ox/dev folder

The ox/dev folder contains header and library files the facilitate the link between Ox and the foreign language. Examples can be found in ox/dev/samples.[1]

The main header file to use in your C/C++ code is oxexport.h.. This in turn imports the following header files:

dependencies of oxexport.h	
jdsystem.h	platform and compiler specific defines
jdtypes.h	basic types and constants
jdmatrix.h	basic matrix services
jdmath.h	mathematical and statistical functions
oxtypes.h	basic Ox constants and types

An Ox class is provided for the following languages:

Ox.cs	C#
Ox.java	Java
Ox.vb	Visual Basic 9

The remaining sections all give examples on extending Ox:

purpose	ox/ directory	section
calling C code from Ox	dev/samples/threes	D2.1
calling Ox exported functions from C	dev/samples/threes	D2.1
calling Fortran code from Ox	dev/samples/fortran	D2.2
returning values in arguments	dev/samples/invert	D2.3
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[1] The Unix convention of forward slashes is adopted.

Chapter D2

Ox Foreign Language Interface

D2.1 Calling C code from Ox

The objective is to write a function in C, compile it into a dynamic link library (DLL), so that the function can be called as if it were part of Ox.

We shall write a function called `Threes`, which creates a matrix of threes (cf. the library function `ones`). The first argument is the number of rows, the second the number of columns. It could be used in Ox code to create a 2×3 matrix of filled with the value 3, e.g.:

```
decl x = Threes(2, 3);
```

The C source code is in `threes.c`:

ox/dev/samples/threes/threes.c

```
#include "oxexport.h"

void OXCALL FnThrees(OxVALUE *rtn, OxVALUE *pv, int cArg)
{
    int i, j, c, r;

    OxLibCheckType(OX_INT, pv, 0, 1);

    r = OxInt(pv, 0);
    c = OxInt(pv, 1);
    OxLibValMatMalloc(rtn, r, c);

    for (i = 0; i < r; i++)
        for (j = 0; j < c; j++)
            OxMat(rtn, 0)[i][j] = 3;
}
```

- The `oxexport.h` header file defines all types and functions required to link to Ox.
- All functions have the same format:
  - `OXCALL` defines the calling convention;
  - `rtn` is the return value of the function. It is a pointer to an `OxVALUE` which is the container for any Ox variable. On input, it is an integer (`OX_INT`) of value 0.

If the function returns a value, it should be stored in `rtn`.
  - `pv` is an array of `cArg` `OxVALUE`s, holding the actual arguments to the function.
  - `cArg` is the number of arguments used in the function call. Unless the function has a variable number of arguments, there is no need to reference this value.
- If the function is written in C++ instead of C, it must be declared as:

```
extern "C" void OXCALL FnThrees
    (OxVALUE *rtn, OxVALUE *pv, int cArg)
```

- First, we check whether the arguments are of type `OX_INT` (we know that there are two arguments, which have index 0 and 1 in `pv`). The call to `OxLibCheckType` tests `pv` (the function arguments) from index 0 to index 1 for type `OX_INT`.

  Arguments must be checked for type before being accessed. Make sure there is a call to `OxLibCheckType` *for each argument (unless you inspect the arguments 'manually'). This check also does type conversion if that is required.*

  In this case, a double would also be valid, but automatically converted to an integer by the `OxLibCheckType` function. Any other argument type would result in a run-time error (checking for the number of arguments is done at compile time).
  The most commonly used types for Ox variables are:

`OX_INT`	integer
`OX_DOUBLE`	double
`OX_MATRIX`	matrix
`OX_STRING`	string
`OX_ARRAY`	array

- For convenience, we copy the first argument to `r`, and the second to `c`. `OxInt` accesses the integer in an `OxVALUE`. The first argument is the array of `OxVALUE`s, the second argument is the index in the array. This specifies the dimension of the requested matrix.
- The return type is a matrix, and that matrix has to be allocated in the `rtn` value, using the right dimensions. This is done with the `OxLibValMatMalloc` function. A run-time error is generated if there is not enough memory to allocate the matrix.
- Finally we have to set all elements of the matrix to the value 3. `OxMat` accesses the allocated matrix. The dimensions of that matrix are accessed by `OxMatc`, `OxMatr`, but here we already know the dimensions.

Note that the function arguments, as contained in `pv`, may only be changed if they are declared as `const`. *It is best to never change the arguments in the function*, except from conversion from int to double and vice versa (automatic conversion using `OxLibCheckType` is always safe). Another exception is when the argument is a pointer in which the caller expects a return value. An example will follow shortly.

D2.1.1 Calling the Dynamic Link Library

After creating the DLL, the function can be used as follows:

ox/dev/samples/threes/threes.ox

```
#include <oxstd.h>

extern "threes,FnThrees" Threes(const r, const c);
```

```
main()
{
    print(Threes(3,3));
}
```

The function is declared as `extern`, with the DLL file in `threes` (the name may contain a relative or absolute path). The name of the function in `threes.dll` is `FnThrees`, but in our Ox code we wish to call it `Threes`. After this declaration, we can use the function `Threes` as any other standard library function (normally this would be in a header file).

Note that DLLs from different platforms can coexist in the same folder, because the Ox will first try the platform-specific version:

`threes.dll`	Windows 32-bit
`threes_64.dll`	Windows 64-bit
`threes.so`	Linux 32-bit
`threes_64.so`	Linux 64-bit
`threes_osx.so`	OS X 32 and 64-bit

The language reference chapter in the Ox book has more information under external declarations; path resolution is discussed under preprocessing.

If the program does not work, check the requirements to successfully link to the Ox DLL. Under Windows:

- `OXCALL` corresponds to the standard call (`__stdcall`) calling convention; this pushes parameters from right to left, and lets the function clean the stack;
- structure packing is at 8 byte boundaries (the default),
- the function is exported, and its name is not decorated.
  Make sure that `FnThrees` is the exact name in the DLL file; some compilers will change the name according to the calling convention (and C++ functions are subject to name mangling, which is avoided by declaring them as extern "C").

D2.1.2 Compiling `threes.c`

The `threes.c` file should compile without problems into a DLL file. Makefiles for a range of compilers are provided:

- `threes/lnx_gcc` — 32-bit linux using gcc
- `threes/lnx_gcc_64` — 64-bit linux using gcc
  The Linux versions do not need to specify the exported functions, nor is the Ox so file needed when linking: imports are resolved at run time. See §D2.1.2.2.
- `threes/osx_gcc` — OS X using gcc
  See §D2.1.2.3.
- `threes/osx_clang` — OS X using clang (the default compiler)
  See §D2.1.2.3.
- `threes/win_gcc` — 32-bit and 64-bit Windows using MinGW
  The 32-bit version links to `ox/dev/liboxwin.a`. The `threes.def` file handles the name decoration. Output is in the local folder, to keep it separate from the DLL compiled with Visual C++. The 64-bit version links to `ox/dev/lib64/liboxwin.a`. More information is in §D2.1.2.4.

- `threes/win_vc9` — 32-bit and 64-bit Windows using Microsoft Visual C++ 9 (Visual Studio 2008)
  The path to `oxexport.h` is specified in the project file. The 64-bit version links to `ox/dev/lib64/oxwin.lib`, the 32-bit version to `ox/dev/oxwin.lib`. The exports of the DLL are defined in `threes.def`, but you could use `__declspec(dllexport)` instead. The `threes.dll` and `threes_64.dll` files are output to the `dev/threes` folder. More information is in §D2.1.2.1.

Note the calling conventions mentioned above, which matters only under Windows. A library file specifies the imported functions, while the definition file to resolve the calls to the Ox DLL (again, Windows only).

D2.1.2.1 Windows: Microsoft Visual C++ 9

Microsoft Visual C++ 9 is part of Visual Studio 2008.

The Microsoft Visual C++ 9 solution (.sln) and project (.vcproj) files can be found in the folder entitled: `ox/dev/samples/threes/win_vc9`. The project sets the additional include directories (project properties, C/C++, General) to `..\..\..\` (this will resolve to ox/dev where the oxexport.h and other header files are). The additional include directories are also set to this path (Linker, General), except for the 64-bit version, which needs links in `..\..\..\lib64`. Finally, `oxwin.lib` is linked in (Linker/Input), and a .def file used to specify the exports: `../threes.def` (Linker, General).

The 32-bit version creates `threes.dll` in the `ox/dev/threes` folder, while the 64-bit version creates `threes_64.dll`

D2.1.2.2 Linux: gcc

Compiling the threes example works under Linux as well, but this time a make file is used: (`dev/samples/threes/lnx_gcc/threes.mak`). This is compiled by executing the command[1]

```
make
```

which creates threes.so. The header file `oxexport.h` and dependencies must be in the search path. Then run from the threes folder:

```
oxl threes
```

to see if it works. The dynamic linker must be able to find threes.so, as discussed in the Unix installation notes.[2] Unix platforms do not use name decoration of C functions.

The make file for the 64-bit version is in `dev/samples/threes/lnx_gcc_64`. To run the program, use OxEdit, or OxMetrics, or from the command line:

```
oxl64 threes
```

D2.1.2.3 OS X: gcc or clang

Under the hood, OS X is a type of Unix. Therefore, developers can use terminal windows and makefiles just as in Linux. There are a few differences:

[1] The `threes` folder is in `/usr/share/OxMetrics7/ox/dev/samples/` which requires root access; you may wish to copy this to your home folder.

[2] Try `oxl -v2 threes.ox` if it does not work. This will show which paths are tried.

- Instead of creating separate 32 and 64 bit binary files, it is possible to create so-called fat binaries (or universal binaries), which hold both the 32 and 64 bit versions. At load time, the appropiate version is used. The compiler command-line argument for this is

  ```
  -arch i386 -arch x86_64
  ```

  Note that the PowerPC architecture is no longer supported.
- It is necessary to install the compiler. Xcode is the interactive compiler, which can be obtained from the Apple Developer (it is actually downloaded from the Mac App store). We are using Xcode 4.5. Next, the command-line tools must be installed. Now `clang` (the default compiler) or `gcc` can be used in a terminal window.
  Open a terminal window and compile threes by executing the command

  ```
  make
  ```

in the appropriate threes folder.[3] This creates threes_osx.so. The header file `oxexport.h` and dependencies must be in the search path. Then load `threes.ox` in OxEdit, and run it to check if it worked.

D2.1.2.4 Windows: MinGW (gcc)

The threes example for the MinGW32 compiler (`www.mingw.com`) is provided in `ox/dev/samples/threes/win_gcc`. This uses the presupplied liboxwin.a file to link to the Ox DLL.

- Open a console window (Command prompt or MSYS) and locate the `threes/win_gcc` folder.
- Assuming that the paths are in your environment settings, type mingw32-make or make to compile the `Makefile` (delete the `.dll` and `.o` files first to enforce recompilation).
- `oxl threes.ox` to check the compiled DLL.
- `ox/dev/liboxwin.a` is the import library for the Ox DLL, created with dlltool using the `--export-all --kill-at` arguments, because in MinGW stdcall functions have no _ prefix but do use the @nn suffix. Note that `jdsystem.h` has a `__MINGW32__` section that defines `JDCALL` (and therefore `OXCALL`) to `__stdcall` and JDCALLC to `__cdecl`.

The makefile for the 64-bit Mingw compiler targeting 64-bit Windows is in `ox/dev/samples/threes/win_gcc_64`. The 64-bit version links to `ox/dev/liboxwin.a` and does not use name deoration. Note that `__MINGW32__` is also defined in Mingw64.

D2.1.2.5 Name decoration

Some Windows compilers may use different name decoration for exported functions. The `oxwin.dll` which contains the Ox runtime exports undecorated names, which works fine with Visual C++. However, sometimes `__stdcall` functions are prefixed with an underscore, and postfixed with the number of bytes required for the arguments. In that case the exports may need:

[3] The `threes` folder is in `/Applications/OxMetrics7/ox/dev/samples/` which requires root access; you may wish to copy this to your Users folder.

```
export FnThrees  = '_FnThrees@12'
```

Code targeting 64-bit Windows does not use this name decoration.

D2.2 Calling FORTRAN code from Ox

Linking Fortran code to Ox does not pose any new problems, apart from needing to know how function calls work in Fortran. Under Windows, this requires knowledge about the function call type and the name decorations. Under Linux or Unix this tends to be irrelevant. The simplest solution is to write C wrappers around the Fortran code, and use a Fortran and C compiler from the same vendor. (An alternative is to use F2C to translate the Fortran code to C.)

Arguments in Fortran functions are always by reference: change an argument in a function, and it will be changed outside the function. For this reason, well-written Fortran code copies arguments to local variables when the change need not be global.

Two examples are provided. The directory `ox/samples/fortran` contains a simple test function in Fortran, and a C wrapper which also provides a function which is called from Fortran. The example uses gcc fortran (one make file is in `fortran/win_gcc`, using MinGW's gfortran, the other is `fortran/lnx_gcc_64` for 64-bit Linux). but other compilers will also be feasible.

D2.3 Calling C/C++ code from Ox: returning values in arguments

Returning a value in an argument only adds a minor complication. Remember that by default all arguments in Ox and C are passed by value, and assignments to arguments will be lost after the function returns. To return values in arguments, pass a reference to a variable in the Ox call, so that the called function may change what the variable points to.

To refresh our memory, here is some simple Ox code:

```
#include <oxstd.h>

func1(a)
{   a = 1;
}
func2(const a)
{   a[0] = 1;
}
main()
{
    decl b;

    b = 0;  func1(b);   print(b);
    b = 0;  func2(&b);  print(b);
}
```

This will print `01`. In `func1` we cannot use the `const` qualifier because we are changing the argument. In `func2` the argument is not changed, only what it points to.

The first serious example is the `invert` function from the standard library, which also illustrates the use of a variable argument list. The code for this project is in `ox/dev/samples/invert`

ox/dev/samples/invert/invert.c

```
#include "oxexport.h"
#include "jdmath.h"

void OXCALL FnInvert(OxVALUE *rtn, OxVALUE *pv, int cArg)
{
    int  r, signdet = 0;  double logdet = 0;

    OxZero(rtn, 0);

    OxLibCheckSquareMatrix(pv, 0, 0);
    if (cArg == 2)           /* either 1 or 3 arguments */
        OxRunError(ER_ARGS, "invert");
    else if (cArg == 3)
        OxLibCheckType(OX_ARRAY, pv, 1, 2);

    r = OxMatr(pv, 0);
    OxLibValMatDup(rtn, OxMat(pv, 0), r, r);

    if (IInvDet(OxMat(rtn, 0), r, &logdet, &signdet) != 0)
    {
        OxRunMessage("invert(): inversion failed");
```

```
            OxFreeByValue(rtn);
            OxZero(rtn, 0);
        }
        if (cArg == 3)
        {
            OxSetDbl( OxArray(pv,1), 0, logdet);
            OxSetInt( OxArray(pv,2), 0, signdet);
        }
    }
```

- `OxLibCheckSquareMatrix(pv, 0, 0)` is the same as making a call to `OxLibCheckType(OX_MATRIX, pv, 0, 0)` followed by a check if the matrix is square.
- Using `invert` with two arguments is an error. When there are three arguments, the code checks if the second and third are of type `OX_ARRAY`.
- `OxMatr` gets the number of rows in the first argument (we already know that it is a matrix, with the same number of rows as columns).
- Next, we duplicate (allocate a matrix and copy) the matrix in the first argument to the return value using `OxLibValMatDup`. We shall overwrite this with the actual inverse.
- `IInvDet` is an internal mathematics function used by Ox to invert a non-singular matrix. This function is also exported as a C function by the Ox run-time dynamic-link library, which is why we can use it here (provided we add `#include "jdmath.h"`).
- If the matrix inversion fails, the matrix in `rtn` is freed, and `rtn` is changed back to an integer with value 0. It is important to free before setting the value to an integer: otherwise a memory leak occurs.
- Otherwise, but only if the second and third argument were provided, do we put the log-determinant (`logdet`) and sign in those argument. `OxArray(pv,1)` accesses the array at element 1 in `pv`. This is then used in the same way as `pv` was used to access the first entry in that array (index 0).

A more complex example is that for the square root free Choleski decomposition `decldl`, again from the standard library. The first argument is the symmetric matrix to decompose, the next two are arrays in which we expect the function to return the lower triangular matrix and vector with diagonal elements.

```
void OXCALL FnDecldl(OxVALUE *rtn, OxVALUE *pv, int cArg)
{
    int  i, j, r;  MATRIX md, ml;

    OxLibCheckSquareMatrix(pv, 0, 0);
    OxLibCheckType(OX_ARRAY, pv, 1, 2);
    OxLibCheckArrayMatrix(pv, 1, 2, OxMat(pv, 0));

    r = OxMatr(pv, 0);
    OxLibValMatDup(OxArray(pv, 1), OxMat(pv, 0), r, r);
    OxLibValMatMalloc(OxArray(pv, 2), 1, r);
    ml = OxMat( OxArray(pv, 1), 0);
    md = OxMat( OxArray(pv, 2), 0);
```

```
    if (!ml || !md)
        OxRunError(ER_OM, NULL);
    if (ml == md)
        OxRunError(ER_ARGSAME, NULL);

    if ( (OxInt(rtn, 0) = !ILDLdec(ml, md[0], r)) == 0)
        OxRunMessage("decldl(): decomposition failed");

                /* diagonal of ml is 1, upper is 0 */
    for (i = 0; i < r; i++)
    {   for (j = i + 1; j < r; j++)
            ml[i][j] = 0;
        ml[i][i] = 1;
    }
}
```

The new functions here are:

- `OxLibCheckArrayMatrix` which checks that the arrays do not point to the matrix to decompose, as in `decldl(msym, &msym, &md)`.
- `OxLibValMatMalloc` allocates space for a matrix.
- `OxRunError` generates a run-time error message. The statement `if (ml == md)` checks if the arrays do not point to the same variable. If so, we have allocated a matrix twice, but end up with the last matrix for both arguments. This prevents code of the form `decldl(msym, &md, &md)`.

D2.4 Calling Ox functions from C

This section deals with reverse communication: inside the C (or C++) code, we wish to call an Ox function. The example is a numerical differentiation routine written in C, used to differentiate a function defined in Ox code.

ox/dev/samples/callback/callback.c (part of)

```
#include "oxexport.h"

/* ... for FNum1Derivative() see callback.c ... */

static int myFunc(int cP, VECTOR vP, double *pdFunc,
    VECTOR vScore, MATRIX mHess, OxVALUE *pvOxFunc)
{
    OxVALUE rtn, arg, *prtn, *parg;

    prtn = &rtn;  parg = &arg;
    OxSetMatPtr(parg, 0, &vP, 1, cP);

    if (!FOxCallBack(pvOxFunc, prtn, parg, 1))
        return 1;
    OxLibCheckType(OX_DOUBLE, prtn, 0, 0);
    *pdFunc = OxDbl(prtn, 0);

return 0;
}

void OXCALL FnNumDer(OxVALUE *rtn, OxVALUE *pv, int cArg)
{
    int c;  OxVALUE *pvfunc;

    OxLibCheckType(OX_FUNCTION, pv, 0, 0);
    pvfunc = pv;                    /* function pointer */
    OxLibCheckType(OX_MATRIX, pv, 1, 1);

    c = OxMatc(pv, 1);
    OxLibCheckMatrixSize(pv, 1, 1, 1, c);
    OxLibValMatMalloc(rtn, 1, c);

    if (!FNum1Derivative(
        myFunc, c, OxMat(pv, 1)[0], OxMat(rtn, 0)[0], pvfunc))
    {
        OxFreeByValue(rtn);
        OxZero(rtn, 0);
    }
}
```

First we discuss FnNumDer which performs the actual numerical differentiation by calling FNum1Derivative:

- Argument 0 in pv must be a function, argument 1 a matrix, from which we only use the first row (expected to hold the parameter values at which to differentiate).[4]
- OxLibCheckMatrixSize checks whether the matrix is $1\times$c (since the c value is taken from that matrix, only the number of rows is checked).
- Finally, the C function FNum1Derivative is called to compute the numerical derivative of myFunc. When successful, it will leave the result in the first row of the matrix in rtn (for which we have already allocated the space).

The myFunc function is a wrapper which calls the Ox function:

- Space for the arguments and the return value is required. There is always only one return value: even multiple returns are returned as one array. Here we also have just one argument for the Ox function, resulting in the OxVALUE rtn and arg. We mainly work with pointers to OxVALUEs, stored here in prtn and parg for convenience. The argument is set to a $1\times$cP matrix. A VECTOR is defined as a double * and a MATRIX as a double **, so that the type of &vP is MATRIX, which is always the type used for a matrix in the OxVALUE.
- FOxCallBack calls the Ox function in the first argument. The next three arguments are the arguments to that Ox function: return type, function arguments, and number of arguments. FOxCallBack returns TRUE when successful, FALSE otherwise.
- After checking the returned value for type OX_DOUBLE, we can extract that double and return it in what pdFunc points to.

The following Ox code uses the pre-programmed Ox function for the numerical differentiation, and then the function just written in callback.c. The dRosenbrock function is the Ox code which is called from C. The difference between the two here is that the second expects and returns a row vector.

ox/dev/windows/callback/callback.ox

```
#include <oxstd.h>
#import <maximize>

extern "callback,FnNumDer" FnNumDer(const sFunc, vP);

fRosenbrock(const vP, const adFunc, const avScore,
    const amHessian)
{
    adFunc[0] = -100 * (vP[1] - vP[0] ^ 2) ^ 2
        - (1 - vP[0]) ^ 2;              // function value
return 1;                           // 1 indicates success
}
dRosenbrock(const vP)
{
    decl f = -100 * (vP[1] - vP[0] ^ 2) ^ 2
        - (1 - vP[0]) ^ 2;
    return f;                      // return function value
```

[4] The Ox 6 version of this example was storing the function argument in a static global variable s_pvOxFunc. This could then be directly used in myFunc, avoiding the final argument. The drawback is that this makes the function call non-reentrant: it is not safe to call it from multiple threads (i.e. in a parallel for loop).

```
}

main()
{
    decl vp = zeros(2, 1), vscore;

    //numerical differentiation using provided Ox function
    Num1Derivative(fRosenbrock, vp, &vscore);
    print(vscore);

    // now using provided C function from DLL
    vscore = FnNumDer(dRosenbrock, vp');// expects row vec
    print(vscore);
}
```

A mistake in the callback function is handled in the same way as other Ox errors. For example, when changing `vP[1]` to `vP[3]` in `dRosenbrock`:

```
Runtime error: '[3] in matrix[1][2]' index out of range
Runtime error occurred in dRosenbrock (16), call trace:
D:\OxMetrics7\ox\dev\samples\callback\callback.ox (16): dRosenbrock
Runtime error: in callback function
Runtime error occurred in main (29), call trace:
D:\OxMetrics7\ox\dev\samples\callback\callback.ox (29): main
```

The callback code presented here is reentrant: it can be safely called simultaneously from multiple threads. If that is not the case, the external call must be labelled as `serial` in the Ox `extern` statement:

```
extern serial "callback,FnNumDer" FnNumDer(const sFunc, vP);
```

D2.5 C macros and functions to access an OxVALUE; using arrays

An `OxVALUE` is a structure that holds all the information of a variable that is used in Ox code. The Ox run time manages the memory of each `OxVALUE`, and provides methods to create and manipulate these from your code. Internally, the `OxVALUE` is a rather complex `struct`. From C, there are two ways to manipulate an `OxVALUE`:

1. Macros to manipulate the `struct` explicitly, and
2. Functions that treat the `OxVALUE` more as an opaque memory object.

The C code presented sofar used quite a few macros, but it is perhaps preferable to use functions.[5]

Here is a comparison of the macro and function versions of some cases seen sofar:

Macro	Function
`r = OxInt(pv, 0);`	`OxValGetInt(pv, &r);`
`c = OxInt(pv, 1);`	`OxValGetInt(pv + 1, &c);`
`OxMat(rtn, 0)[i][j] = 3;`	`OxValGetMat(rtn)[i][j] = 3;`
`OxZero(rtn, 0);`	`OxValSetZero(rtn);`
`r = OxMatr(pv, 0);`	`r = OxValGetMatr(pv);`
`OxSetDbl(OxArray(pv,1),0,logdet);`	`OxValSetDouble(` `OxValGetArrayVal(pv,1), logdet);`

`OxSetMatPtr(parg, 0, &vP, 1, cP);`	`OxValSetZero(parg);`
	`OxValSetMat(parg, &vP, 1, cP);`
	needs `OxFreeByValue` afterwards

`*pdFunc = OxDbl(prtn, 0);`	`OxValGetDouble(prtn, pdFunc);`

Note that an allocated `OxVALUE` must be freed, unless it is passed back to Ox code. Also note that `OxValSetMat` frees the object first, which is why `OxValSetZero` is used to first initialize it to integer zero. This is a subtle difference with the macro versions that do not imply a call to `OxFreeByValue`.[6] More information is under `OxValSet`... in Chapter D4.

When using Java or C#, the macros cannot be used, and only the functions are available.

An Ox array is an array of `OxVALUE`s. `ox/dev/array` provides an example on how these can be accessed from C.

[5] Traditionally, macros are more efficient, although that need not be the case with modern compilers.

[6] An argument may hold it's own copy, or be a reference. `OxFreeByValue` can determine this, and will only free the memory if appropriate. When an `OxVALUE` is uninitialized, it holds 'random' bytes, which may erroneously indicate the need for freeing the object.

Chapter D3

Who is in charge?

D3.1 Introduction

An Ox program can have only one `main` function, which is where program execution starts. The same is true for C, C++, Java, etc. In the previous chapter, the foreign code was compiled into a DLL that was called from Ox. In that case Ox is in charge.

Alternatively, the foreign language can be the executable that is in charge. It remains possible to make calls to Ox, but specific functions are called:

1. Using low-level maths functions only
   In this case Ox is used as a mathematical and statistical library. This does not pose any new challenges, except for using the documentation in §D4.5. An example is provided in `ox/dev/oxlib`. We use this to illustrate how Ox can be used from Java and C#.
2. Calling Ox functions.
   Any Ox code can be launched and run.

D3.2 Using Ox as a mathematical and statistical library

D3.2.1 Using Ox as a library from C/C++

This simply amounts to calling any of the mathematical and statistical functions exported by the Ox DLL. An example is in `ox/dev/samples/oxlib/oxlib.c`.

D3.2.2 Using Ox as a library from Java

Two Java examples are provided. The first is a plain command-line application:

ox/dev/samples/oxlib/HelloOx.java

```
/* HelloWorld.java */

import com.sun.jna.Pointer;
import com.sun.jna.ptr.IntByReference;
import com.sun.jna.ptr.DoubleByReference;
```

```
import ox.*;

public class HelloOx {
    static public void main(String argv[]) {

        double d = Ox.c_abs(0.5, 0.5);
        System.out.println ("Hello from Ox = " + d);

        DoubleByReference zr = new DoubleByReference();
        DoubleByReference zi = new DoubleByReference();

        Ox.c_div(0.5, 0.5, 0.5, 0.5, zr, zi);
        System.out.println(
        "Hello from Ox = re=" + zr.getValue() + " im=" + zi.getValue());

        double[] vx = {1, 0, 2, 3};
        System.out.println(vx[0] + vx[1] + vx[2] + vx[3]);
        double dsum = Ox.DVecsum(vx, 4);
        System.out.println("DVecsum: " + dsum);

        DoubleByReference logdet = new DoubleByReference();
        IntByReference sign = new IntByReference();

        Pointer pmat = Ox.MatAllocBlock(2, 2);
        Ox.MatCopyVecr(pmat, vx, 2, 2);
        Ox.IInvDet(pmat, 2, logdet, sign);
        Ox.VecrCopyMat(vx, pmat, 2, 2);
        Ox.MatFreeBlock(pmat);
        System.out.println("m[0][]: " + vx[0] + " " + vx[1]);
        System.out.println("m[1][]: " + vx[2] + " " + vx[3]);
        System.out.println("logdet= " + logdet.getValue());
        System.out.println("sign= " + sign.getValue());
    }
}
```

- If not yet done so, the JDK must be installed to enable `javac`.
  Java Native Access (JNA) is used for simplified calling to native code in the Ox DLL. JNA must be downloaded (`jna.jar` and `platform.jar`).
  The `dev/Ox.java` file defines the Ox class that imports the Ox functionality.
- We've created a subfolder for the Ox interface: `oxlib/java/ox`, where a copy of `dev/Ox.java` is put. `Ox.java` defines the exported functions and constant values. This is then compiled in a Console (or Terminal) window from the `oxlib/java` folder:

  ```
  javac -classpath /usr/share/java/jna.jar ox/Ox.java
  ```

  The correct path to `jna.jar` has to be specified (under Linux I have it in /usr/share/java/). This creates `oxlib/java/ox/Ox.class`.
- To compile HelloOx:

  ```
  javac -classpath /usr/share/java/jna.jar:. HelloOx.java
  ```

  Use a semicolon instead of a colon for the path separator under Windows.
  And to run HelloOx:[1]

[1] To run, the Ox DLL must be in the search path. Under Linux, the Ox environment must

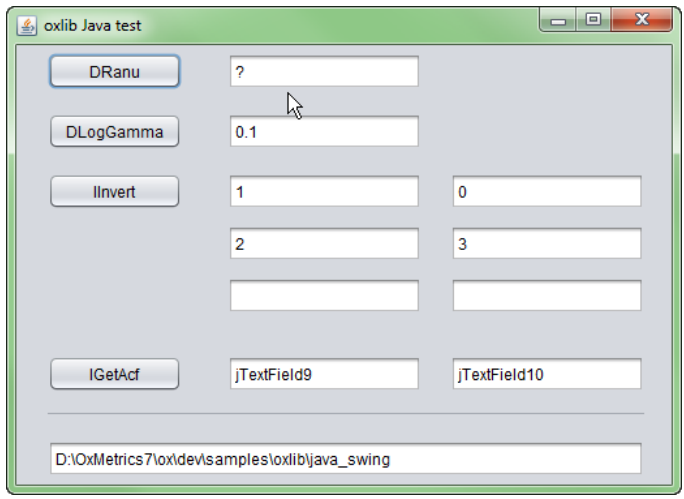
```
java -classpath /usr/share/java/jna.jar:. HelloOx
```

- `DoubleByReference` is used to pass a pointer to a double to the `c_div` call.
- A `double[]` is used when the Ox function expects a `VECTOR`.
- The matrix is created inside the Ox run time (and freed there), and stored in a `Pointer` object. The matrix cannot be accessed directly. Instead, it is vectorized into a `double[]` that can be referenced.

The following table lists the types that may be encountered in the Ox foreign language interface:

C/Ox type	Java equivalent
`int`	`int`
`int *`	`IntByReference`
`BOOL`	`int`
`double`	`double`
`double *`	`DoubleByReference`
`char *`	`String`
`VECTOR`	`double[]`
`MATRIX`	`Pointer` (see example)
`OxVALUE *`	`Pointer`

The second example is a version developed using the NetBeans IDE, see `dev/samples/oxlib/java_swing`, which puts a dialog in front of the oxlib code:



also be found: OX7PATH="/usr/share/OxMetrics7/ox/include:/usr/share/OxMetrics7"; export OX7PATH

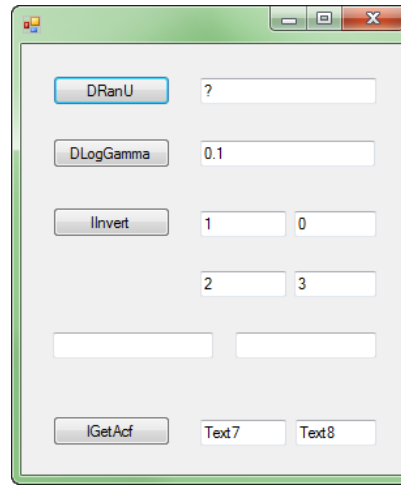
D3.2.3 Using Ox as a library from C#

ox/dev/samples/oxlib/win_cs2008/OxTest/Form1.cs

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Windows.Forms;

namespace OxTest
{
    public partial class Form1 : Form
    {
        public Form1()
        {
            InitializeComponent();
        }
        private void Command1_Click(object sender, EventArgs e)
        {
            double d1 = 0.5;
            // Call RanSetRan at least once to initialize rng environment
            Ox.RanSetRan("Default");
            d1 = Ox.DRanU();
            Text1.Text = Convert.ToString(d1);
        }
        private void Command2_Click(object sender, EventArgs e)
        {
            double d1 = Convert.ToDouble(Text2.Text);
            try
            {
                d1 = Ox.DLogGamma(d1);
                Text2.Text = Convert.ToString(d1);
            }
            catch (BadImageFormatException exception)
            {
                Text2.Text = "failed";
            }
        }
        private void Command3_Click(object sender, EventArgs e)
        {
            double[] mat = new double[4];
            IntPtr pmat = default(IntPtr);
            int result = 0;
            Int32 sign = 0;
            double logdet = 0.0;

            mat[0] = Convert.ToDouble(Text3.Text);
            mat[1] = Convert.ToDouble(Text4.Text);
            mat[2] = Convert.ToDouble(Text5.Text);
            mat[3] = Convert.ToDouble(Text6.Text);

            pmat = Ox.MatAllocBlock(2, 2);
            Ox.MatCopyVecr(pmat, mat, 2, 2);
```

```
            Ox.SetNaN(ref logdet);
            result = Ox.IInvDet(pmat, 2, ref logdet, ref sign);
            Ox.VecrCopyMat(mat, pmat, 2, 2);
            Ox.MatFreeBlock(pmat);

            Text3.Text = Convert.ToString(mat[0]);
            Text4.Text = Convert.ToString(mat[1]);
            Text5.Text = Convert.ToString(mat[2]);
            Text6.Text = Convert.ToString(mat[3]);

            textBox1.Text = "logdet=" + Convert.ToString(logdet);
            textBox2.Text = "sign det=" + Convert.ToString(sign);
        }
        private void Command4_Click(object sender, EventArgs e)
        {
            double[] Vec = new double[6];
            double[] VecAcf = new double[6];
            int result = 0;

            Vec[0] = 1;  Vec[1] = 2;  Vec[2] = 3;
            Vec[3] = 0;  Vec[4] = 1;  Vec[5] = 4;

            result = Ox.IGetAcf(Vec, 6, 2, VecAcf, 0);

            Text7.Text = Convert.ToString(VecAcf[0]);
            Text8.Text = Convert.ToString(VecAcf[1]);
        }
    }
}
```

- C# has Platform Invocation Services (PInvoke) to allow managed code to call unmanaged functions that are implemented in the Ox DLL. The `dev/Ox.cs` file defines the Ox class that imports the Ox functionality.
- Load the `OxTest.sln` solution file in Visual Studio 2008 (or convert to a newer version), to learn more about the program.
- The Ox functionality is accessed from a dialog:



Pressing a button will result in a call to the Ox DLL.

- `ref logdet` is used to pass a pointer to a double (`logdet` in this case) to the `Ox.IInvDet` call.
- A `double[]` is used when the Ox function expects a `VECTOR`.
- The matrix is created inside the Ox run time (and freed there), and stored in a `IntPtr` object. The matrix cannot be accessed directly. Instead, it is vectorized into a `double[]` that can be referenced in C#.

The following table lists the types that may be encountered in the Ox foreign language interface:

C/Ox type	C# equivalent	
`int`	`int`	
`int *`	`int`	call with `ref`
`BOOL`	`int`	
`double`	`double`	
`double *`	`double`	call with `ref`
`char *`	`string`	
`VECTOR`	`double[]`	
`MATRIX`	`IntPtr` (see example)	
`OxVALUE *`	`IntPtr`	

D3.2.4 Using Ox as a library from VB 9

Visual Basic 2008 (VB 9.0) differs substantially from Visual Basic 6. Most notably, integers are now 32 bits and array referencing starts at zero (as in C/C++/Java/C#/Ox).

An Ox class is provided in dev/Ox.vb. This was actually converted from the C# version using an online tool.[2]

[2] www.developerfusion.com/tools/convert/csharp-to-vb

D3.3 Creating and using Ox objects

It is more common that the foreign language in charge wishes to call Ox code, rather than the underlying matrix and statistical library. That means that the foreign language needs to

1. Start the Ox run-time engine, load and compile Ox code
   Use `OxMain` or `OxMainCmd`. The former expects an array of strings, in the same was as the C main function. The latter takes a string as an argument, ans is more convenient from Java or C#. The `-r` switch is used to compile but not (yet) run the code.
2. Make function calls, or create an object of a class and call its methods
   An object is created with `FOxCreateObject`. Function members of that object are called with `FOxCallBackMember`.
   Alternatively, a function can be called with `FOxCallBack`, after creating an OxVALUE with the name of the function as a string.
3. Shut down the Ox run-time engine when done.
   `OxRunExit` followed by `OxMainExit`.

Three examples of this process are provided: C, Java and C#. We focus on the Java version below. All versions use the following Ox code:

ox/dev/samples/object/class_test.ox

```
#include <oxstd.h>

class Test
{
    Test();
    ReturnDbl();
    ReturnMat();
    Func1(const a);
    Print();
    ~Test();

    decl m_mX;
};

Test::Test()
{
    println("Test object constructed");
    m_mX = 0;
}
Test::~Test()
{
    println("Test object destructed");
}
Test::ReturnDbl()
{
    return 5.3;
}
Test::ReturnMat()
{
    return <1.5, 3.5, 4.5; 7, 8, 9>;
}
```

```
Test::Func1(const a)
{
    println("Argument 1=", a);
    return "done";
}
Test::Print()
{
    println("m_mX=", m_mX);
}
```

D3.3.1 Creating and using Ox objects from Java

ox/dev/samples/object/javaCallObject.java

```
import com.sun.jna.Pointer;
import com.sun.jna.ptr.IntByReference;
import com.sun.jna.ptr.DoubleByReference;

import ox.*;

public class CallObject {

    static public void main(String argv[]) {

        if (Ox.OxMainCmd("-r- ../class_test") <= 1)
        {
            System.out.println("Java: Failed to start Ox program");
            return;
        }
        else
            System.out.println("Java: Ox program successfully started");

        Pointer oxval = Ox.OxStoreCreate(1);
        Pointer rtnval = Ox.OxStoreCreate(1);
        Pointer clval = Ox.OxStoreCreate(1);

        /* create an Ox object */
        if (Ox.FOxCreateObject("Test", clval, Pointer.NULL, 0) != 1)
        {
            System.out.println("Java:Failed to create object\n");
            return;
        }
        System.out.println("Java: Created an object of class Test\n");

        if (Ox.FOxCallBackMember(clval, "Print", rtnval, Pointer.NULL, 0) != 1)
        {
            System.out.println("Java: Failed to call Test::Print");
            return;
        }

        int i, j, k, r, c;

        Ox.FOxCallBackMember(clval, "ReturnMat", rtnval, Pointer.NULL, 0);
        if (Ox.OxValHasType(rtnval, Ox.OxTypes.OX_MATRIX.getValue()) != 0)
        {
```

```
            r = Ox.OxValGetMatr(rtnval);
            c = Ox.OxValGetMatc(rtnval);
            System.out.println(
                "Java: Return value is a " + r + " x " + c + " matrix:");

            double[] vx = new double[r * c];
            Ox.OxValGetVecr(rtnval, vx);
            for (i = k = 0; i < r; ++i)
            {
                System.out.print("Java: ");
                for (j = 0; j < c; ++j, ++k)
                    System.out.print(" " + vx[k]);
                System.out.println("");
            }
        }
        else
            System.out.println("Java: Return value is not a matrix");

        /* change the value of the m_mX member variable to a matrix */
        Ox.OxValSetMatZero(oxval, 3, 3);
        Ox.FOxSetDataMember(clval, "m_mX", oxval);
        Ox.FOxCallBackMember(clval, "Print", rtnval, Pointer.NULL, 0);

        Ox.OxStoreDelete(oxval, 1);
        Ox.OxStoreDelete(rtnval, 1);
        Ox.OxStoreDelete(clval, 1);

        Ox.OxRunExit();
        Ox.OxMainExit();
    }
}
```

- `Ox.OxMainCmd` specifies that Ox file that should be loaded and compiled (this could also be a `.oxo` file[3]).
- `OxVALUE` objects are created and managed in the Ox run-time by using `OxStoreCreate`. These are initialized to integers with value zero.
- Next, an object of class `Test` is created and stored in `clval`. `FOxCreateObject` also calls the constructor, which takes no arguments. This is followed by a call to `Print`, which again takes no argument.
- Then we call `Test::ReturnMat` from the object, which takes no arguments, but returns a matrix in `rtnval`. The returned matrix is converted to a vector `vx`, which can be handled inside the Java code.
- Next, a matrix of zeros is created in the `oxval` variable using `OxValSetMatZero`. The `m_mX` data member of the object is set to this matrix using `FOxSetDataMember`.
- Finally, the created `OxVALUE`s are removed with `OxStoreDelete` (executing the call to the destructor as well), and the Ox run time is closed down.

[3] Ox Professional has a command -line switch to link in all dependencies: `-cl`

This is the output under Windows:

```
Ox Professional version 7.00 (Windows/U/MT) (C) J.A. Doornik, 1994-2012
Java: Ox program successfully started
Test object constructed
Java: Created an object of class Test

m_mX=0
Java: Return value is a 2 x 3 matrix:
Java:  1.5 3.5 4.5
Java:  7.0 8.0 9.0
Java: test=3
m_mX=
      0.00000      0.00000      0.00000
      0.00000      0.00000      0.00000
      0.00000      0.00000      0.00000
Test object destructed
```

D3.4 Adding a user-friendly interface

Ox is limited in terms of user interaction, only providing console style input using the `scan` function. It is possible, however, to use much more powerful external tools to add dialogs and menus. In that way, a much better interface could be written than ever possible directly in Ox. Indeed, there are no plans to make generic interface components an intrinsic part of Ox: this would always lag behind the latest developments.

Various approaches could be considered to add a user interface:

(1) Write a separate interactive program which creates an input file.
This input file is read by an Ox program that is run separately.

(2) Write a separate interactive program which generates an Ox source file.
This is similar to (1), but now a whole Ox program is written, rather than the input configuration.
This approach is taken by PcNaive: it collects user input on Monte Carlo design, generates an Ox program from this, and calls `OxRun` to run the generated code. It can also retrieve settings from previously generated source code, to produce a sophisticated interactive package.

(3) Use OxPack to add an interactive front-end, using OxMetrics for output. The program can then be started from OxMetrics using OxPack.
This is what PcNaive uses, and discussed in Chapter D5.

(4) Write a DLL which exports dialogs to be used in Ox source code.
This approach is used by TSM (see `www.timeseriesmodelling.com`, created by James Davidson), using the OxJapi package (a wrapper around the AWT GUI toolkit of Java, available from `personal.vu.nl/c.s.bos/software.html`).

(5) Call Ox source code from an interactive Java, C# or C++ program.
In this case an Ox object can be created in the foreign language, and function members called, see §D3.3.

(6) Call Ox source code from an interactive Java, C# or C++ program, with output (text and graphs) appearing in OxMetrics.

The example in the next section uses method (6). An application called RanApp is developed. This offers a set of actions and a dialog to change settings. Each action results in an Ox function being called. RanApp contains the 'main' function: it launches and controls the Ox run-time system; in method (4) that would be the other way round.

D3.4.1 Using Java and the NetBeans IDE

The Java RanApp application was developed using NetBeans. It needs `Ox.java` for the link to the Ox DLL, and `OxMetrics.java` for the link to the OxMetrics7 DLL. The full example is in `ox/samples/ranapp/ranapp_java`.

The code illustrates several principles:

- Providing a bridge between Ox and OxMetrics, to send all the Ox output to OxMetrics.
  It is vital that this all runs in the same thread.

  Here is the Java equivalent of `ox/dev/ox_oxmetrics_bridge.cpp`:

  ..... *ox/dev/windows/ranapp/ranapp_java/RanApp.java (part of)*

```
public static void OxOxMetricsSetHandlers(Boolean bRestart) {
  if (bRestart)
  {
    OxMetrics.OxOxMetricsRestart();
    Ox.OxMainExit();
  }
  Ox.OxMainInit();// call first, then replace io and drawing functions

  if (OxMetrics.OxOxMetricsUsingStdHandles() == 0)
  {
    Ox.SetOxPipe(0);
    Ox.SetOxMessage(OxMetrics.OxMetricsGetOxHandlerA("OxMessage"));
    Ox.SetOxRunMessage(OxMetrics.OxMetricsGetOxHandlerA("OxRunMessage"));
    Ox.SetOxPuts(OxMetrics.OxMetricsGetOxHandlerA("OxPuts"));
    Ox.SetOxTextWindow(OxMetrics.OxMetricsGetOxHandlerA("OxTextWindow"));
  }
  Ox.SetOxDrawWindow(OxMetrics.OxMetricsGetOxHandlerA("OxDrawWindow"));
  Ox.SetOxDraw(OxMetrics.OxMetricsGetOxHandlerA("OxDraw"));

  Ox.FOxLibAddFunctionEx("GetRanAppSettings", FnGetRanAppSettings, 3,
        Ox.OxTypes.OX_SERIAL.getValue());
}
```

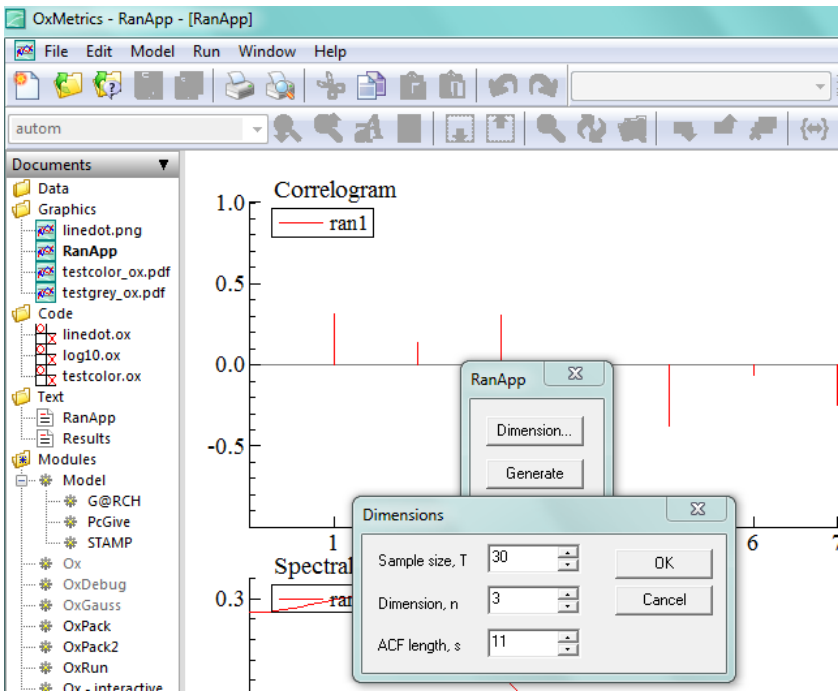
  The one difference is that this function also installs the `GetRanAppSettings` function using `FOxLibAddFunctionEx`.
- Switching between different Ox codes, one based on function, the other on creating an object of a class. Switching to the latter will make the dialog yellow.
- Adding a Java function that can be called from Ox using JNA's CallBack interface.
- Replacing the OxExit function through a Callback.

D3.4.2 Using Visual C++ and MFC

The knowledge from the previous sections already suffices to write an interface using `FOxCallBack`. There is, however, a second form of simplified callbacks which calls a function by its text name. This method does not allow for arguments, and bypasses the `main` function. The RanApp example in this section uses the simplified method, and adds additional functions to be called from Ox to get dialog driven input.

The full example is in `ox/samples/ranapp/ranapp_win_mfc`. The code uses Microsoft Foundation Class (MFC) and Microsoft Visual C++, and is therefore Windows specific Similar code could be written using other compilers and application frameworks. Here we shall only treat Ox specific sections of the code.

The RanApp application requires a correctly installed copy of *OxMetrics*. RanApp reports all text and graphics output in *OxMetrics*, achieved by adding just one function call (this requires linking with `oxmetrics7.lib`). The next capture shows RanApp on top of its graphical output, with the Dimensions dialog active.



. . . . . *ox/dev/windows/ranapp/ranapp_win_mfc/RanApp.cpp (part of)*

```
#include "stdafx.h"
#include "RanApp.h"
#include "RanAppDlg.h"
#include "RanDimDlg.h"

#include "oxexport.h"
#include "ox_oxmetrics.h"
#include "ox_oxmetrics_bridge.h"
```

```
int g_iMainIP;


// ... FnGetRanAppSettings listed below ...
// replaces standard Ox exit function
// ... part deleted ...

extern "C" void OXCALL OxRunOxExit(int i)
{
    AfxMessageBox( "Ox run-time error" );
    AfxThrowUserException( );
}

static int iDoOxRun(LPCTSTR sExePath)
{
    CString soxfile = "-r- \"";
    soxfile += sExePath;
    soxfile += "\"";
    soxfile.Replace("_64", "");     // strip _64 from 64-bit exe name
    soxfile.Replace(".exe", ".ox");

    g_iMainIP = 0;

    // Must startup OxMetrics and install linking functions
    if (!FOxOxMetricsStartA("RanApp", "RanApp", FALSE))
        return 0;         // fail if cannot start OxMetrics

    OxOxMetricsSetHandlers(FALSE);

    SetOxExit(OxRunOxExit);      // replace exit function
    FOxLibAddFunction("ccc$GetRanAppSettings",
        FnGetRanAppSettings, 0);  // install new function

    g_iMainIP = OxMainCmd(soxfile);//"-r- path\ranapp.ox"

    if (g_iMainIP <= 1)
    {
        AfxMessageBox( "Ox compilation error" );
    }

return g_iMainIP;
}
```

- `iDoOxRun` simulates a call to Ox with command line arguments comparable to running Ox from the command line.
- `FOxOxMetricsStart` starts *OxMetrics* for client-server communication. When successful, Ox calls to `print` and graphics functions will appear in *OxMetrics*. `FOxOxMetricsStart` resides in `oxmetrics7.dll` (for OxMetrics 7).
- `OxOxMetricsSetHandlers` resides in `ox/dev/ox_oxmetrics_bridge.cpp`, which is part of the project.
- Next, we set up the command line. The first argument is always the name of the program, so is not really important. The second argument, argument 1, is the name

of the Ox code to compile; that code is in `ranapp.ox`, and here the full path name is obtained from the `sExePath` string. The third argument prevents the Ox program from running, restricting to a compile and link only.

- `SetOxExit` replaces the default OxExit function with a new version.
- `FOxLibAddFunction` adds `FnGetRanAppSettings` as a function which can be called from the Ox code as `GetRanAppSettings`. The `ccc` before the dollar symbol defines it as having three constant arguments. The implementation is listed below.
- `OxMain` compiles the code and returns a value > 1 when successful. That value is stored in `iMainIP` and used in subsequent calls to specific Ox functions.
- RanApp can only be run if `oxwin.dll` and `oxmetrics7.dll` are in the search path for the executable.
- When RanApp is run, and `ranapp.ox` compiled successfully, the Generate button lights up. Then, when Generate is pressed, the `OnGenerate` function from `ranapp.ox` (given below) is called, and the Draw and Variance buttons become active. These buttons also lead to a call to underlying Ox code. The C++ calls are:

ox/dev/windows/ranapp/RanAppDlg.c (part of)
```
static BOOL callOxFunction(char *sFunction)
{
    BOOL ret_val = FALSE;
    TRY
    {
        FOxRun(g_iMainIP, sFunction);
        ret_val = TRUE;
    }
    CATCH_ALL(e)
    {
    }
    END_CATCH_ALL

return ret_val;
}
void CRanAppDlg::OnDimension()
{
    callOxFunction("OnDimension");
}
void CRanAppDlg::OnGenerate()
{
    m_variance.EnableWindow();
    m_draw.EnableWindow();

    callOxFunction("OnGenerate");
}
void CRanAppDlg::OnDraw()
{
    callOxFunction("OnDraw");
}
void CRanAppDlg::OnVariance()
{
    callOxFunction("OnVariance");
}
```

Below is a listing of `ranapp.ox`, the program behind this application. It is a simple Ox program which draws random numbers in `OnGenerate`, prints their variance matrix in `OnVariance`, and draws the correlogram and spectrum in `OnDraw`.

ox/dev/windows/ranapp/RanApp.ox
```
#include <oxstd.h>
#include <oxdraw.h>

GetRanAppSettings(const acT, const acN, const acAcf);

static decl s_mX;
static decl s_cT = 30;
static decl s_cN = 2;
static decl s_cAcf = 4;

OnDimension()
{
    if (GetRanAppSettings(&s_cT, &s_cN, &s_cAcf))
```

```
        println("T = ", s_cT, " n = ", s_cN,
            " lag length = ", s_cAcf);
}
OnGenerate()
{
    s_mX = rann(s_cT, s_cN);
}
OnVariance()
{
    print( variance(s_mX) );
}
OnDraw()
{
    DrawCorrelogram(0, s_mX[][0]', "ran1", s_cAcf);
    DrawSpectrum(1, s_mX[][0]', "ran1", s_cAcf);
    ShowDrawWindow();
}
```

- Eventough `GetRanAppSettings()` is defined, it still has to be declared.
- `OnDimension()` calls `GetRanAppSettings()` to get new values, printing the new settings if successful. The arguments are passed as references so that they may be changed. The C++ code is:

```
extern "C" void OXCALL FnGetRanAppSettings(
    OxVALUE *rtn, OxVALUE *pv, int cArg)
{
    CRanDimDlg dlg;

    OxLibCheckType(OX_ARRAY, pv, 0, 2);
    OxLibCheckType(OX_INT, OxArray(pv, 0), 0, 0);
    OxLibCheckType(OX_INT, OxArray(pv, 1), 0, 0);
    OxLibCheckType(OX_INT, OxArray(pv, 2), 0, 0);

                // initialize dialog with current settings
    dlg.m_cT = OxInt(OxArray(pv, 0), 0);
    dlg.m_cDim = OxInt(OxArray(pv, 1), 0);
    dlg.m_cAcf = OxInt(OxArray(pv, 2), 0);

    if (dlg.DoModal() == IDOK)
    {
         OxInt(OxArray(pv, 0), 0) = dlg.m_cT;
         OxInt(OxArray(pv, 1), 0) = dlg.m_cDim;
         OxInt(OxArray(pv, 2), 0) = dlg.m_cAcf;
         OxInt(rtn, 0) = 1;      // return 1 if successful
    }
    else
        OxInt(rtn, 0) = 0;
}
```

- The three arguments are checked for type array, then the first in each array is checked for type integer.
- `OxArray(pv, 0)` access the first element in pv as an array, `OxInt(., 0)` the integer in the first element of the array.

- If the user presses OK in the dialog, the new values are set in the arguments, and the return value is changed to one.

Chapter D4

Ox Exported Functions

D4.1 Introduction

This chapter documents the *Ox* related functions which are exported from the Ox DLL. The low level mathematical and statistical functions are listed in §D4.5. The OxMetrics specific functions are documented in §D4.4.

§D4.1 lists the *Ox* related functions. All these functions section require `oxexport.h`.

Functions which interface with Ox use the `OXCALL` specifier. This, in turn, is just a relabelling of `JDCALL`, defined in `ox/dev/jdsystem.h`. Currently, this declares the calling convention for the Microsoft, MinGW, Borland and Watcom compilers on the Intel platform. For other compilers on this platform, and on other platforms, it defaults to nothing. So, to add support for a new compiler, you could:

1. leave `jdsystem.h` unchanged, and set the right compiler options when compiling (this is the preferred approach);
2. add support for the new compiler in `jdsystem.h`.

Ox extension function syntax

```
void OXCALL FnFunction(OxVALUE *rtn, OxVALUE *pv, int cArg);
```

`rtn`	in:	pointer to an `OxVALUE` of type `OX_INT` and value 0
	out:	receives the return value of pvFunc
`pv`	in:	the arguments of the function call; *they must be checked for type before being accessed.*
	out:	unchanged, apart from possible conversion from `OX_INT` to `OX_DOUBLE` or vice versa
`cArg`	in:	number of elements in `pv`; unless the function has a variable number of arguments, there is no need to reference this value.

No return value.

Description

This is the syntax required to make a function callable from Ox. `FnFunction` should be replaced by an appropriate name, but is not the name under which the function is known inside an Ox program.

The standard types for Ox variables are:

Ox types	description
OX_INT	integer
OX_DOUBLE	double
OX_MATRIX	matrix
OX_STRING	string
OX_ARRAY	array
OX_FUNCTION	function
OX_CLASS	class object
OX_INTFUNC	internal function
OX_FILE	open file

D4.2 Ox function summary

FOxCallBack, FOxCallBackMember

```
BOOL FOxCallBack(OxVALUE *pvFunc, OxVALUE *rtn, OxVALUE *pv,
    int cArg);
BOOL FOxCallBackMember(OxVALUE *pvClass, const char *sMember,
    OxVALUE *rtn, OxVALUE *pv, int cArg);
```

pvFunc	in:	the function to call, must be of type OX_FUNCTION, OX_INTFUNC, or OX_STRING
pvClass	in:	the object from which to call a member, must be of type OX_CLASS
sMember	in:	name of the member function
rtn	out:	receives the return value of the function call
pv	in:	the arguments of pvFunc
cArg	in:	number of elements in pv

Return value

TRUE if the function is called successfully, FALSE otherwise.

Description

Calls an Ox function from C.

If the returned value rtn is not passed back to Ox, call OxFreeByValue(rtn) to free it.

FOxCreateObject

```
BOOL FOxCreateObject(const char *sClass, OxVALUE *rtn,
    OxVALUE *pv, int cArg);
```

sClass	in:	name of class
rtn	in:	pointer to Ox_VALUE
	out:	receives the created object
pv	in:	the arguments for the constructor
cArg	in:	number of elements in pv
pvClass	in:	the object from which to delete, previously created with FOxCreateObject

Return value

Returns TRUE if the function is called successfully, FALSE otherwise.

Description

FOxCreateObject creates an object of the named class which can be used from C; the constructor will be called by this function. Use OxDeleteObject to delete the object.

FOxGetDataMember

```
BOOL FOxGetDataMember(OxVALUE *pvClass, const char *sMember,
    OxVALUE *rtn);
```

pvClass	in:	the object from which to get a data member, must be of type OX_CLASS
sMember	in:	name of the data member
rtn	out:	receives the return value of the function call

Return value

TRUE if the function is called successfully, FALSE otherwise.

Description

Gets a data member from an object. The returned value is for reference only, and should not be changed, and should only be used for temporary reference.

FOxLibAddFunction

```
BOOL FOxLibAddFunction(char *sFunc, OxFUNCP pFunc, BOOL fVarArg);
```

sFunc	in:	string describing function
pFunc	in:	pointer to C function to install
fVarArg	in:	TRUE: has variable argument list

Return value

TRUE if function installed successfully, FALSE otherwise.

Description

OxFUNCP is a pointer to a function declared as:

```
void OXCALL Func(OxVALUE *rtn, OxVALUE *pv, int cArg);
```

The syntax of sFunc is:

arg_types$*function_name*\0

arg_types is a c (indicating a const argument) or a space, with one entry for each declared argument.

This function links in C library functions statically, e.g. for part of the drawing library:

```
FOxLibAddFunction("cccc$Draw",          fnDraw,        0);
FOxLibAddFunction("ccccc$DrawT",        fnDrawT,       0);
FOxLibAddFunction("ccc$DrawX",          fnDrawX,       0);
FOxLibAddFunction("ccccc$DrawMatrix",   fnDrawMatrix,  1);
FOxLibAddFunction("cccccc$DrawTMatrix", fnDrawTMatrix, 1);
FOxLibAddFunction("ccccc$DrawXMatrix",  fnDrawXMatrix, 1);
```

This function is not required when using the extern specifier for external linking, as used in most examples in this chapter.

FOxLibAddFunctionEx

```
BOOL  FOxLibAddFunctionEx(char *sFunc, OxFUNCP pFunc, int cArgs,
    int flFlags);
```

sFunc	in:	name of the function
pFunc	in:	pointer to C function to install
cArg	in:	number of required arguments
flFlags	in:	0, or a combination of: OX_VARARGS (variable no of arguments) OX_SERIAL (cannot be called in parallel)

Return value

TRUE if function installed successfully, FALSE otherwise.

Description

OxFUNCP is a pointer to a function declared as:

```
void OXCALL Func(OxVALUE *rtn, OxVALUE *pv, int cArg);
```

This function links in C library functions statically, e.g.:

```
FOxLibAddFunctionEx("fprint", fnFprint, 2, OX_VARARGS | OX_SERIAL);
```

This function is not required when using the extern specifier for external linking, as used in most examples in this chapter.

FOxRun

```
BOOL FOxRun(int iMainIP, char *sFunc);
```

iMainIP	in:	return value from OxMain
sFunc	in:	name in Ox code of function to call

Return value

TRUE if the function is run successfully, FALSE otherwise.

Description

Calls a function by name, bypassing main().

FOxSetDataMember

```
BOOL FOxSetDataMember(OxVALUE *pvClass, const char *sMember,
    OxVALUE *pv);
```

pvClass	in:	the object in which to set a data member, must be of type OX_CLASS
sMember	in:	name of the data member
pv	in:	new value of the data member

Return value

TRUE if the function is called successfully, FALSE otherwise.

Description

Sets a data member from an object. The assigned value is taken over (if it is by value, it is transferred, and pv will have lost its by value property (OX_VALUE).

IOxRunInit

```
int  IOxRunInit(void);
```

Return value

Zero for success, or the number of link errors.

Description

Links the compiled code and initializes to prepare for running the code.

IOxVersion IOxVersionIsProfessional IOxVersionOxo

```
int  IOxVersion(void);
int  IOxVersionOxo(void);
int  IOxVersionIsProfessional(void);
```

Return value

`IOxVersion` returns 100 times the Ox version number, so `100` for version 1.00.
`IOxVersionOxo` returns 100 times the version number of compiled Ox code (.oxo files), so `100` for version 1.00. Note that this changes less often than the version of Ox.
`IOxVersionIsProfessional` ruturns 1 for Ox Professional, 0 for Ox Console.

OxCloneObject

```
void OxCloneObject(OxVALUE *rtn, OxVALUE *pvObject, BOOL bDeep);
```

`rtn`	out:	cloned object
`pvObject`	out:	object to duplicate
`bDeep`	out:	TRUE (deep copy) or FALSE (shallow copy)

No return value.

Description

`OxCloneObject` clones the object by taking a duplicate. Use `OxDeleteObject` to delete a cloned object.

OxDeleteObject

```
void OxDeleteObject(OxVALUE *pvClass);
```

`sClass`	in:	name of class

No return value.

Description

`OxDeleteObject` deletes the object; this calls the destructor, and deallocates all memory owned by the object. Use `FOxCreateObject` to create an object.

OxFnDouble, OxFnDouble2, OxFnDouble3, OxFnDouble4, OxFnDoubleInt

```
void OxFnDouble(OxVALUE *rtn, OxVALUE *pv,
    double (OXCALL * fn1)(double) );
void OxFnDouble2(OxVALUE *rtn, OxVALUE *pv,
    double (OXCALL * fn2)(double,double) );
void OxFnDouble3(OxVALUE *rtn, OxVALUE *pv,
    double (OXCALL * fn3)(double,double,double) );
void OxFnDouble4(OxVALUE *rtn, OxVALUE *pv,
    double (OXCALL * fn4)(double,double,double,double) );
void OXCALL OxFnDoubleInt(OxVALUE *rtn, OxVALUE *pv,
    double (OXCALL * fndi)(double,int) )
```

rtn	out:	return value of function
pv	in:	arguments for function fn
fn1	in:	function of one double, returning a double
fn2	in:	function of two doubles, returning a double
fn3	in:	function of three doubles, returning a double
fn4	in:	function of four doubles, returning a double
fndi	in:	function of a double and an int, returning a double

No return value.

Description

These functions are to simplify calling C functions, as for example in:

```
static void OXCALL
    fnProbgamma(OxVALUE *rtn, OxVALUE *pv, int cArg)
    {   OxFnDouble3(rtn, pv, DProbGamma);
    }
static void OXCALL
    fnProbchi(OxVALUE *rtn, OxVALUE *pv, int cArg)
    {   OxFnDouble2(rtn, pv, DProbChi);
    }
static void OXCALL
    fnProbnormal(OxVALUE *rtn, OxVALUE *pv, int cArg)
    {   OxFnDouble(rtn, pv, DProbNormal);
    }
```

OxFreeByValue

```
void OxFreeByValue(OxVALUE *pv);
```

pv	in:	pointer to value to free
	out:	freed value

No return value.

Description

Frees the matrix/string/array (i.e. pv is OX_MATRIX, OX_ARRAY, or OX_STRING) if it has property OX_VALUE.

OxGetMainArgs, OxGetOxArgs

```
void OxGetMainArgs(int *pcArgc, char ***pasArgv);
void OxGetOxArgs(int *pcArgc, char ***pasArgv);
```

pcArgc	in:	pointer to integer
	out:	destination holds number of arguments returned
pasArgv	in:	pointer to array (pointer) of strings (char pointer)
	out:	destination points to the array of arguments

No return value.

Description

Queries Ox for the current executable arguments (OxGetMainArgs), and the arguments specified to the running Ox program (available to the Ox code), OxGetOxArgs.

Note that just a pointer to the array of characters is passed, and the contents may not be modified (see the OxSet variants for changing the arguments).

By convention, the first argument for the executable is the name of the executable, while for the Ox program it is the name of the Ox file .

OxGetPrintlevel

```
int  OxGetPrintlevel(void);
```

Return value

returns the current print level (see `OxSetPrintlevel`).

OxGetUserExitCode

```
int  OxGetUserExitCode(void);
```

Return value

Returns the current exit code, as set by calling the Ox function `exit()` (the default is 0).

OxLibArgError

```
void OxLibArgError(int iArg);
```

`iArg`	in:	argument index

No return value.

Description

Reports an error in argument `iArg`, and generates a run-time error.

OxLibArgTypeError

```
void OxLibArgTypeError(int iArg, int iExpect, int iFound);
```

`iArg`	in:	argument index
`iExpect`	in:	expected type, one of `OX_INT`, `OX_DOUBLE`, `OX_MATRIX`, etc.
`iFound`	in:	found type

No return value.

Description

Reports a type error in argument `iArg`, and generates a run-time error.

OxLibCheckArrayMatrix

```
void OxLibCheckArrayMatrix(OxVALUE *pv, int iFirst, int iLast,
    MATRIX m);
```

`pv`	in:	array of values of type `OX_ARRAY`
`iFirst`	in:	first in array to check
`iLast`	in:	last in array to check
`m`	in:	matrix

No return value.

Description

Checks if any of the values in `pv[iFirst]...pv[iLast]` (these must be of type `OX_ARRAY`) coincide with the matrix m.

OxLibCheckMatrixSize

```
void OxLibCheckMatrixSize(OxVALUE *pv, int iFirst, int iLast,
    int r, int c);
```

`pv`	in:	array of values of any type
`iFirst`	in:	first in array to check
`iLast`	in:	last in array to check
`r`	in:	required row dimension
`c`	in:	required column dimension

No return value.

Description

Checks whether all the values in `pv[iFirst]...pv[iLast]` are of type `OX_MATRIX`, and whether they have the required dimension and are non-empty.

OxLibCheckSquareMatrix

```
void OxLibCheckSquareMatrix(OxVALUE *pv, int iFirst, int iLast);
```

`pv`	in:	array of values of any type
`iFirst`	in:	first in array to check
`iLast`	in:	last in array to check

No return value.

Description

Checks whether all the values in `pv[iFirst]...pv[iLast]` are of type `OX_MATRIX`, and whether the matrices are square and non-empty.

OxLibCheckType

```
void OxLibCheckType(int iType, OxVALUE *pv, int iFirst,int iLast);
```

`iType`	in:	required type, one of `OX_INT`, `OX_DOUBLE`, `OX_MATRIX`, etc.
`pv`	in:	array of values of any type
	out:	`OX_INT` changed to `OX_DOUBLE` or vice versa
`iFirst`	in:	first in array to check
`iLast`	in:	last in array to check

No return value.

Description

Checks whether all the values in `pv[iFirst]...pv[iLast]` are of type `iType`. If the argument(s) cannot be converted (typecast) to the requested type, a run-time error is generated. More specifically:

1. if the argument does not have a value, it is an error;
2. if the argument is of the requested type, is is a success;
3. else it is an error if the argument is an empty matrix or cannot be converted (typecast) to the specified type. The following conversions will succeed
   int from double, matrix[1][1], string (first character);
   double from int, matrix[1][1], string (up to 8 bytes mapped);
   matrix from int, double, string (first character);
   string from int, double, function, class.

OxLibValArrayCalloc

```
void OxLibValArrayCalloc(OxVALUE *pv, int c);
```

`pv`	in:	value
	out:	allocated to type array
`c`	in:	number of elements

No return value.

Description

Use `OxValSetArray` instead.

OxLibValMatDup, OxLibValMatMalloc

```
void OxLibValMatDup(OxVALUE *pv, MATRIX mSrc, int r, int c);
void OxLibValMatMalloc(OxVALUE *pv, int r, int c);
```

Use `OxValSetMat/OxValSetMatZero` instead.

OxLibValStrMalloc

```
void OxLibValStrMalloc(OxVALUE *pv, int c);
```

`pv`	in:	value
	out:	allocated to type string
`c`	in:	number of characters

No return value.

Description

Makes `pv` of type `OX_STRING` and allocates a space for it (including a terminating `'\0'` character when $c > 0$). You could use `OxFreeByValue` to free the matrix, but normally that would be left to the Ox run-time system.

If `pv` is not received from Ox, you should set it to an integer before calling this function, for example:

```
OxVALUE tmp;
OxValSetZero(&tmp);
OxLibValStrMalloc(&tmp, 20);
```

Failure to do so could bring down the Ox system.

OxMain,OxMain_T,OxMainCmd

```
int  OxMain(int argc, char *argv[]);
int  OxMainCmd(char *sCommand);
```

`argc`	in:	number of command line arguments
`argv`	in:	command line argument list (first is program name)
`sCommand`	in:	command line as one string

Return value

The entry point for `main()` if successful, or a value ≤ 1 if there was a compilation or link error.

Description

Processes the Ox command line, including compilation, linking and running. The arguments to `OxMain` are provided as an array of pointers to strings, with the first entry being ignored.

The arguments to `OxMainCmd` are provided as one command line string, with arguments separated by a space. A part in double quotes is considered one argument, so `"-r- ranapp.ox"` and `"-r- "ranapp.ox""` are the same (the latter is written as `"-r- \"ranapp.ox\""` in C).

OxMainExit

```
void OxMainExit(void);
```

No return value.

Description

Deallocates run-time buffers.

OxMainInit

```
void OxMainInit(void);
```

No return value.

Description

Sets output destination to `stdout`, and links the standard run-time and drawing library.

OxMakeByValue

```
void OxMakeByValue(OxVALUE *pv);
```

`pv`	in:	pointer to value to make by value
	out:	copied value (if not already by value)

No return value.

Description

Makes the matrix/string/array (i.e. `pv` is `OX_MATRIX`, `OX_ARRAY`, or `OX_STRING`) by value. That is, if it doesn't already have the `OX_VALUE` property, the contents are copied, and the `OX_VALUE` flag is set. Note that a newly allocated value automatically has the `OX_VALUE` flag.

OxMessage

```
void OxMessage(char *s);
```

`s`	in:	text to print

No return value.

Description

Prints a message.

OxPuts

```
void OxPuts(char *s);
```

`s`	in:	text to print

No return value.

Description

Prints text (equivalent to using `print(s)` inside the Ox code).

OxRunAbort

```
void OxRunAbort(int i);
```

`i`	in:	currently not used

No return value.

Description

Exits the run-time interpreter at the next end-of-line. The code should have end-of-line coding on (so not using `-on`), and end-of-line interpretation on (either using `-rn` or debugging). This exits cleanly, so that, when an external program is running Ox functions (e.g. using `FOxRun`), the next call will work as expected.

OxRunError

```
void OxRunError(int iErno, char *sToken);
```

`iErno`	in:	error number as defined in `oxexport.h`, or: −1: skips text of error message
`sToken`	in:	NULL or offending token

No return value.

Description

Reports a run-time error message using `OxRunErrorMessage`.

OxRunErrorMessage

```
void OxRunErrorMessage(char *s);
```

`s`	in:	message text

No return value.

Description

Reports the specified run-time error message, the call trace, and exits the program.

OxRunExit

```
void OxRunExit(void);
```

No return value.

Description

Cleans up after running a program.

OxRunMainExitCall

```
void OxRunMainExitCall(void (OXCALL * fn)(void));
```

`fn`	in:	function to be called when Ox `main` finishes

No return value.

Description

Schedules a function to be called at the end of `main`. This can be used if a library needs a termination call (or, e.g. for a final barrier synchronization in parallel code). Currently, only 10 such functions can be added.

OxRunMessage

```
void OxRunMessage(char *s);
```

`s`	in:	message text

No return value.

Description

Reports a run-time message.

OxRunErrorMessage

```
void OxRunWarningMessage(char *sFunc, char *sMsg);
```

`sFunc`	in:	name of function reporting warning
`sMsg`	in:	text of user-defined warning message

No return value.

Description

Reports user-determined warning message (of type `WFL_USER`, which can be switched off in Ox code with `oxwarning`).

OxSetMainArgs, OxSetOxArgs

```
void  OxSetMainArgs(int cArgc, char *asArgv[]);
void  OxSetOxArgs(int cArgc, char **asArgv);
```

cArgc	in:	number of arguments
asArgv	in:	array (pointer) of argument strings (char pointer)

No return value.

Description

Specifies the current executable arguments (`OxSetMainArgs`), and the arguments specified to the running Ox program (available to the Ox code), `OxSetOxArgs`.

By convention, the first argument for the executable is the name of the executable, while for the Ox program it is the name of the Ox file.

The OxMPI package provides an example of the use of `OxGetMainArgs` and `OxSetMainArgs`, because MPI needs to rewrite arguments to communicate information.

OxSetPrintlevel

```
void OxSetPrintlevel(int iSet);
```

iSet	in:	print level

No return value.

Description

-1	no output,
0	output from print and println is suppressed, but messages and warnings are printed,
1	normal output.

OxSetUserExitCode

```
void OxSetUserExitCode(int iSet);
```

iSet	in:	exit code

OxStoreCreate, OxStoreDelete

```
OxVALUE *OXCALL OxStoreCreate(int c);
void    OXCALL  OxStoreDelete(OxVALUE *pv, int c);
```

pv	in:	pointer to `OxVALUE`
c	in:	number of `OxVALUE` in pv

Return value

`OxStoreCreate` returns a pointer to the first element in the created array of `OxVALUE`s. They are initialized to an integer with value 0.

Description

These functions can be useful to work with `OxVALUE`s, but leaving ownership of the memory within the Ox DLL (e.g. using languages other than C/C++). Every call to `OxStoreCreate` must be matched by `OxStoreDelete`.

If an element is made an object by using `FOxCreateObject`, it will be automatically be deleted (and the destructor called) by `OxStoreDelete`.

To get access to an element beyond the first use `OxValGetVal`.

OxValColumns

```
int  OxValColumns(OxVALUE *pv);
```

pv	in:	OxVALUE to get size of

No return value.

Description
OxValColumns as Ox function columns

OxValDuplicate

```
OxVALUE OxValDuplicate(OxVALUE *pv)
```

pv	out:	Ox variable to duplicate

Return value
Returns an Ox variable that is the duplicate of the argument. For objects, just the referencce is returned (use OxCloneObject to take a copy.

OxValGet...

```
OxVALUE *OxValGetArray(OxVALUE *pv);
int      OxValGetArrayLen(OxVALUE *pv);
OxVALUE *OxValGetArrayVal(OxVALUE *pv, int i);
void    *OxValGetBlob(OxVALUE *pv, int *pI1, *int pI2);
const char * OxValGetClassName(OxVALUE *pv);
BOOL     OxValGetDouble(OxVALUE *pv, double *pdVal);
BOOL     OxValGetInt(OxVALUE *pv, int *piVal);
MATRIX   OxValGetMat(OxVALUE *pv);
int      OxValGetMatc(OxVALUE *pv);
int      OxValGetMatr(OxVALUE *pv);
int      OxValGetMatrc(OxVALUE *pv);
OxVALUE *OxValGetStaticObject(OxVALUE *pv);
char    *OxValGetString(OxVALUE *pv);
BOOL     OxValGetStringCopy(OxVALUE *pv, char *s, int mxLen);
int      OxValGetStringLen(OxVALUE *pv);
OxVALUE *OxValGetVal(OxVALUE *pv, int i);
BOOL     OxValGetVecc(OxVALUE *pv, VECTOR vX);
BOOL     OxValGetVecr(OxVALUE *pv, VECTOR vX);
```

pv	in:	OxVALUE to get information from
	out:	could have changed to reflect requested type
i	in:	index in array
pdVal	out:	double value (if successful)

Return value

OxValGetArray	array of OxVALUEs or NULL if not OX_ARRAY
OxValGetArrayLen	array length or 0 if not OX_ARRAY
OxValGetArrayVal	ith OxVALUE or NULL if not OX_ARRAY or index is beyond array bounds
OxValGetBlob	returns the contents of the OX_BLOB
OxValGetClassName	returns the name of the class for this object
OxValGetDouble	TRUE if value in pv can be interpreted as a double
OxValGetInt	TRUE if value in pv can be interpreted as an integer
OxValGetMat	MATRIX if value in pv can be interpreted as a matrix or NULL if failed
OxValGetMatc	number of columns if successful or 0 if failed
OxValGetMatr	number of rows if successful or 0 if failed
OxValGetMatrc	number of elements if successful or 0 if failed
OxValGetStaticObject	returns the global OxVALUE for this object, which holds the static members
OxValGetString	pointer to string or NULL if not OX_STRING
OxValGetStringLen	string length or 0 if not OX_STRING
OxValGetVal	returns the ith OxVALUE in pv (without checking the pv array bounds)

Description

Gets information from an OxVALUE. A type conversion is applied to pv if the OxVALUE is not of the requested type (which is unlike the macro versions of §D4.3). The conversion is similar to making a call to OxLibCheckType first, and then using the macro version. If conversion to the requested type cannot be made, this is reflected in the return value.

OxValHasType, OxValHasFlag

```
BOOL OxValHasType(OxVALUE *pv, int iType);
BOOL OxValHasFlag(OxVALUE *pv, int iFlag);
```

pv	in:	OxVALUE to get information from
iType	in:	type to test for
iFlag	in:	flag (property) to test for

Return value

TRUE if pv has the specified type/property.

OxValRows

```
int  OxValRows(OxVALUE *pv);
```

pv	in:	OxVALUE to get size of

No return value.

Description

OxValRows as Ox function rows

OxValSet...

```
void OxValSetArray(OxVALUE *pv, int c);
void OxValSetBlob(OxVALUE *pv, int i1, int i2, void *p);
void OxValSetDouble(OxVALUE *pv, double dVal);
```

```
void OxValSetInt(OxVALUE *pv, int iVal);
void OxValSetNull(OxVALUE *pv);
void OxValSetMat(OxVALUE *pv, MATRIX mVal, int r, int c);
void OxValSetMatZero(OxVALUE *pv, int r, int c);
void OxValSetString(OxVALUE *pv, const char *sVal);
void OxValSetVecc(OxVALUE *pv, VECTOR vX, int r, int c);
void OxValSetVecr(OxVALUE *pv, VECTOR vX, int r, int c);
void OxValSetZero(OxVALUE *pv);
```

pv	in:	OxVALUE to set
	out:	changed value
dVal	in:	double value
iVal	in:	integer value
sVal	in:	string value
mVal[r][c]	in:	matrix value
vX[r×c]	in:	vectorized matrix value

No return value.

Description

OxValSetArray	sets pv to an array of c elements (initialized to null)
OxValSetBlob	sets pv to an opaque type storing two integeres and a pointer
OxValSetDouble	sets pv to a double
OxValSetInt	sets pv to an integer
OxValSetMat	sets pv to a copy of the specified matrix
OxValSetMatZero	sets pv to a matrix filled with zeros
OxValSetNull	sets pv to an integer with value zero and property OX_NULL
OxValSetString	sets pv to a string (the string is duplicated)
OxValSetVecc	sets pv to a copy of the specified vec of the matrix
OxValSetVecr	sets pv to a copy of the specified vecr of the matrix
OxValSetZero	sets pv to an integer with value zero

OxValSetDouble, OxValSetInt, OxValSetMat, OxValSetMatZero, OxValSetVecc, OxValSetVecr, and OxValSetString call OxFreeByValue before changing the value (unlike the macro versions); so, if the argument is not received from Ox (e.g. a local OxVALUE variable), you should first set it to zero or null to avoid a spurious call to free memory.

OxValSetZero, OxValSetNull, and OxValSetBlob do *not* call OxFreeByValue.

OxValSetNull sets pv to an integer of value zero with property OX_NULL. Using such a value in an expression in Ox leads to a run-time error (variable has no value). A compound type (matrix, string, array) can be freed using OxFreeByValue, but normally that would be left to the Ox run-time system. If pv is not received from Ox, you should set it to an integer before calling this function, for example:

```
OxVALUE tmp;
OxValSetZero(&tmp);
OxValSetMatZero(&tmp, 2, 2);
```

Failure to do so could bring down the Ox system.

OxValSizec, OxValSizer, OxValSizerc

```
int  OxValSizec(OxVALUE *pv);
int  OxValSizer(OxVALUE *pv);
int  OxValSizerc(OxVALUE *pv);
```

`pv` in: `OxVALUE` to get size of

No return value.

Description

`OxValSizec` as Ox function `sizec`
`OxValSizer` as Ox function `sizer`
`OxValSizerc` as Ox function `sizerc`

OxValTransfer

```
OxVALUE OxValTransfer(OxVALUE *pv)
```

`pv` out: Ox variable to transfer

Return value

Transfers an Ox variable. The returned object is by value: if the original was by value it is now not any more (i.e. the contents are stolen, but pv still refers to it); otherwise a duplicate is made.

OxValType

```
int  OxValType(OxVALUE *pv);
```

`pv` in: `OxVALUE` to get information from

Return value

returns the type of `pv`.

SetOxExit

```
void SetOxExit(void (OXCALL * pfnNewOxExit)(int) );
```

pfnNewOxExit	in:	new exit handler function

No return value.

Description

Installs a exit handler function for `OxExit` which is called when a run-time error or a fatal error occurs. The default `OxExit` function does nothing.

A run-time error is handled by `OxRunErrorMessage` as follows:

1. Report the text of the error message.
2. If `OxRunError` is called with `iErno` > 1, then call `OxExit(iErno)`.
3. If control is passed on, call `OxExit(0)`.
4. If control is passed on, and Ox is in run-time mode: the run-time engine unwinds and exits after cleaning up (or when interpreting: is ready to accept the next command). If Ox is not in run-time mode: treat as fatal error.

A fatal error is handled as follows:

1. Call `OxExit(1)`.
2. If control is passed on, call `exit(1)`.

Fatal errors can occur during compilation when Ox runs out of memory, or any of the symbol/literal/code tables are full.

SetOxGets

```
void SetOxGets(
    char * (OXCALL * pfnNewOxGets)(char *s, int n) );
```

pfnNewOxGets	in:	new `OxGets` function
s	out:	read input
n	in:	allocated size of s

No return value.

Description

Replaces the `OxGets` function by `pfnNewOxGets`. Is used together with `SetOxPipe` to redirect the output from `scan`.

`pfnNewOxGets` should return to `s` if successful, and `NULL` if it failed.

SetOxMessage

```
void SetOxMessage(
    void (OXCALL * pfnNewOxMessage)(char *) );
```

pfnNewOxMessage	in:	new message handler function

No return value.

Description

Installs a message handler function which is used by `OxMessage`.

SetOxPipe

```
void SetOxPipe(int cPipe);
```

cPipe	in:	> 0: sets pipe buffer size, 0 uses default buffer size, < 0 frees pipe

No return value.

Description

Activates piping of output to another destination than `stdout`. The output from the `print` function will from now on be handled by the `OxPuts` function, and input by `OxGets`. A subsequent attempt for output or input will fail if no new handler for `OxPuts` or `OxGets` has been installed.

SetOxPuts

```
void SetOxPuts(void (OXCALL * pfnNewOxPuts)(char *s) );
```

`pfnNewOxPuts`	in:	new `OxPuts` function
`s`	in:	null-terminated string to output

No return value.

Description

Replaces the `OxPuts` function by `pfnNewOxPuts`. Is used together with `SetOxPipe` to redirect the output from `print`.

SetOxRunMessage

```
void SetOxRunMessage(void (OXCALL * pfnNewOxRunMessage)(char *) );
```

`pfnNewOxRunMessage`	in:	new message handler function

No return value.

Description

Installs a message handler function which is used by `OxRunMessage` and `OxRunErrorMessage`.

SOxGetTypeName

```
char * SOxGetTypeName(int iType);
```

`iType`	in:	type, one of `OX_INT`, `OX_DOUBLE`, `OX_MATRIX`, etc.

Return value

A pointer to the text of the type name.

SOxIntFunc

```
char * SOxIntFunc(void);
```

Return value

A pointer to the name of the currently active internal function.

D4.3 Macros to access OxVALUEs

The OxVALUE is the container for all Ox types. It contains the type identifier, a range of property flags, and the actual data. The type, flags and data can be accessed through functions listed above, or through macros when using C or C++. All constants, types and macros are defined in oxtypes.h. The Visual Basic file oxwin.bas defines the constants and flags for use in Basic programs. For example, macros are defined to access the type of an OxVALUE:

ISINT(pv)	TRUE if integer type
ISDOUBLE(pv)	TRUE if double type
ISMATRIX(pv)	TRUE if MATRIX type
ISSTRING(pv)	TRUE if string type (array of characters)
ISARRAY(pv)	TRUE if array of OxVALUEs
ISFUNCTION(pv)	TRUE if function type (written in Ox code)
ISCLASS(pv)	TRUE if class object type
ISINTFUNC(pv)	TRUE if internal (library) function
ISFILE(pv)	TRUE if file type
GETPVTYPE(pv)	gets the type of the argument
ISNULL(pv)	TRUE if has OX_NULL property
ISADDRESS(pv)	TRUE if has OX_ADDRESS property

An OxVALUE is a structure which contains a union of other structures. For example when using OxVALUE *pv:

GETPVTYPE(pv)	content	description
OX_INT	pv->type	type and property flags
	pv->t.ival	integer value
OX_DOUBLE	pv->type	type and property flags
	pv->t.dval	double value
OX_MATRIX	pv->type	type and property flags
	pv->t.mval.data	MATRIX value
	pv->t.mval.c	number of columns
	pv->t.mval.r	number of rows
OX_STRING	pv->type	type and property flags
	pv->t.sval.size	string length
	pv->t.sval.data	actual string (null terminated)
OX_ARRAY	pv->type	type and property flags
	pv->t.aval.size	array length
	pv->t.aval.data	pointer to array of OxVALUEs

The macros below provide easy access to these values. They all access an element in an array of `OxVALUE`s. None of these check the input type, and it is assumed that the correct type is already known.

macro	purpose	input type
`OxArray`(pv, i)	accesses the array value in `pv[i]`	`OX_ARRAY`
`OxArrayLen`(pv, i)	accesses the array length in `pv[i]`	`OX_ARRAY`
`OxDbl`(pv, i)	accesses the double value in `pv[i]`	`OX_DOUBLE`
`OxInt`(pv, i)	accesses the integer value in `pv[i]`	`OX_INT`
`OxMat`(pv, i)	accesses the `MATRIX` value in `pv[i]`	`OX_MATRIX`
`OxMatc`(pv, i)	accesses the no of columns in `pv[i]`	`OX_MATRIX`
`OxMatr`(pv, i)	accesses the no of rows in `pv[i]`	`OX_MATRIX`
`OxMatrc`(pv, i)	gets the no of elements in `pv[i]`	`OX_MATRIX`
`OxSetDbl`(pv, i, d)	sets `pv[i]` to `OX_DOUBLE` of value d	—
`OxSetInt`(pv, i, j)	sets `pv[i]` to `OX_INT` of value j	—
`OxSetMatPtr`(pv, i, m, cr, cc)	sets `pv[i]` to `OX_MATRIX` pointing to the `cr` $\times$ `cc` matrix `m`	—
`OxStr`(pv, i)	accesses the string value in `pv[i]`	`OX_STRING`
`OxStrLen`(pv, i)	accesses the string length in `pv[i]`	`OX_STRING`
`OxZero`(pv, i)	sets `pv[i]` to `OX_INT` of value 0	—

D4.4 Ox-OxMetrics function summary

This section documents the *Ox* related functions that are specific for use with OxMetrics. These functions are exported from `oxmetrics7.dll`. All functions in this section require `ox_oxmetrics.h`.

FOxOxMetricsStart,FOxOxMetricsStartBatch

```
BOOL FOxOxMetricsStart(LPCTSTR OxModuleName,
    LPCTSTR OxWindowName, BOOL bUseStdHandles);
BOOL FOxOxMetricsStartBatch(LPCTSTR OxModuleName,
    LPCTSTR OxWindowName, BOOL bUseStdHandles, int iBatch);
```

`OxModuleName`	in:	name to be used for module
`OxWindowName`	out:	name of output window in OxMetrics
`bUseStdHandles`	in:	`TRUE`: use standard input/output, else use OxMetrics pipe
`iBatch`	in:	index of batch automation function, use -1 if no batch

Return value

`TRUE` if successful.

Description

These functions establish a link to OxMetrics, and can only be used with OxMetrics under Windows. The required header file is `ox_oxmetrics.h`.

The DLL which is linked to is `oxmetrics7.dll`. It exports the same functionality as OxMetrics, see the OxMetrics Developer's Kit.

OxOxMetricsFinish

```
void OxOxMetricsFinish(BOOL bFocusText);
```

`bFocusText`	in:	`TRUE`: switch to OxMetrics and set focus to the output window

No return value.

Description

Closes the link to OxMetrics, and can only be used with OxMetrics under Windows. The required header file is `ox_oxmetrics.h`. `OxOxMetricsFinish` matches `FOxOxMetricsStart`.

OxMetricsGetOxHandlerA

```
void * OXCALL OxMetricsGetOxHandlerA(const char *sName);
```

`sName`	in:	name of the handler to get

Return value

A pointer to the requested handler.

Description

Use the `sName` argument to get the required OxMetrics handler (function) for Ox:

"OxDraw"
"OxDrawWindow"
"OxMessage"
"OxPuts"
"OxRunMessage"
"OxTextWindow"

OxOxMetricsRestart

```
void OxOxMetricsRestart();
```

No return value.

Description

Restarts the link to OxMetrics after `OxMainInit` is called (e.g. to compile a new Ox file (`OxMainInit` should be called again after `OxMainExit`). `OxMainInit` sets Ox to using Console output (stdout).

OxOxMetricsUsingStdHandles

```
BOOL OxOxMetricsUsingStdHandles();
```

Return value

`TRUE` if `FOxOxMetricsStart` was called using `bUseStdHandles` set to `TRUE`.

D4.5 Ox exported mathematics functions

D4.5.1 `MATRIX` and `VECTOR` types

This section documents the C functions exported from the OxWin DLL to perform mathematical tasks. With the DLL installed, any C or C++ function could call these functions to perform a mathematical task. The primary purpose is, if you, for example, wish to use some random numbers in your C extension to Ox. It is also possible to just use these functions without using Ox at all.

To use any of the functions in this section, you need to include both `jdtypes.h` and `jdmath.h` (in this order), e.g.

```
#include "/ox/dev/jdtypes.h"
#include "/ox/dev/jdmath.h"
```

Or, if you have set up the information for your compiler such that `/ox/dev` is in the include search path:

```
#include "jdtypes.h"
#include "jdmath.h"
```

Several types are defined in `ox/dev/jdtypes.h`, of which the most important are `MATRIX`, `VECTOR` and `BOOL`.

The `MATRIX` type used in this library is a pointer to a column of pointers, each pointing to a row of doubles. A `VECTOR` is just a pointer to an array of doubles. In a `MATRIX`, consecutive rows (the `VECTOR`s) do occupy contiguous memory space (although that would not be strictly necessary in this pointer to array of pointers model). Suppose `m` is a 3 by 3 matrix, then the memory layout can be visualized as:

`m`	$\longrightarrow$ `m[0]`		
	`m[0]` $\longrightarrow$	`m[0][0], m[0][1], m[0][2]`	first row
	`m[1]` $\longrightarrow$	`m[1][0], m[1][1], m[1][2]`	second row
	`m[2]` $\longrightarrow$	`m[2][0], m[2][1], m[2][2]`	third row

Matrices can be manipulated as follows, using the 3×3 matrix `m`:

- `m[0]` is a `VECTOR`, the first row of `m`;
- `&m[1]` is a `MATRIX`, the last two rows of `m`;
- `&m[1][1]` is a `VECTOR`, the last two elements of the second row.
- `&(&m[1])[1]` is a `MATRIX`, the last two elements of the second row (this is only a 1 row matrix, since there is no pointer to the third row).

A `MATRIX` is allocated by a call to `MatAlloc` and deallocated with `MatFree`. For a `VECTOR` the functions are `VecAlloc` and `free`, e.g.:

```
MATRIX m;  VECTOR v;  int i, j;

m = MatAlloc(3, 3);
v = VecAlloc(3);


if (!m || !v)          /* yes: error exit */
    printf("error: allocation failed!");

MatZero(m, 3, 3);           /* set m to 0 */
MatZero(&v, 1, 3);          /* set v to 0 */
```

```
for (i = 0; i < 3; ++i)  /* set both to 1 */
{   for (j = 0; j < 3; ++j)
        m[i][j] = 1;
    v[i] = 1;
}
/* ... do more work                        */

MatFree(m2, 3, 3);   /* done: free memory */
free(v);
```

Note that the memory of a matrix is owned by the original matrix. It is **NOT** safe to exchange rows by swapping pointers. Rows also cannot be exchanged between different matrices; instead the elements must be copied from one row to the other. Columns have to be done element by element as well.

As a final example, we show how to define a matrix which points to part of another matrix. For example, to set up a matrix which points to the 2 by 2 lower right block in `m`, allocate the pointers to rows:

```
MATRIX m2 = MatAlloc(2, 0);
m2[0] = &m[1][1];
m2[1] = &m[2][1];
// do work with m and m2, then free m2:

MatFree(m2, 2, 0);
```

Again note that the memory of the elements is still owned by `m`; deallocating `m` deletes what m2 tries to point to.

When a language supports C-style DLLs, but not the pointer-to-pointer model used in the `MATRIX` type, the following functions may be used to provide the necessary mapping:

`MatAllocBlock`	function version of `MatAlloc`
`MatCopyVecc`	store column-vectorized matrix in a `MATRIX`
`MatCopyVecr`	store row-vectorized matrix in a `MATRIX`
`MatFreeBlock`	function version of `MatFree`
`MatGetAt`	get an element in a `MATRIX`
`MatSetAt`	set an element in a `MATRIX`
`VeccCopyMat`	store a `MATRIX` as a column vector
`VecrCopyMat`	store a `MATRIX` as a row vector

D4.5.2 Exported matrix functions

The following list gives the exported C functions, with their Ox equivalent.

`c_abs`	`cabs`
`c_div`	`cdiv`
`c_erf`	`cerf`
`c_exp`	`cexp`
`c_log`	`clog`
`c_mul`	`cmul`
`c_sqrt`	`csqrt`

DBessel01	bessel
DBesselnu	bessel
DBetaFunc	betafunc
DDawson	dawson
DDensBeta	densbeta
DDensChi	denschi
DDensF	densf
DDensGamma	densgamma
DDensGH	densgh
DDensGIG	densgig
DDensMises	densmises
DDensNormal	densn
DDensPoisson	denspoisson
DDensT	denst
DDiagXSXt	outer
DDiagXtSXtt	outer
DErf	erf
DExpInt	expint
DExpInt1	expint
DExpInte	expint
DGammaFunc	gammafunc
DGamma	gammafact
DGetInvertEps	inverteps
DGetInvertEpsNorm	
DLogGamma	loggamma
DPolyGamma	polygamma
DProbBeta	probbeta
DProbBVN	probbvn
DProbChi	probchi
DProbChiNc	probchi
DProbF	probf
DProbFNc	probf
DProbGamma	probgamma
DProbMises	probmises
DProbMVN	probmvn
DProbNormal	probn
DProbPoisson	probpoisson
DProbT	probt
DProbTNc	probt
DQuanBeta	quanbeta
DQuanChi	quanchi
DQuanF	quanf
DQuanGamma	quangamma
DQuanMises	quanmises
DQuanNormal	quann
DQuanT	quant

DRanBeta	ranbeta
DRanChi	ranchi
DRanExp	ranexp
DRanF	ranf
DRanGamma	rangamma
DRanGIG	rangig
DRanInvGaussian	raninvgaussian
DRanLogNormal	ranlogn
DRanLogistic	ranlogistic
DRanMises	ranmises
DRanNormalPM	rann
DRanStable	ranstable
DRanT	rant
DRanU	ranu
DRanU	ranu
DTailProbChi	tailchi
DTailProbF	tailf
DTailProbNormal	tailn
DTailProbT	tailt
DTraceAB	trace(AB)
DTrace	trace
DVecsum	sumr(A)
DecQRtMul	decqrmul
EigVecDiv	
FCubicSpline	spline
FFT1d	fft1d
FftComplex	fft
FftDiscrete	dfft
FftReal	fft
FIsInf	isinf
FIsNaN	isnan
FPPtDec	choleski
FPeriodogram	periodogram
FPeriodogramAcf	
IDecQRt	decqr
IDecQRtEx	decqr
IDecQRtRank	decqr
IDecSVD	decsvd
IEigValPoly	polyroots
IEigen	eigen
IEigenSym	eigensym
IGenEigVecSym	eigensymgen
IGetAcf	acf
IInvDet	invert
IInvert	invert
ILDLbandDec	decldlband

ILDLdec	decldl
ILUPdec	declu, determinant
ILUPlogdet	declu, determinant
IMatRank	rank
INullSpace	nullspace
IOlsNorm	ols2c, ols2r
IOlsQR	ols2, ols2
IRanBinomial	ranbinomial
IRanLogarithmic	ranlogarithmic
IRanNegBin	rannegbin
IRanPoisson	ranpoisson
ISymInv	invertsym
ISymInvDet	invertsym
IntMatAlloc	
IntMatFree	
IntVecAlloc	
LDLbandSolve	solveldlband
LDLsolve	solveldl
LDLsolveInv	solveldl
LUPsolve	solvelu
LUPsolveInv	solvelu
MatABt	A*B'
MatAB	A*B
MatAcf	acf
MatAdd	A+c*B
MatAllocBlock	
MatAlloc	
MatAtB	A'B
MatBBt	BB'
MatBSBt	BSB'
MatBtBVec	A=B-y; A'A
MatBtB	B'B
MatBtSB	B'SB
MatCopyTranspose	
MatCopyVecc	
MatCopyVecr	
MatCopy	
MatDup	A = B
MatFreeBlock	
MatFree	
MatGenInvert	1 / A, decsvd
MatGenInvertSym	1 / A, decsvd
MatGetAt	
MatI	unit
MatNaN	
MatRan	ranu

MatRann	rann
MatReflect	reflect
MatSetAt	
MatStandardize	standardize
MatTranspose	transpose operator: ’
MatVariance	variance
MatZero	zeros
MatZero	zeros
OlsQRacc	ols
RanDirichlet	randirichlet
RanGetSeed	ranseed
RanSetRan	ranseed
RanSetSeed	ranseed
RanSubSample	ransubsample
RanUorder	ranuorder
RanWishart	ranwishart
SetFastMath	use command line switch to turn off
SetInf	= M_INF
SetInvertEps	inverteps
SetNaN	= M_NAN
SortVec	sortr
SortMatCol	sortc
SortmXByCol	sortbyc
SortmXtByVec	sortbyr
ToeplitzSolve	solvetoeplitz
VecAllocBlock	
VecCopy	
VecDiscretize	discretize
VecDupBlock	
VecFreeBlock	
VecTranspose	
VeccCopyMat	
VecrCopyMat	

D4.5.3 Matrix function reference

c_abs, c_div, c_erf, c_exp, c_log, c_mul, c_sqrt

```
double c_abs(double xr, double xi);
BOOL c_div(double xr, double xi, double yr, double yi,
    double *zr, double *zi);
void c_erf(double x, double y, double *erfx, double *erfy);
void c_exp(double xr, double xi, double *yr, double *yi);
void c_log(double xr, double xi, double *yr, double *yi);
void c_mul(double xr, double xi, double yr, double yi,
    double *zr, double *zi);
```

```
void c_sqrt(double xr, double xi, double *yr,double *yi);
```

Return value

`c_abs` returns the result. `c_div` returns FALSE in an attempt to divide by 0, TRUE otherwise. The other functions have no return value.

DBessel01, DBesselNu

```
double DBessel01(double x, int type, int n);
double DBesselNu(double x, int type, double nu);
```

`x`	in:	x, point at which to evaluate
`type`	in:	character, type of Bessel function: `'J'`, `'Y'`, `'I'`, `'K'`
`n`	in:	integer, 0 or 1: order of Bessel function
`nu`	in:	double, fractional order of Bessel function

Return value

Returns the Bessel function.

DBetaFunc

```
double DBetaFunc(double dX, double dA, double dB);
```

Return value

Returns the incomplete beta function $B_x(a, b)$.

DDawson

```
double DDawson(double x);
```

Return value

Returns the Dawson integral.

DDens...

```
double DDensBeta(double x, double a, double b);
double DDensChi(double x, double dDf);
double DDensF(double x, double dDf1, double dDf2);
double DDensGamma(double g, double r, double a);
double DDensGH(double dX, double dNu, double dDelta,
    double dGamma, double dBeta);
double DDensGIG(double dX, double dNu, double dDelta,
    double dGamma);
double DDensMises(double x, double dMu, double dKappa);
double DDensNormal(double x);
double DDensPoisson(double dMu, int k);
double DDensT(double x, double dDf);
```

Return value

Value of density at `x`.

DecQRtMul

```
void DecQRtMul(MATRIX mQt, int cX, int cT, MATRIX mY, int cY,
    int cR);
void DecQRtMult(MATRIX mQt, int cX, int cT, MATRIX mYt, int cY,
    int cR);
```

`mQt[cX][cT]`	in:	householder vectors of QR decomposition of X
`mYt[cY][cT]`	in:	matrix Y
	out:	$Q'Y$
`mY[cT][cY]`	in:	matrix Y
	out:	$Q'Y$
`cR`	in:	row rank of X'

Return value

Computes $Q'Y$.

Description

Performs multiplication by Q' after a QR decomposition.

DDiagXSXt, DDiagXtSXtt

```
double DDiagXSXt(int iT, MATRIX mX, MATRIX mS, int cS);
double DDiagXtSXtt(int cX, MATRIX mXt, MATRIX mS, int cS);
```

`mXt[cX][cS]`	in:	matrix X
`mX[cS][cX]`	in:	matrix X'
`mS[cS][cS]`	in:	symmetric matrix S

Return value

DDiagXtSXtt returns $Xt[][iT]'SXt[][iT]$; DDiagXSXt returns $X[iT][]SX[iT][]'$.

Description

Performs multiplication by Q' after a QR decomposition.

DErf, DExpInt, DExpInte, DExpInt1

```
double DErf(double x);
double DExpInt(double x);
double DExpInte(double x);
double DExpInt1(double x);
```

Return value

`DErf` returns the error function erf(x).
`DExpInt` returns the exponential integral Ei(x).
`DExpInte` returns the exponential integral $\exp(-x)$Ei(x).
`DExpInt1` returns the exponential integral E1(x).

DGamma, DGammaFunc

```
double DGamma(double z);
double DGammaFunc(double dX, double dR);
```

Return value

`DGamma` returns the complete gamma function $\Gamma(z)$.
`DGammaFunc` returns the incomplete gamma function $G_x(r)$.

DGetInvertEps

```
double DGetInvertEps(void);
double DGetInvertEpsNorm(MATRIX mA, int cA);
```

Return value

`DGetInvertEps` returns inversion epsilon, ϵ_{inv}, see `SetInvertEps`.
`DGetInvertEpsNorm` returns $\epsilon_{inv}||A||_\infty$.

DLogGamma

```
double DLogGamma(double dA);
```

Return value

Returns the logarithm of the gamma function.

DPolyGamma

```
double DPolyGamma(double dA, int n);
```

Return value

Returns the derivatives of the loggamma function; $n = 0$ is first derivative: digamma function, and so on.

DProb...

```
double DProbBeta(double x, double a, double b);
double DProbBVN(double dLo1, double dLo2, double dRho);
double DProbChi(double x, double dDf);
double DProbChiNc(double x, double df, double dNc);
double DProbF(double x, double dDf1, double dDf2);
double DProbFNc(double x, double dDf1, double dDf2, double dNc);
double DProbGamma(double x, double dR, double dA);
double DProbMises(double x, double dMu, double dKappa);
double DProbMVN(int n, VECTOR vX, MATRIX mSigma);
double DProbNormal(double x);
double DProbPoisson(double dMu, int k);
double DProbT(double x, int iDf);
double DProbTNc(double x, double dDf, double dNc);
```

Return value

Probabilities of value less than or equal to `x`.

DQuan...

```
double DQuanBeta(double x, double a, double b);
double DQuanChi(double p, double dDf);
double DQuanF(double p, double dDf1, double dDf2);
double DQuanGamma(double p, double r, double a);
double DQuanMises(double p, double dMu, double dKappa);
double DQuanNormal(double p);
double DQuanT(double p, int iDf);
double DQuanTD(double p, double dDf)
```

Return value

Quantiles at `p`.

DRan...

```
double DRanBeta(double a, double b);
double DRanChi(double dDf);
double DRanExp(double dLambda);
double DRanF(double dDf1, double dDf2);
double DRanGamma(double dR, double dA);
```

```
double DRanGIG(double dNu, double dDelta, double dGamma);
double DRanInvGaussian(double dMu, double dLambda);
double DRanLogNormal(void);
double DRanLogistic(void);
double DRanMises(double dKappa);
double DRanNormalPM(void);
double DRanStable(double dA, double dB);
double DRanStudentT(double dDf)
double DRanT(int iDf);
double DRanU();
```

Return value

Returns random numbers from various distributions.

`DRanU` generates uniform $(0, 1)$ pseudo random numbers according to the active generation method (see `RanSetRan`).

`DRanNormalPM` standard normals (PM = polar-Marsaglia).

Note that, if the Ox run-time is bypassed, and this functions is called directly, the application will crash unless `RanSetRan` is called to initialize the random number environment

DTail...

```
double DTailProbChi(double x, double dDf);
double DTailProbF(double x, double dDf1, double dDf2);
double DTailProbNormal(double x);
double DTailProbT(double x, int iDf);
```

Return value

Probabilities of values greater than `x`.

DTrace, DTraceAB

```
double DTrace(MATRIX mat, int cA);
double DTraceAB(MATRIX mA, MATRIX mB, int cM, int cN);
     mA[cM][cN]          in:  matrix
     mB[cN][cM]          in:  matrix
```

Return value

DTrace returns the trace of A.

DTraceAB returns the trace of AB.

DVecsum

```
double DVecsum(VECTOR vA, int cA);
     vA[cA]              in:  vector
```

Return value

DVecsum returns the sum of the elements in the vector.

EigVecDiv

```
void EigVecDiv(MATRIX mE, VECTOR vEr, VECTOR vEi, int cA)
     vEr[cA]             out: real part of eigenvalues
     vEi[cA]             out: imaginary part of eigenvalues
     mE[cA][cA]          in:  matrix with eigenvectors in rows
                         out: rescaled eigenvectors
```

Return value
Scales each eigenvector (in rows) with the largest row element.

FCubicSpline

```
BOOL FCubicSpline(VECTOR vY, VECTOR vT, int cT, double *pdAlpha,
    VECTOR vG, VECTOR vX, double *pdCV, double *pdPar, BOOL fAuto,
    int iDesiredPar);
BOOL FCubicSplineTime(VECTOR vY, int cT, double dAlpha, VECTOR vG,
    BOOL fHP)
```

`vY[cT]`	in:	variable of which to compute spline
`vT[cT]`	in:	x-variable or NULL (then against time)
`cT`	in:	number of observations, T
`dAlpha`	in:	bandwidth parameter (if $\leq$ 1e-20: 1600 is used)
`vG[cT]`	out:	natural cubic spline, according to `vY` (unsorted), unless `vX` is given, in which case it is according to `vX` (the sorted `vT`)
`pdCV`	in:	NULL or pointer
	out:	cross-validation value
`vX[cT]`	in:	NULL or vector
	out:	xaxis (sorted `vT`) for drawing, only if `vT != NULL`
`pdPar`	in:	NULL or pointer
	out:	equivalent number of parameters
`iDesiredPar`	in:	desired equivalent no of parameters or 0
`fHP`	in:	FALSE: use spline, TRUE: Hodrick-Prescott

Return value
Returns TRUE if successful, FALSE if out of memory.
`FCubicSpline` fits a natural cubic spline to a scatter, skips missing values. `FCubicSplineTime` fits a natural cubic spline to evenly spaced data, *not* skipping over missing values.

FFT1d, FftComplex, FftReal, FftDiscrete

```
int  FFT1d(MATRIX mDest, MATRIX mSrc, int cM, int iForward,
    int isComplex)
void FftComplex(VECTOR vXr, VECTOR vXi, int iPower, int iForward);
void FftReal(VECTOR vXr, VECTOR vXi, int iPower, int iForward);
BOOL FftDiscrete(VECTOR vXr, VECTOR vXi, int cN, int iForward);
```

mDest[c_1][cN]	in:	matrix; $c_1 = 2$ unless isComplex=FALSE and iForward$= 0$
	out:	FFT (or inverse FFT) first vector is real part, second imaginary
mSrc[c_2][cN]	in:	data matrix, first vector is real part, second imaginary; $c_2 = 2$ unless isComplex=FALSE and iForward$= 1$
	out:	unchanged
vXr[n]	in:	vector with real part, $n = 2^{\texttt{iPower}}$ (discrete FFT: $n =$ cN)
	out:	FFT (or inverse FFT) real part
vXi[n]	in:	vector with imaginary part, $n = 2^{\texttt{iPower}}$ (discrete FFT: $n =$ cN)
	out:	FFT (or inverse FFT) imaginary part
iPower	in:	the vector sizes is $2^{\texttt{iPower}}$
iForward	in:	indicates whether an FFT (iForward $= 1$) or an inverse FFT must be performed (iForward $= 0$)

Return value

FFT1d and FftDiscrete return FALSE if there is not enough memory, TRUE otherwise. Also see under fft and dfft.

FIsInf, FIsNaN

```
BOOL FIsNaN(double d);
BOOL FIsInf(double d);
```

d	in:	value to check

Description

Returns TRUE if the argument is infinity (.Inf) or not-a-number (.NaN) respectively.

FPeriodogram, FPeriodogramAcf

```
BOOL FPeriodogram(VECTOR vX, int cT, int iTrunc, int cS,
    VECTOR vS, int iMode);
BOOL FPeriodogramAcf(VECTOR vAcf, int cT, int iTrunc, int cS1,
    VECTOR vS, int iMode, int cTwin)
```

vX[cT]	in:	variable of which to compute correlogram
cT	in:	number of observations, T
iTrunc	in:	truncation parameter m
cS	in:	no of points at which to evaluate spectrum
vS[cS]	out:	periodogram
iMode	in:	0: (truncated) periodogram, 1: smoothed periodogram using Parzen window, 2: estimated spectral density using Parzen window (as option 1, but divided by c(0)).
vAcf[cT]	in:	ACF
	out:	overwritten by weighted ACF
cS1	in:	> 0: no of points at which to evaluate spectrum ≤ 0: using all points with window $2\pi/$cTwin

Return value
Returns TRUE if successful, FALSE if out of memory.

FPPtDec

```
BOOL FPPtDec(MATRIX mA, int cA)
```

`mA[cA][cA]`	in:	symmetric p.d. matrix to be decomposed
	out:	contains P

Return value
`TRUE`: no error;
`FALSE`: Choleski decomposition failed.

Description
Computes the Choleski decomposition of a symmetric pd matrix A: $A = PP'$. P has zeros above the diagonal.

IDecQRt...

```
int IDecQRt(MATRIX mXt, int cX, int cT, int *piPiv, int *pcR);
int IDecQRtEx(MATRIX mXt, int cX, int cT, int *piPiv, VECTOR vTau);
int IDecQRtRank(MATRIX mQt, int cX, int cT, int *pcR);
```

`mXt[cX][cT]`	in:	X' data matrix
	out:	householder vectors of QR decomposition of X, holds H in lower diagonal, and R in upper diagonal
`piPiv[cX]`	in:	allocated vector or NULL
	out:	pivots (if argument is NULL on input, there will be no pivoting)
`pcR`	in:	pointer to integer
	out:	row rank of X'
`vTau[cX]`	in:	allocated vector
	out:	$-2/h'h$ for each vector h of H
`mQt[cX][cT]`	in:	output from `IDecQRtEx`

Return value
`IDecQRtEx` returns 1 if successful, 0 if out of memory. `IDecQRt` and `IDecQRtRank` return:

0:	out of memory,
1:	success,
2:	ratio of diagonal elements of $(X'X)$ is large, rescaling is adviced,
-1:	$(X'X)$ is (numerically) singular,
-2:	combines 2 and -1.

Description
Performs QR decomposition. `IDecQRt` amounts to a call to `IDecQRtEx` followed by `IDecQRtRank` to determine the rank and return value.

IDecSVD

```
int IDecSVD(MATRIX mA, int cM, int cN, VECTOR vW, int fDoU,
    MATRIX mU, int fDoV, MATRIX mV, int fSort);
```

`mA[cM][cN]`	in:	matrix to decompose, `cM` $\geq$ `cN`
	out:	unchanged
`vW[cN]`	in:	vector
	out:	the n (non-negative) singular values of A
`fDoU`	in:	TRUE: U matrix of decomposition required
`mU[cM][cN]`	in:	matrix
	out:	the matrix U (orth column vectors) of the decomposition if `fDoU == TRUE`. Otherwise used as workspace. `mU` may coincide with `mA`.
`fDoV`	in:	`TRUE`: V matrix required
`mV[cM][cN]`	in:	matrix
`mV[cN][cN]`	out:	the matrix V of the decomposition if `fDoV == TRUE`. Otherwise not referenced. `mV` may coincide with `mU` if `mU` is not needed.
`fSort`	in:	if `TRUE` the singular values are sorted in decreasing order with U, V accordingly.

Return value

0: success

k: if the k-th singular value (with index k - 1) has not been determined after 50 iterations. The singular values and corresponding U, V should be correct for indices $\geq$ k.

Description

Computes the singular value decomposition.

IEigValPoly,IEigen

```
int IEigValPoly(VECTOR vPoly, VECTOR vEr, VECTOR vEi, int cA);
int IEigen(MATRIX mA, int cA, VECTOR vEr, VECTOR vEi, MATRIX mE);
```

`vPoly[cA]`	in:	coefficients of polynomial $a_1 \dots a_m$ ($a_0 = 1$).
	out:	unchanged.
`mA[cA][cA]`	in:	unsymmetric matrix.
	out:	used as working space. `IEigVecReal`: holds eigenvecs in rows (eigenvalue i is complex: row i is real, row $i + 1$ is imaginary part).
`vEr[cA]`	out:	real part of eigenvalues
`vEi[cA]`	out:	imaginary part of eigenvalues
`mE[cA][cA]`	in:	NULL or matrix.
	out:	if !NULL: holds eigenvecs in rows (eigenvalue i is complex: row i is real, row $i + 1$ is imaginary part).

Return value

0 success

1 maximum no of iterations (50) reached

2 NULL pointer arguments or memory allocation not succeeded.

Description

`IEigValPoly` computes the roots of a polynomial, see `polyroots()`.

`IEigen` computes the eigenvalues and optionally the eigenvectors of a double unsymmetric matrix. On output, the eigenvectors are *not* standardized by the largest

element. EigVecDiv can be used for standardization: it takes the eigenvectors and values from IEigen as input, and gives the standardized eigenvectors on output.

IEigenSym

```
int  IEigenSym(MATRIX mA, int cA, VECTOR vEval, int fDoVectors);
```

mA[cA][cA]	in:	symmetric matrix.
	out:	work space.
if fDoVectors $\neq$ 0: the rows contain the normalized eigenvectors (ordered).		
vEv[cA]	out:	ordered eigenvalues (smallest first)
fDoVectors	in:	eigenvectors are to be computed

Return value

See IEigen.

Description

IEigenSym computes the eigenvalues of a symmetric matrix, and optionally the (normalized) eigenvectors.

IGenEigVecSym

```
int  IGenEigVecSym(MATRIX mA, MATRIX mB, VECTOR vEval,
    VECTOR vSubd, int cA);
```

mA[cA][cA]	in:	symmetric matrix.
	out:	the rows contain the normalized eigenvectors (sorted according to eigenvals, largest first)
mB[cA][cA]	in:	symmetric pd. matrix.
	out:	work
vEval[cA]	out:	ordered eigenvalues (smallest first)
vSubd[cA]	out:	index of ordered eigenvalues
cA	in:	dimension of matrix;

Return value

0,1,2: see IEigen; -1: Choleski decomposition failed.

Description

Solves the general eigenproblem $Ax = \lambda Bx$, where A and B are symmetric, B also positive definite.

IGetAcf

```
int IGetAcf(VECTOR vX, int cT, int cLag, VECTOR vAcf, BOOL bCov);
```

vX[cT]	in:	variable of which to compute correlogram
cT	in:	number of observations
cLag	in:	required no of correlation coeffs
vAcf[cLag]	out:	correlation coeffs 1... cLag (0. if failed); unlike acf(), the autocorrelation at lag 0 (which is 1) is not included.
bCov	in:	FALSE: autocorrelation, else autocovariances

Return value

`IGetAcf` uses the full sample means (the standard textbook correlogram). `IGetAcf` skips over missing values, in contrast to `MatAcf`. Also see under `acf` and `DrawCorrelogram`.

IInvert, IInvDet

```
int  IInvert(MATRIX mA, int cA);
int  IInvDet(MATRIX mA, int cA, double *pdLogDet, int *piSignDet);
```

`mA[cA][cA]`	in:	ptr to matrix to be inverted
	out:	contains the inverse, if successful
`pdLogDet`	out:	the *logarithm* of the absolute value of the determinant of A
`piSignDet`	out:	the sign of the determinant of A; 0: singular; $-1, -2$: negative determinant; $+1, +2$: positive determinant; $-2, +2$: result is unreliable

Return value

0: success; 1,2,3: see `ILDLdec`.

Description

Computes inverse of a matrix using LU decomposition.

ILDLbandDec

```
int ILDLbandDec(MATRIX mA, VECTOR vD, int cB, int cA);
```

`mA[cB][cA]`	in:	ptr to sym. pd. band matrix to be decomposed
	out:	contains the L matrix (except for the 1's on the diagonal)
`vD[cA]`	out:	the reciprocal of D (not the square root!)
`cB`	in:	1+bandwidth

Return value

See `ILDLdec`.

Description

Computes the Choleski decomposition of a symmetric positive band matrix. The matrix is stored as in `decldlband`.

ILDLdec

```
int  ILDLdec(MATRIX mA, VECTOR vD, int cA);
```

`mA[cA][cA]`	in:	ptr to sym. pd. matrix to be decomposed only the lower diagonal is referenced;
	out:	the strict lower diagonal of A contains the L matrix (except for the 1's on the diagonal)
`vD[cA]`	out:	the reciprocal of D (not the square root!)

Return value

0 no error;
1 the matrix is negative definite;
2 the matrix is (numerically) singular;
3 NULL pointer argument

Description

Computes the Choleski decomposition of a symmetric positive definite matrix.

ILUPdec

```
int ILUPdec(MATRIX mA, int cA, int *piPiv, double *pdLogDet,
    int *piSignDet, MATRIX mUt);
```

`mA[cA][cA]`	in:	ptr to matrix to be decomposed
	out:	the strict lower diagonal of A contains the L matrix (except for the 1's on the diagonal) the upper diagonal contains U.
`piPiv[cA]`	out:	the pivot information
`pdLogDet`	out:	the *logarithm* of the absolute value of the determinant of A
`piSignDet`	out:	the sign of the determinant of A; 0: singular; $-1, -2$: negative determinant; $+1, +2$: positive determinant; $-2, +2$: result is unreliable
`mUt[cA][cA]`	in:	NULL or matrix
	out:	used as workspace

Return value

0	no error;
-1	out of memory;
≥ 1	the matrix is (numerically) singular; the return value is one plus the singular pivot.

Description

Computes the LU decomposition of a matrix A as: PA = LU.

ILUPlogdet

```
int ILUPlogdet(MATRIX mU, int cA, int *piPiv, double dNormEps,
    double *pdLogDet);
```

`mU[cA][cA]`	in:	LU matrix, only diagonal elements are used
`piPiv[cA]`	in:	the pivot information (NULL: no pivoting)
`dNormEps`	in:	norm(A)*eps, use result from DGetInvertEpsNorm on original matrix A
`pdLogDet`	out:	the *logarithm* of the absolute value of the determinant of A

Return value

Returns the sign of the determinant of $A = LUP$; 0: singular; $-1, -2$: negative determinant; $+1, +2$: positive determinant; $-2, +2$: result is unreliable.

Description

Computes the log-determinant from the LU decomposition of a matrix A.

IMatRank

```
int IMatRank(MATRIX mA, int cM, int cN, double dEps,
    BOOL bAbsolute);
```

`mA[cM][cN]`	in:	`cM` by `cN` matrix of rank `cN`
	out:	unchanged
`dEps`	in:	tolerance to use
`bAbsolute`	in:	`TRUE`: use `dEps`, `FALSE`: `dEps` $\times$ norm

Return value

-1: failure: out of memory; -2: failure: couldn't find all singular values;

≥ 0: rank of matrix.

Description

Uses `IDecSVD` to find the rank of an $m \times n$ matrix A.

IntMatAlloc, IntMatFree, IntVecAlloc

```
INTMAT IntMatAlloc(int cM, int cN);
void IntMatFree(INTMAT im, int cM, int cN);
INTVEC IntVecAlloc(int cM);
```

`cM`, `cN`	in:	required matrix dimensions

Return value

`IntMatAlloc` returns a pointer to the newly allocated `cM` $\times$ `cN` matrix of integers (`INTMAT` corresponds to `int **`), or `NULL` if the allocation failed, or if `cM` was 0. Use `IntMatFree` to free such a matrix.

`IntVecAlloc` returns a pointer to the newly allocated `cM` vector of integers (`INTVEC` corresponds to `int *`), or `NULL` if the allocation failed, or if `cM` was 0. Use the standard C function `free` to free such a matrix.

The allocated types are a matrix or vector of *integers*; there is no corresponding type in Ox, and the allocated matrix cannot be passed directly to Ox code. Also note that these are implemented as macros.

INullSpace

```
int INullSpace(MATRIX mA, int cM, int cN, BOOL fAppend);
```

`mA[cM][cM]`	in:	`cM` by `cN` matrix of rank `cN`, `cM` $>$ `cN` (allocated size must be `cM` by `cM`)
	out:	null space of A is appended (fAppend==TRUE) or mA is overwritten by null space.

Return value

-1: failure: couldn't find all singular values, or out of memory;

≥ 0: rank of null space.

Description

Uses `IDecSVD` to find the orthogonal complement A^*, $m \times m - n$, of an $m \times n$ matrix A of rank n, $n < m$, such that $A^{*\prime}A^* = I$, $A^{*\prime}A = 0$.

Note that the append option requires that A has full column rank (if not the last $m - n$ columns of U are appended).

IOlsNorm, IOlsQR, OlsQRacc

```
int IOlsNorm(MATRIX mXt, int cX, int cT, MATRIX mYt, int cY,
    MATRIX mB, MATRIX mXtXinv, MATRIX mXtX, BOOL fInRows);
```

`mXt[cX][cT]`	in:	X data matrix
	out:	unchanged
`mYt[cY][cT]`	in:	Y data matrix
	out:	unchanged
`mB[cY][cX]`	in:	allocated matrix
	out:	coefficients
`mXtXinv[cX][cX]`	in:	allocated matrix or NULL
	out:	$(X'X)^{-1}$ if !NULL
`mXtX[cX][cX]`	in:	allocated matrix or NULL
	out:	$X'X$ if !NULL
`fInRows`	in:	if FALSE, input is `mXt[cT][cX]`, `mYt[cT][cY]`

```
int IOlsQR(MATRIX mXt, int cX, int cT, MATRIX mYt, int cY,
    MATRIX mB, MATRIX mXtXinv, MATRIX mXtX, VECTOR vW);
```

`mXt[cX][cT]`	in:	X data matrix
	out:	QR decomposition of X, but only if all three return arguments `mB`, `mXtXinv`, `mXtX` are NULL
`mYt[cY][cT]`	in:	Y data matrix
	out:	$Q'Y$
`mB[cY][cX]`	in:	allocated matrix or NULL
	out:	coefficients if !NULL
`mXtXinv[cX][cX]`	in:	allocated matrix or NULL
	out:	$(X'X)^{-1}$ if !NULL
`mXtX[cX][cX]`	in:	allocated matrix or NULL
	out:	$X'X$ if !NULL
`vW[cT]`	in:	vector
	out:	workspace

Return value

0: out of memory,
1: success,
2: ratio of diagonal elements of $(X'X)$ is large, rescaling is adviced,
-1: $(X'X)$ is (numerically) singular,
-2: combines 2 and -1.

```
void OlsQRacc(MATRIX mXt, int cX, int cT, int *piPiv, int cR,
    VECTOR vTau, MATRIX mYt, int cY, MATRIX mB, MATRIX mXtXinv,
    MATRIX mXtX)
```

`mXt[cX][cT]`	in:	result from `IDecQRt`
	out:	may have been overwritten
`piPiv[cX]`	in:	pivots (output from `IDecQRt`)
`pcR`	in:	row rank of X' (output from `IDecQRt`)
`vTau[cX]`	in:	scale factors (output from `IDecQRt`)
...		other arguments are as for `IOlsQR`

Description

performs ordinary least squares (OLS).

IRanBinomial, IRanLogarithmic, IRanNegBin, IRanPoisson

```
int IRanBinomial(int n, double p);
int IRanLogarithmic(double dA);
int IRanNegBin(int iN, double dP);
int IRanPoisson(double dMu);
```

Return value

Returns random numbers from Binomial/Logarithmic/Negative binomial/Poisson distributions.

ISymInv,ISymInvDet

```
int ISymInv(MATRIX mA, int cA);
int ISymInvDet(MATRIX mA, int cA, double *pdLogDet);
```

`mA[cA][cA]`	in:	ptr to sym. pd. matrix to be inverted
	out:	contains the inverse, if successful
`pdLogDet`	in:	address of double or NULL
	out:	contains the log determinant (if not NULL on input)

Return value

0: success; 1,2,3: see `ILDLdec`.

LDLbandSolve

```
void LDLbandSolve(MATRIX mL, VECTOR vD, VECTOR vX, VECTOR vB,
    int cB, int cA);
```

`mL[cB][cA]`	in:	L from calling `ILDLbandDec`
`vD[cA]`	in:	the reciprocal of D
`vX[cA]`	out:	the solution vX (if (`vX == vB`) then vB is overwritten by the solution)
`vB[cA]`	in:	pointer containing the r.h.s. of $Lx = b$
`cB`	in:	1+bandwidth

No return value.

Description

Solves $Ax = b$, with $A = LDL'$ a symmetric positive definite band matrix.

LDLsolve

```
void LDLsolve(MATRIX mL, VECTOR vD, VECTOR vX, VECTOR vB, int cA);
```

`mL[cA][cA]`	in:	ptr to a matrix of which the strict lower diagonal must contain L from the Choleski decomposition computed using `ILDLdec`. (the upper diagonal is not referenced);
`vD[cA]`	in:	contains the reciprocal of D
`vX[cA]`	in:	pointer containing the r.h.s. of $Lx = b$;
`vB[cA]`	out:	contains the solution x (if (`vX == vB`) then vB is overwritten by the solution)

No return value.

Description

Solves $Ax = b$, with $A = LDL'$ a symmetric positive definite matrix.

LDLsolveInv

```
void LDLsolveInv(MATRIX mLDLt, MATRIX mAinv, int cA);
```

`mLDLt[cA][cA]`	in:	ptr to a matrix holding $L : L'$ with $1/D$ on the diagonal
`mAinv[cA][cA]`	in:	ptr to a matrix.
	out:	contains the inverse

No return value.

Description

Computes the inverse of a symmetric matrix A, L, D must be the Choleski decomposition.

LUPsolve, LUPsolveInv

```
void LUPsolve(MATRIX mL, MATRIX mU, int *piPiv, VECTOR vB,int cA);
void LUPsolveInv(MATRIX mL, MATRIX mU, int *piPiv, MATRIX mAinv,
    int cA);
```

`mL[cA][cA]`	in:	the strict lower diagonal contains the L matrix (except for the 1's on diag, so that `mL` and `mU` may coincide)
`mU[cA][cA]`	in:	the upper diagonal contains U: $PA = LU$ output from `ILUPdec`.
`piPiv[cA]`	in:	the pivot information (P)
`vB[cA]`	in:	rhs vector of system to be solved: $Ax = b$.
	out:	contains x.
`mAinv[cA][cA]`	in:	ptr to a matrix.
	out:	contains the inverse of A

No return value.

Description

Solves $AX = B$, with $A = LU$ a square matrix. Normally, this will be preceded by a call to `ILUPdec`. That function returns LU stored in one matrix, which can then be used for both `mL` and `mU`.

MatAcf

```
MATRIX MatAcf(MATRIX mAcf, MATRIX mX, int cT, int cX, int mxLag);
```

`mAcf[mxLag+1] [cX]`	out:	correlation coefficients (0. if failed)
`mX[cT][cX]`	in:	variable of which to compute correlogram
`cT`	in:	number of observations
`mxLag`	in:	required no of correlation coeffs

Return value

Returns `mAcf` if successful, NULL if not enough observations.

MatAdd

```
MATRIX MatAdd(MATRIX mA, int cM, int cN, MATRIX mB, double dFac,
    MATRIX mAplusB);
```

`mA[cM][cN]`	in:	matrix A
`mB[cM][cN]`	in:	matrix B
`dFac`	in:	scalar c
`mAplusB[cM][cN]`	out:	$A + cB$

Return value
returns mAplusB =$A + cB$.

MatAB, MatABt, MatAtB, MatBSBt, MatBtSB, MatBBt, MatBtB, MatBtBVec

```
MATRIX MatAB(MATRIX mA, int cA, int cC, MATRIX mB,int cB,mat mAB);
```
mA[cA][cC]	in:	matrix A
mB[cC][cB]	in:	matrix B
mAB[cA][cB]	out:	AB

```
MATRIX MatABt(MATRIX mA, int cA, int cC, MATRIX mB,
    int cB, mat mABt);
```
mA[cA][cC]	in:	matrix A
mB[cB][cC]	in:	matrix B
mABt[cA][cB]	out:	AB'

```
MATRIX MatAtB(MATRIX mA, int cA, int cC, MATRIX mB,
    int cB, mat mAtB);
```
mA[cA][cC]	in:	matrix A
mB[cA][cB]	in:	matrix B
mAtB[cC][cB]	out:	$A'B$

```
MATRIX MatBBt(MATRIX mB, int cB, int cS, MATRIX mBBt);
```
mB[cB][cS]	in:	matrix B
mBBt[cB][cB]	out:	matrix containing BB'

```
MATRIX MatBSBt(MATRIX mB, int cB, MATRIX mS,
    int cS, MATRIX mBSBt);
```
mB[cB][cS]	in:	matrix B
mS[cS][cS]	in:	symmetric matrix S or NULL (equivalent to $S = I$)
mBSBt[cB][cB]	out:	matrix containing BSB'

```
MATRIX MatBtSB(MATRIX mB, int cB, MATRIX mS,
    int cS, MATRIX mBtSB);
```
mB[cB][cS]	in:	matrix B
mS[cB][cB]	in:	symmetric matrix S or NULL (equivalent to $S = I$)
mBtSB[cS][cS]	out:	matrix containing $B'SB$

```
MATRIX MatBtB(MATRIX mB, int cB, int cS, MATRIX mBtB);
```
mB[cB][cS]	in:	matrix B
mBtB[cS][cS]	out:	matrix containing $B'B$

```
MATRIX MatBtBVec(MATRIX mB, int cB, int cS, VECTOR vY, MATRIX mBtB);
```
mB[cB][cS]	in:	matrix B
vY[cS]	in:	vector y
mBtB[cS][cS]	out:	matrix containing $(B - y)'(B - y)$

Return value
MatAB returns mAB =AB.
MatABt returns mABt =AB'.
MatAtB returns mAtB =$A'B$.

MatBBt returns mBBt $=BB'$.
MatBSBt returns mBSBt $=BSB'$.
MatBtSB returns mBtSB $=B'SB$.
MatBtB returns mBtB $=B'B$.
MatBtBVec returns mBtB $=(B-y)'(B-y)$.

MatAlloc, MatAllocBlock

```
MATRIX MatAlloc(int cM, int cN);
MATRIX MatAllocBlock(int cR, int cC);
```

cM, cN	in:	required matrix dimensions

Return value

Returns a pointer to the newly allocated cM $\times$ cN matrix, or NULL if the allocation failed, or if cM was 0. Use MatFree to free the matrix.

Description

MatAlloc(a,b) is the macro version which maps to MatAllocBlock(a,b).

MatCopy...

```
MATRIX MatCopy(MATRIX mDest, MATRIX mSrc, int cM,int cN);
MATRIX MatCopyTranspose(MATRIX mDestT, MATRIX mSrc,
    int cM, int cN);
void   MatCopyVecr(MATRIX mDest, VECTOR vSrc_r, int cM, int cN);
void   MatCopyVecc(MATRIX mDest, VECTOR vSrc_c, int cM, int cN);
```

mSrc[cM][cN]	in:	$m \times n$ matrix A to copy
vSrc_r[cM*cN]	in:	vectorized $m \times n$ matrix (stored by row)
vSrc_c[cM*cN]	in:	vectorized $m \times n$ matrix (stored by column)
mDest[cM][cN]	in:	allocated matrix
	out:	copy of source matrix
mDestT[cN][cM]	in:	allocated matrix
	out:	copy of transpose of mSrc

Return value

MatCopy and MatCopyTranspose return a pointer to the destination matrix which holds a copy of the source matrix.

MatDup

```
MATRIX MatDup(MATRIX mSrc, int cM, int cN);
```

mSrc[cM][cN]	in:	$m \times n$ matrix A to duplicate

Return value

Returns a pointer to a newly allocated matrix, which must be deallocated with MatFree. A return value of NULL indicates allocation failure.

MatFree, MatFreeBlock

```
void MatFree(MATRIX mA, int cM, int cN);
void MatFreeBlock(MATRIX m);
```

mA[cM][cN]	in:	matrix to free, previously allocated using MatAlloc or MatDup

No return value.

Description

`MatFree(m,a,b)` is the macro version which maps to `MatFreeBlock(m)`.

MatGenInvert, MatGenInvert

```
MATRIX MatGenInvert(MATRIX mA, int cM, int cN, MATRIX mRes,
    VECTOR vSval);
MATRIX MatGenInvertSym(MATRIX mAs, int cM, MATRIX mRes, VECTOR vSval);
```

`mA[cM][cN]`	in:	$m \times n$ matrix A to invert
`mAs[cM][cM]`	in:	$m \times m$ symmetric matrix A to invert
`mRes[cN][cM]`	in:	allocated matrix (may be equal to `mA`)
	out:	generalized inverse of A using SVD
`vSval[ min(cM,cN)]`	in:	NULL or allocated vector
	out:	sing.vals of A (if $m \geq n$) or A' (if $m < n$);

Return value

`!NULL`: pointer to mRes indicating success;

`NULL`: failure: not enough memory or couldn't find all singular values.

Description

Uses `IDecSVD` to find the generalized inverse.

MatGetAt

```
double MatGetAt(MATRIX mSrc, int i, int j);
```

`mSrc`	in:	matrix
`i`	in:	row index
`j`	in:	column index

Return value

Returns `mSrc[i][j]`.

MatI

```
MATRIX MatI(MATRIX mDest, int cM);
```

`mDest[cM][cM]`	in:	allocated matrix
	out:	identity matrix

Return value

Returns a pointer to `mDest`.

MatNaN

```
MATRIX MatNaN(MATRIX mDest, int cM, int cN);
```

`mDest[cM][cN]`	in:	allocated matrix
	out:	matrix filled with the NaN value (Not a Number)

Return value

Returns a pointer to `mDest`.

MatPartAcf

```
MATRIX MatPartAcf(MATRIX mPartAcf, MATRIX mAcf, int cAcf, MATRIX mY,
    int cY, double *pdLogDet, BOOL bFilter)
```

`mPartAcf`	in:	matrix: `mPartAcf[cAcf][1+cY]`
	out:	partial autocorrelation function in first column (`mY` is NULL; first value will be 1), or residuals from filter applied to `mY` (then last column holds variances)
`mAcf[cAcf][1]`	in:	autocovariance function, only first column is used
`mY[cAcf][cY]`	in:	NULL, or data columns to apply filter or smoother to
`pdLogDet`	in:	NULL, or pointer to double
	out:	determinant of filter
`bFilter`	in:	`TRUE`: apply filter to, else smoother

Return value

Returns `mPartAcf` if successful, NULL if not enough observations.

MatRan, MatRann

```
MATRIX MatRan(MATRIX mA, int cR, int cC);
MATRIX MatRann(MATRIX mA, int cR, int cC);
```

`mA[cR][cC]`	in:	allocated matrix
	out:	filled with random numbers

Return value

Both functions return `mA`

`MatRan` generates uniform random numbers, `MatRann` standard normals.

MatReflect, MatTranspose

```
MATRIX MatReflect(MATRIX mA, int cA);
MATRIX MatTranspose(MATRIX mA, int cA);
```

`mA[cA][cA]`	in:	matrix
	out:	transposed matrix.

Return value

Both return a pointer to `mA`.

Description

MatTranspose transposes a square matrix. MatReflect reflects a square matrix around its secondary diagonal.

MatSetAt

```
void  MatSetAt(MATRIX mDest, double d, int i, int j);
```

`mDest`	in:	matrix to change
	out:	changed: `mDest[i][j] = d`
`d`	in:	value
`i`	in:	row index
`j`	in:	column index

No return value.

MatStandardize

```
MATRIX MatStandardize(MATRIX mXdest, MATRIX mX, int cT, int cX);
```

`mXdest[cT][cX]`	out:	standardized mX matrix
`mX[cT][cX]`	in:	data which to standardize
`cT`	in:	number of observations

Return value

Returns mXdest if successful, NULL if not enough observations.

MatVariance

```
MATRIX MatVariance(MATRIX mXtX, MATRIX mX, int cT, int cX,
    BOOL fCorr);
```

`mXtX[cX][cX]`	out:	variance matrix (fCorr is FALSE) or correlation matrix (fCorr is TRUE)
`mX[cT][cX]`	in:	variable of which to compute correlogram
`cT`	in:	number of observations

Return value

Returns mXtX if successful, NULL if not enough observations.

MatZero

```
MATRIX MatZero(MATRIX mDest, int cM, int cN);
```

`MatZero[cM][cN]`	in:	allocated matrix
	out:	matrix of zeros

Return value

Returns a pointer to `mDest`.

RanDirichlet

```
void   RanDirichlet(VECTOR vX, VECTOR vAlpha, int cAlpha);
```

`vX[cAlpha - 1]`	out:	random values
`vAlpha[cAlpha]`	in:	shape parameters

RanGetSeed

```
int    RanGetSeed(int *piSeed, int cSeed);
```

`piSeed`	in:	`NULL` (only returns the seed count), or array with `cSeed` integer elements
`piSeed`	out:	current seeds

Return value

Returns the number of seeds used in the current generator..

RanInit

```
void  RanInit()
```

No return value.

Must be called to initialize the default random number generator.

RanNewRan, RanSetRan

```
void   RanNewRan(DRANFUN fnDRanu,
    RANSETSEEDFUN fnRanSetSeed, RANGETSEEDFUN fnRanGetSeed);
void   RanSetRan(const char *sRan);
```

sRan	in:	string, as in Ox function ranseed
fnDRanu	in:	pointer to new random number generator (same syntax as DRanU)
fnRanSetSeed	in:	pointer to new set seed function (same syntax as RanSetSeed)
fnRanGetSeed	in:	pointer to new get seed function (same syntax as RanSetGeed)

Description

RanSetRan chooses one of the built-in generators. RanNewRan installs a new generator.

RanSetSeed

```
void   RanSetSeed(int *piSeed, int cSeed);
```

piSeed	in:	NULL (means a reset to initial seed), or array with cSeed new seeds (which may not be 0)

Description

Sets the seeds for the current random number generator.

RanUorder, RanSubSample, RanWishart

```
void  RanUorder(VECTOR vU, int cU);
void  RanSubSample(VECTOR vU, int cU, int cN);
void  RanWishart(MATRIX mX, int cX, int cT);
```

vU[cU]	out:	random values
mX[cX][cX]	out:	random values, Wishart(cT, $\mathbf{I}_{\texttt{cX}}$)

SetFastMath

```
void   SetFastMath(BOOL fYes);
```

fYes	in:	TRUE: switches *Fastmath* mode on, else switches it off

Description

When *FastMath* is active, memory is used to optimize some matrix operations. *FastMath* mode uses memory to achieve the speed improvements. The following function are *FastMath* enhanced: MatBtB, MatBtBVec

SetInvertEps

```
void   SetInvertEps(double dEps);
```

dEps	in:	sets inversion epsilon ϵ_{inv} to dEps if dEps ≥ 0, else to the default.

Description

The following functions return singular status if the pivoting element is less than or equal to ϵ_{inv}: ILDLdec, ILUPdec, ILDLbandDec, IOrthMGS. Less than $10\epsilon_{inv}$ is used by IOlsQR.

A singular value is considered zero when less than $||A||_\infty 10\epsilon_{inv}$ in MatGenInvert.

The default value for ϵ_{inv} is $1000 \times$ DBL_EPSILON.

SetInf, SetNaN

```
void SetInf(double *pd);
void SetNaN(double *pd);
```

`*pd`	out:	set value

Description

Sets the argument to infinity (`.Inf`) or not-a-number (`.NaN`).

SortVec, SortMatCol, SortmXtByVec, SortmXByCol

```
int SortVec(VECTOR vX, int cT);
int SortMatCol(MATRIX mX, int iCol, int cT);
int SortmXtByVec(int cT, VECTOR vBy, MATRIX mXt, int cX);
int SortmXByCol(int iCol, MATRIX mX, int cT, int cX);
```

`vX[cT]`	in:	vector
	out:	sorted vector
`mX[cT][.]`	in:	matrix
	out:	matrix with column `iCol` sorted (`SortMatCol`)
`mX[cT][cX]`	in:	matrix
	out:	matrix with columns sorted according to column `iCol` (`SortmXByCol`)
`mXt[cX][cT]`	in:	matrix
	out:	matrix with rows sorted according to vector `vBy[cT]` (`SortmXtByVec`)

Description

Sorting functions (.NaNs are pushed to the beginning).

ToeplitzSolve

```
void ToeplitzSolve(VECTOR vR, int cR, int cM, MATRIX mB,
    int cB, VECTOR v_1);
```

`vR[cR]`	in:	vector specifying Toeplitz matrix
`cM`	in:	dimension of Toeplitz matrix, `cM` $\geq$ `cR`, remainder of `vR` is assumed zero.
`mB[cM][cB]`	in:	`cM` $\times$ `cB` rhs of system to be solved
	out:	contains X, the solution to $AX = B$
`v_1[cM]`	in:	work vector
	out:	changed, `v_1[0]` is the logarithm of the determinant

Return value

0: success; 1: singular matrix or `v_1` is NULL.

Description

Solves $AX = B$ when A is symmetric Toeplitz.

VecAlloc, VecDup, VecFree

```
VECTOR VecAlloc(int cM);
VECTOR VecDup(VECTOR vSrc, int cM);
void VecFree(VECTOR vX);
```

`cM`	in:	required size of vector
`vSrc[cM]`	in:	m vector to duplicate
`vX`	in:	m vector to free

Return value

`VecAlloc` gives a pointer to the newly allocated vector, or `NULL` if the allocation failed, or if `cM` was 0.

`VecDup` gives a pointer to the newly allocated destination vector, which holds a copy of the source vector. A return value of `NULL` indicates allocation failure.

Description

These are implemented as macros, and memory is allocated and freed in the caller's process.

A vector allocated with `VecAlloc` may be freed by using the standard C function `free` or using the macro `VecFree`.

VecAllocBlock, VecDupBlock, VecFreeBlock

```
VECTOR VecAllocBlock(int cM);
VECTOR VecDupBlock(VECTOR vSrc, int cM);
void VecFreeBlock(VECTOR vX);
```

`cM`	in:	required size of vector
`vSrc[cM]`	in:	m vector to duplicate
`vX`	in:	m vector to free

Return value

`VecAllocBlock` returns a pointer to the newly allocated vector, or `NULL` if the allocation failed, or if `cM` was 0.

`VecDupBlock` returns a pointer to the newly allocated destination vector, which holds a copy of the source vector. A return value of `NULL` indicates allocation failure.

Description

These are implemented as functions, and memory is allocated and freed in the Ox DLL.

A vector allocated with `VecAllocBlock` must be freed by using `VecFreeBlock`.

VecCopy

```
VECTOR VecCopy(VECTOR vDest, VECTOR vSrc, int cX)
```

`vDest[cM]`	in:	m vector: destination for copy
`vSrc[cM]`	in:	m vector to copy

Return value

Return a pointer to `vDest`.

VecrCopyMat, VeccCopyMat

```
void VecrCopyMat(VECTOR vDest_r, MATRIX mSrc, int cM, int cN);
void VeccCopyMat(VECTOR vDest_c, MATRIX mSrc, int cM, int cN);
```

`vDest_r[cM*cN]`	in:	allocated vector
	out:	vectorized $m \times n$ matrix (stored by row)
`vDest_c[cM*cN]`	in:	allocated vector
	out:	vectorized $m \times n$ matrix (stored by column)
`mSrc[cM][cN]`	in:	$m \times n$ source matrix

No return value.

VecDiscretize

```
VECTOR VecDiscretize(VECTOR vY, int cY, double dMin, double dMax,
    VECTOR vDisc, int cM, VECTOR vT, int iOption);
```

`vY[cY]`	in:	T vector to discretize
`dMin`	in:	first point
`dMax`	in:	last point, if `dMin == dMax`, the data minimum and maximum will be used
`vDisc[cM]`	in:	m vector
	out:	discretized data
`vT[cY]`	in:	`NULL` or T vector
	out:	if `!NULL`: points (x-axis)

Return value

Return a pointer to `vDisc`, which holds the discretized data.

VecTranspose

```
VECTOR VecTranspose(VECTOR vA, int cM, int cN);
```

`vA[cM * cN]`	in:	$M \times N$ matrix stored as vector
	out:	$N \times M$ transposed matrix.

Return value

Returns a pointer to `vA`.

Description

VecTranspose transposes a matrix which is stored as a column.

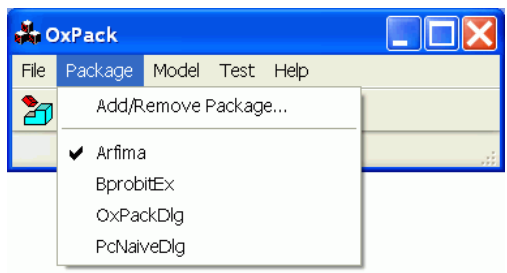
Chapter D5

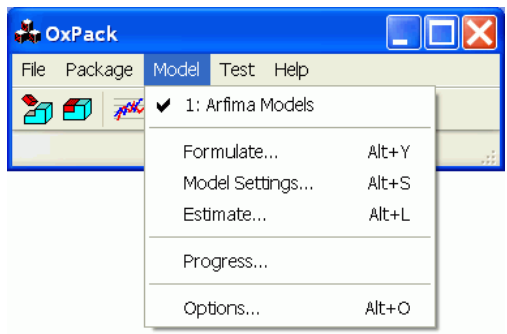
Modelbase and OxPack

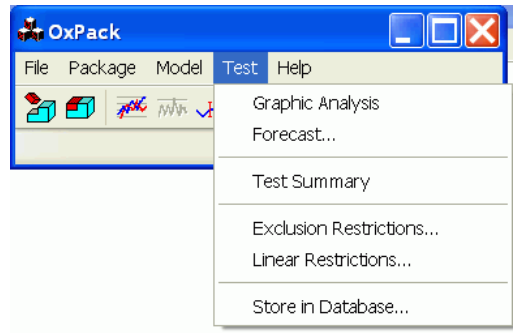
D5.1 Introduction

OxPack allows for interactive use of a `Modelbase`-derived class in cooperation with OxMetrics. This can be achieved solely by adding Ox code – no special Windows programming is required (currently it only works under Windows, but Linux and Mac are on the horizon). In particular, it is possible to create dialogs, and define menu entries.

The following three captures show the OxPack menus, after estimating a model with the Arfima package:

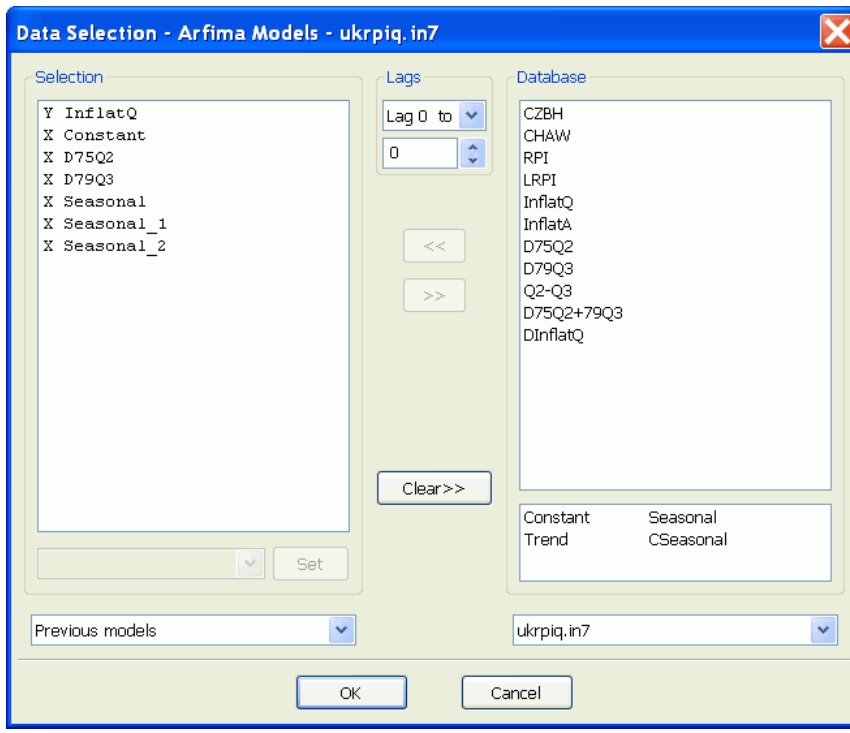




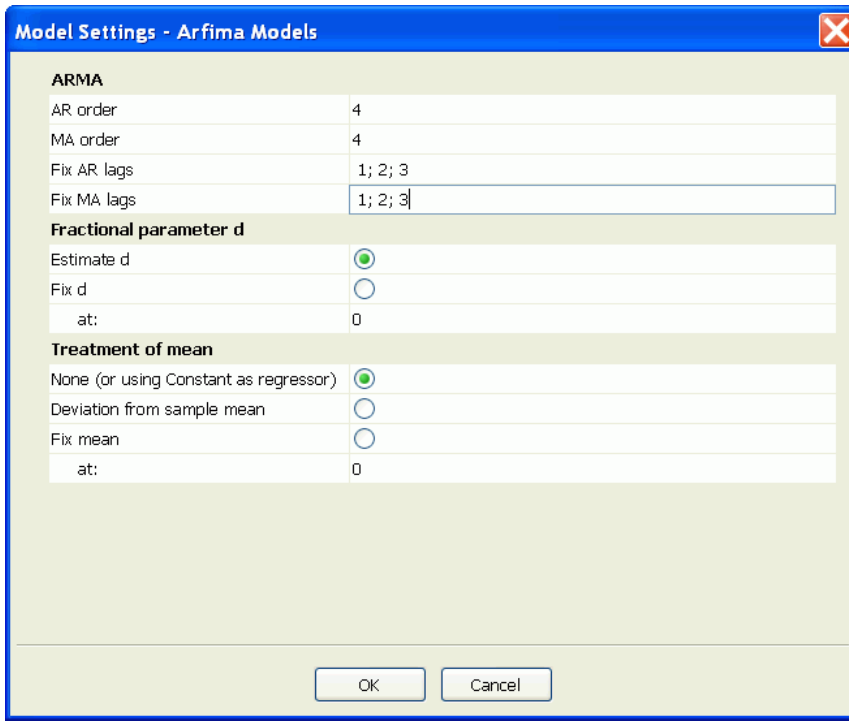


Before a package can be used, it must be added using the Package menu. This menu is also used to choose a package to run. The items on the Model and Test menu are determined by the package. The menus are configured from the package through the `SendMenu` function.

- Model/Formulate
  This brings up the Model Formulation dialog:



  The Arfima package uses `OxPackSpecialDialog` to show the `OP_FORMULATE` dialog. Modelbase uses `SendVarStatus()` in the package to determine the type of variables available to build the model, and `SendSpecials()` to add special variables in the dialog (here they are: Constant, Trend and Seasonal, CSeasonal).
- Model/Model Settings
  The model settings determine the remaining model specification, here:



When the user selects Model Settings on the model menu (or automatically after successful formulation), OxPack calls `ReceiveMenuChoice("OP_SETTINGS")`.

- Model/Estimate
  When the user clicks on Estimate, OxPack first calls `ReceiveData()` and `ReceiveModel()`, to allow the package to extract the data and model formulation using the `"OxPackGetData"` function. (The package implements this function call as a string to avoid a link error when using the package directly from Ox.) Next, the `Estimate` function is called.
- Model/Options
  Options refer to settings which may be less frequently changed. When OxPack calls `ReceiveMenuChoice("OP_OPTIONS")`, the default `Modelbase` implementation allows for the maximization options to be set.
- Test menu
  The menu entries are determined from the return value of `SendMenu("Test")`. The package can again use dialogs to allow the user to choose options.

D5.2 Examples

The following sample code is in `ox/samples/oxpack`:

- `OxPackDlg`
  Provides an example of all dialogs that can be used in the OxPack application.
- `BprobitEx`
  Provides an example of a Modelbased package that implements an estimation pro-

cedure (Probit), and a test menu.

- `OxPackApp`
  Provides an example of an OxPack application which uses a file instead of an OxMetrics database, as well as a descriptive example that uses it's own dialog for variable selection.

Remember to use the exact class name when adding the packages: OxPackDlg, BprobitEx and OxPackApp respectively.

D5.3 Porting from Ox 3

The OxPack related code used in Ox 3 is not compatible with Ox 4. The reason is that most of the processing that OxPack 3 did has now been moved to the Ox code. The benefits of this are

- Model menu can now be customized;
- Estimate dialog is controlled from the Ox code;
- an application need not use an OxMetrics database.

An example of this is the new PcNaive, which is now written in Ox using OxPack (actually, it is part of PcGive, but that is based on the same principle). These improvements could not have been done without changing the code, unfortunately.

Comparing `BprobitEx.ox` from version 3 and 4 allows us to highlight the changes[1] in the new version:[2]

- The constructor calls `SetSelSampleMode(SAM_ANYVALID);`, making use of more flexible sample selection facilities of the Database class. As a consequence, `SetSelSample`, which was hiding the Modelbase version is not required anymore.
- The `Buffering` has been changed somewhat.
- `IsCrossSection` is now only relevant when running batch code, just returning `FALSE` or `TRUE`.
- `SendDialog` and `ReceiveDialog` have been replaced by just one function, `ReceiveMenuChoice`, which is called when a menu entry is selected by the user. `ReceiveMenuChoice` can offer two types of dialogs: `OxPackSpecialDialog` to show a predefined, but customizable, dialog, and `OxPackDialog` for an free-form OxPack-style dialog.
- The model formulation dialog must now be initiated from the Ox code when `ReceiveMenuChoice("OP_FORMULATE")` is called.
  Modelbase has a virtual function `DoFormulateDlg` to help with this.
- `ReceiveModel` does not get the method and estimation sample anymore, as this has been moved to a dialog that is created and called from the Ox code: `ReceiveMenuChoice("OP_ESTIMATE")`. Therefore, it only sets the maximum sample as the default here.
  Modelbase has a virtual function `DoEstimateDlg` to help with this.
- `GetModelSettings` and `SetModelSettings` now first call the Modelbase version, because that provides the maintains the default sample selection settings.

[1] It may also be helpful at first to have another look at the Modelbase code, which is in the `ox/src` folder.

[2] A few additional changes were made to the code to make it a self-contained example.

- `BatchVarStatus` is not used anymore. It's objective was to guess the model class from the variable statuses. However, that proved unreliable, and now a second argument to the `package` batch command is used if there is more than one model class.
- `BatchCommands` is required for OxPack to recognize any added batch commands. `BatchMethod` is used to translate the method string, as specified in the `estimate` batch command, to the `m_iMethod` value.
- The help strings have changed somewhat, as has the method for locating the help html file, see D5.7.

D5.4 OxPack functions that can be called from Ox

Note that these function is only available when running via OxPack.

The function names in this section are written as a string. That way, the function is not resolved until run-time, and the code can be used without OxPack, provided the call is never attempted.

OxPackBufferOff, OxPackBufferOn

```
"OxPackBufferOff"();
"OxPackBufferOn"();
```

No return value.

Description

Switches buffering of text output on and off.

OxPackDialog

```
"OxPackDialog"(const aDialog, const asOptions, const aValues);
```

`aDialog`	in:	array, dialog definition
`asOptions`	in:	address of variable
	out:	array with variable labels
`aValues`	in:	address of variable
	out:	array with dialog values

Return value

`TRUE` if OK is pressed, `FALSE` otherwise.

Description

The `aDialog` argument is an array of arrays, with each entry consisting of just a text label, or of four or more fields defining the edit control:

1. text label
2. control type
3. control value
4. control arguments
5. control label

An example is:

```
decl adlg, asopt, avalues, i;

adlg =
    {   { "GARCH(p,q)" },
        { "p =", CTL_INT, m_cP, "p" },
        { "q =", CTL_INT, m_cQ, "q" },
        { "Startup of variance recursion"},
        { "Condition",     CTL_RADIO, m_iInitMethod, "init"},
        { "Mean variance", CTL_RADIO},
        { "Estimate",      CTL_RADIO},
        { "Model settings"},
        { "Student-t",     CTL_CHECK, m_bStudent, "student"}
    };
if ("OxPackDialog"(adlg, &asopt, &avalues))
{
```

```
    // process return values
    // method one: we know the location
    m_cP = avalues[0];
    m_cQ = avalues[1];
    m_iInitMethod = avalues[2];
    m_bStudent = avalues[3];
    // method two: use the labels
    for (i = 0; i < sizeof(asopt); ++i)
    {
        switch_single(asopt[i])
        {
            case "p" :        m_cP = avalues[i];
            case "q" :        m_cQ = avalues[i];
            case "init" :     m_iInitMethod = avalues[i];
            case "student" :  m_bStudent = avalues[i];
        }
    }
    return TRUE;
}
return FALSE;
```

If the user presses OK in the dialog, the results are returned in the remaining two arguments. For `asOptions` this is the list of field labels. in the above example it would be

```
{  "p", "q", "init", "student"  }
```

The selected values are returned in `asValues`. For the example it could be:

```
{  1, 1, 2, 0  }
```

Possible values for the control type are:

- Labels and groups:

CTL_LABEL	text label
CTL_GROUP	start of a group
CTL_SUBGROUP	start of a sub group

- Boolean and integer values:

CTL_CHECK	check box (0 or 1)
CTL_INT	integer
CTL_INTRANGE	integer within a specified range
CTL_RADIO	single radio button
CTL_RADIOBOX	group of radio buttons
CTL_SELECT	drop-down list of single-select item

- Double and date values:

CTL_DOUBLE	double
CTL_DATE	date/time value, returned as a double

- String values:

CTL_EDITOR	pop-up text editor
CTL_FILE	prompt for existing file name
CTL_FILESAVE	prompt for file name for saving
CTL_FOLDER	prompt for folder name
CTL_STRING	string

- Matrix values:

CTL_MATRIX	matrix, pop-up matrix editor
CTL_STRMAT	matrix, edited as a string

- Sample selection values:

CTL_SAMPLEINDEX	index in a fixed frequency sample
CTL_SAMPLERANGE	period (range) in a fixed frequency sample
CTL_DATEINDEX	index in a date variable
CTL_DATERANGE	period in a date variable

- List:

CTL_LISTBOX	one optional listbox in the dialog

- Enabler and disabler:

CTL_ENABLER	enables controls based on previous control
CTL_DISABLER	disables controls based on previous control

- Variable reference (address):

CTL_VARIABLE	reference to an Ox variable

The text label can have leading tabs (\t) to indent the label. The control value gives the current value of the edit field. The last item is a field label, this can be used to identify the return value; only entries with a field label have a return value.
The arguments for the control type are:

- Labels and groups:

control type	value	control arguments
CTL_LABEL		
CTL_GROUP	int: 1=expand,0=collapse,−1=disable	
CTL_SUBGROUP	int: 1=start,0=end	

CTL_LABEL defines a text label that takes a whole line. Use " ", CTL_LABEL to insert an empty line. A text string followed by nothing else is like a CTL_LABEL, but shown in bold.
The integer argument to CTL_GROUP is 1 if the group is initially expanded, 0 if initially collapsed.
The CTL_SUBGROUP precedes a CTL_GROUP entry to introduce a sub group. The integer argument is 1 to start a subgroup and 0 to end it.
An example is:

```
{   { "PcNaive" },
    { "Monte Carlo Settings", CTL_GROUP, 1 },
    { "Replications", CTL_INT,  m_cRep,     "m_cRep" },
    { "Some text", CTL_LABEL },
    { "", CTL_SUBGROUP, 1 },
    { "Advanced Monte Carlo Settings", CTL_GROUP, 0 },
```

```
    { "Discard", CTL_INT,  m_cTdiscard, "m_cTdiscard" },
    { "", CTL_SUBGROUP, 0 },
    { "Monte Carlo Output", CTL_GROUP, 0 },
    { "Asymptotics",  CTL_CHECK,m_bAsymp,   "m_bAsymp" }
}
```

- Boolean and integer values:

control type	value	control arguments
CTL_CHECK	int: 0 or 1	
CTL_INT	int	
CTL_INTRANGE	int	int:min, int:max
CTL_INTRANGE	int	int:min, int:max, int:step
CTL_RADIO	int	
CTL_RADIOBOX	int	string/array
CTL_RADIOBOX	int	string/array, base
CTL_SELECT	int	string/array
CTL_SELECT	int	string/array, base

  CTL_INTRANGE and CTL_INTRANGE are rendered as spin buttons. CTL_INTRANGE can have an optional argument after the minimum and maximum to specify the step size.
  CTL_RADIO radio buttons are grouped: only the first has a value and a label. CTL_RADIOBOX is more convenient, because all the radio buttons are specified in one command. The argument is either a string, using | as a separator, or an array of strings. A value of -1 disables the CTL_RADIO and CTL_RADIOBOX control.
  CTL_SELECT is rendered as a drop-down box, only allowing a choice from those specified. The argument is either a string, using | as a separator, or an array of strings. A value of -1 disables the CTL_SELECT control.
  Both CTL_RADIOBOX and CTL_SELECT allow an optional base argument, if it is required that the first choice is not zero but the base.
  Some further examples:

```
{
    { "Rank",   CTL_INTRANGE,   cr, 1, 20, "cr" },
    { "",       CTL_RADIOBOX, type, "AR|ECM|SEM", "t1" },
    { "Type 2", CTL_SELECT,   type, "AR|ECM|SEM", "t2" },
    { "AR",     CTL_RADIO,    type, "t3" },
    { "ECM",    CTL_RADIO },
    { "SEM",    CTL_RADIO }
}
```

- Double and date values:

control type	value	control arguments
CTL_DOUBLE	double	
CTL_DATE	double	

  The double value for a CTL_DATE control is a calendar index, and displayed as a date (or time). The user can enter a date or time, which is automatically translated to a calendar index.
- String values:

control type	value	control arguments
CTL_EDITOR	string	
CTL_FILE	string	
CTL_FILESAVE	string	
CTL_FOLDER	string	
CTL_STRING	string	

- Matrix values:

control type	value	control arguments
CTL_MATRIX	matrix	
CTL_MATRIX	matrix	iMinR, iMaxR, iMinC, iMaxC
CTL_MATRIX	matrix	iMinR, iMaxR, iMinC, iMaxC, iType, asRow, asCol
CTL_MATRIX	matrix	asRow, asCol
CTL_STRMAT	matrix	

CTL_MATRIX without additional arguments uses the matrix editor with the dimensions fixed by that of the input matrix. More flexibility regarding dimensions can be specified by the four integers setting the minimum, maximum row count, and the minimum and maximum column count. The integer iType argument is not yet used (use 0 here). The optional asRows and asCols arguments are arrays of strings specifying labels.
Some examples:

```
{
   { "Y",  CTL_MATRIX, m_mY, 1, 5, 1, 5, "m_mY" },
   { "A",  CTL_MATRIX, m_mA, m_asY, {}, "m_mA" },
   { "B",  CTL_MATRIX, m_mB, {}, m_asY~m_asZ, "m_mB" }
}
```

- Sample selection values:

control type	value	control arguments
CTL_SAMPLEINDEX	int	int: iT1, 1×5 matrix
CTL_SAMPLERANGE	int	int: iT1, iT2, 1×5 matrix
CTL_DATEINDEX	int	dbl: dT1, dTmin, dTmax, dObsPerWeek
CTL_DATERANGE	int	dbl: dT1, dT2, dTmin, dTmax, dObsPerWeek

CTL_SAMPLEINDEX and CTL_SAMPLERANGE are for fixed-frequency samples. The sample is specified in a 1×5 matrix with start year, start period, end year, end period and frequency. iT1 is the integer offset in the sample, while iT1,iT2 is a subsample start and end specified as offsets in the sample
CTL_DATEINDEX and CTL_DATERANGE are for samples using calendar dates. The period ranges from dTmin to dTmax. The step size dObsPerWeek is used to spin up or down in greater steps (≤ 1 for weekly data, otherwise daily data).
Some examples:

```
if (isdated)
    adlg ~=
    {   { "starts at", CTL_DATEINDEX,
                m_mData[m_iT1sel + t1est][0],
                m_mData[m_iT1sel][0],
                m_mData[m_iT2sel][0], 1.0, "t1" },
        { "ends at", CTL_DATEINDEX,
                m_mData[m_iT1sel + t2est][0],
                m_mData[m_iT1sel][0],
```

```
                m_mData[m_iT2sel][0], 1.0, "t2" }
    };
else
    adlg ~=
    {   { "start", CTL_SAMPLEINDEX, t1est, selsam, "t1"},
        { "end",   CTL_SAMPLEINDEX, t2est, selsam, "t2"}
    };
```

- List:

control type	value	control arguments
CTL_LISTBOX	array of s strings	
CTL_LISTBOX	array of s strings	int:selupto
CTL_LISTBOX	array of s strings	$1\times \leq s$ matrix:selmat

  Adding CTL_LISTBOX to the dialog controls creates a list on the right-hand side with the array of strings. If no argument is given, all are preselected. If the integer argument selupto is given, entries up to selupto are selected. If a matrix is given, the entries will be selected where the the matrix has a non-zero, and deselected for a zero.
  The return value will always be the first in the return array, and consists of a $1 \times s$ matrix with 1 if the entry is selected and 0 otherwise. The corresponding label is "listbox" (so no label need to be specified).
  In the following example there are m_cY strings in m_asY, so they are all selected:

```
{   { "Forecast" },
    { "Equations", CTL_LISTBOX, m_asY, m_cY }
}
```

- Enabler and disabler:

control type	value	control arguments
CTL_ENABLER	int	int: control_count
CTL_ENABLER	int	int: control_count, int: starting offset
CTL_DISABLER	int	int: control_count
CTL_DISABLER	int	int: control_count, int: starting offset

  CTL_ENABLER enables the next control_count control if the previous integer valued control has the specified value. CTL_DISABLER does the opposite: it disables where CTL_ENABLER enables and vice versa.
  Some examples:

```
{
    { "Type", CTL_SELECT, type, "AR|ECM|SEM", "type" },
    { "", CTL_ENABLER, 1, 1 },
    { "\tRank",   CTL_INTRANGE,   cr, 1, 20, "cr" },
    { "Set count", CTL_CHECK,  bSet,  "bSet" },
    { "", CTL_ENABLER, TRUE, 1 },
    { "\tCount",   CTL_INT,    cCount, "cCount" }
}
```

- Variable reference (address):

control type	value	control arguments
CTL_VARIABLE	array: reference to variable	—

  CTL_VARIABLE is different from the other control types in that it takes the reference (address) of an Ox variable, and modifies that variable directly. *The corresponding entry in* aValues *will always be zero*. The reference can be to any type, but only the following can be edited: integer, double, string, matrix, array, object. The type of a component can not be changed.

Some examples:

```
decl mat = <1,2;3,4>;
decl arr = {{"C","D",{"e",5,5.0,.NaN}}};
//...
{
        { "Matrix",         CTL_VARIABLE,   &mat, "value1" },
        { "Array",          CTL_VARIABLE,   &arr, "value2" },
}
```

OxPackGetData

```
"OxPackGetData"(const sType);
"OxPackGetData"(const sType, const iVarType);
"OxPackGetData"(const sType, const iVarType, const iLag1,
    const iLag2);
"OxPackGetData"(const sType, const sName);
```

sType	in:	string, type of data to obtain from OxPack
iVarType	in:	int, variable group (only when sType equals "SelGroup", "GetGroupCount" or "GetGroupLagCount")
iLag1,iLag2	in:	int, begin and end lag (only when sType equals "GetGroupLagCount")
sName	in:	string, variable name (sType equals "DbVariable") or database name (sType equals "DbName")

Return value

The following relate to the currently active database in OxMetrics, and can be called at any stage. Note that only "DbName", "DbNames" and "DbSample" refresh the information from OxMetrics.

sType	returns
"DbDates"	<> if the database is undated, else $T_d \times 1$ vector with datas
"DbFullPath"	string with full path and name of currently selected database
"DbName"	string with name of currently selected database
"DbName", "name"	selects named database, returning name of selected database
"DbNames"	array with d strings, names of databases loaded in OxMetrics
"DbSample"	array with 5 integers, database sample: frequency, year1, period1, year2, period2
"DbVariable"	array with a data vector ($T_d \times 1$) and 5 integers: sample of variable (frequency, year1, period1, year2, period2)
"DbVarMatrix"	$T_d \times k_d$ matrix with database content
"DbVarNames"	array with k_d strings, database variable names and the actual variable

The following are available after a call to the "OP_FORMULATE" dialog and relate to the current model formulation:

sType	returns
"Deterministic"	integer: 3 (using centred seasonals), 2 (seasonals), -1 (no seasonals)
"GetGroupCount"	integers, number of variables in the group
"GetGroupLagCount"	integers, number of variables in the group within the specified lag lengths
"SelGroup"	$3k$ array, specifying name, start lag, end lag of the selection group. This can be used as input for Database::Select().

The following are available after the data has been loaded from OxMetrics. They refer to the selection that has been made from the database, excluding special variables. So if the model is CONS, Constant, CONS_1, INC and INC_1, then the base variables are CONS and INC, and $k_s = 2$. OxPack loads a copy of the data from OxMetrics when the menu "OP_ESTIMATE" is activated, so that the contents remains unchanged. Prior to that menu call, or if it is skipped, the data is not available.

sType	returns
"Dates"	<> if the database is undated, else $T_d \times 1$ vector with datas
"Matrix"	$T_d \times k_s$ matrix with selected data (base variables only: no lags)
"Names"	array with k_s strings, selected base variable names
"Sample"	array with 5 integers, database sample: frequency, year1, period1, year2, period2

OxPackReadProfile...

```
"OxPackReadProfileInt"(const sKey, const sLabel, int iDefault);
"OxPackReadProfileDouble"(const sKey, const sLabel, int dDefault);
"OxPackReadProfileString"(const sKey, const sLabel, int sDefault);
```

sKey	in:	string, key name, or 0 to use package name
sLabel	in:	string, label name
iDefault	in:	int, default value if label does not exist
dDefault	in:	double, default value if label does not exist
sDefault	in:	string, default value if label does not exist

Return value

The value of the label, or the default. Of type integer, double or string respectively.

Description

Reads persistent settings from the registry. See Modelbase::LoadOptions for an example.

OxPackSendMenuChoice

```
"OxPackSendMenuChoice"(const sMenuID);
```

`sMenuID` in: string, menu identifier.

No return value.

Description

Selects a menu choice. This can be useful to automatically move to a next stage after a previous menu action or dialog.

OxPackSetMarker

```
"OxPackSetMarker"(const iMarker);
```

`iMarker` in: int, 1: mark the next line.

No return value.

Description

Sets a marker at the next output location, and will start displaying output from there (thus avoiding scrolling to the bottom of the output).
`"OxPackSetMarker"(0)` has currently no effect (unlike in OxPack 3).

OxPackSpecialDialog

```
"OxPackSpecialDialog"(const sDialog, const sTitle, ...,
    const aReturn);
```

`sDialog`	in:	string, dialog identifier
`sTitle`	in:	0 for default title, or string with dialog title
`...`	in:	arguments differ by dialog
`aReturn`	in:	address of variable
	out:	dialog return value(s)

Return value

`TRUE` if OK is pressed, `FALSE` otherwise.

Description

The following `sDialog` dialogs are defined:

`sDialog`	description
`"OP_EQUATIONS"`	Equations editor
`"OP_EQUATIONS_SEM"`	Equations editor for SEM
`"OP_FILE_OPEN"`	File Open dialog
`"OP_FILE_SAVE"`	File Save dialog
`"OP_FORMULATE"`	Model formulation dialog
`"OP_FORMULATE_CODE"`	Code formulation dialog
`"OP_FORMULATE_NODB"`	Model formulation dialog without database
`"OP_FUNCTIONS"`	Functions
`"OP_MATRIX"`	Matrix editor
`"OP_MATRIX_CTL"`	Matrix editor with controls for columns
`"OP_MESSAGE"`	Message box
`"OP_PROGRESS"`	Progress dialog
`"OP_SELECTVAR"`	Select variables dialog
`"OP_TEXT"`	Text editor
`"OP_YESNO"`	Yes/No Message box
`"OP_VARIABLE"`	Variable editor

"OP_EQUATIONS"

```
"OxPackSpecialDialog"("OP_EQUATIONS", sTitle, asY, asX, mSel,
    bZeroOne, aReturn);
```

asY	in:	array of strings, list of n Y variables
asX	in:	array of strings, list of k X variables
mSel	in:	$n \times m$ matrix with current selection, $m = k$ if bZeroOne is TRUE; $m = 1 + k$ otherwise (first column is count s_i, rest holds s_i selection indices)
bZeroOne	in:	(optional) int, TRUE: use 0,1 matrix for selection (default), else use selection indices
aReturn	in:	address of variable
	out:	$n \times m$ matrix with new selection

if bZeroOne is TRUE, the information regarding the order within each equation is not retained.

"OP_EQUATIONS_SEM"

```
"OxPackSpecialDialog"("OP_EQUATIONS_SEM", sTitle, asEqns,
    iYvar, iIvar, iUvar, aReturn);
```

asEqns	in:	array$[n+1]$, first is an array of equation names, remainder n are array with equation specifications (name, start-lag, end-lag)
iYvar	in:	int, Y variable (endogenous) identifier
iIvar	in:	int, I variable (identity) identifier
iUvar	in:	int, U variable (unrestricted, i.e. always in all equations) identifier
aReturn	in:	address of variable
	out:	array$[n+1]$ with new equations

Simultaneous equations model formulation after "OP_FORMULATE" (which specifies the unrestricted reduced form from which can be selected).

"OP_FILE_OPEN"

```
"OxPackSpecialDialog"("OP_FILE_OPEN", sTitle, sName, aReturn);
```

sName	in:	strings, default name, can have "*" for name or for extension. Multiple extensions must be separated by a semicolon (e.g. "*.ox;*.h").
aReturn	in:	address of variable
	out:	string, name of selected file

"OP_FILE_SAVE"

```
"OxPackSpecialDialog"("OP_FILE_SAVE", sTitle, sName, aReturn);
```

sName	in:	strings, default name, can have "*" for name or for extension.
aReturn	in:	address of variable
	out:	string, name of selected file

"OP_FORMULATE"

```
"OxPackSpecialDialog"("OP_FORMULATE", sTitle, asSpecials,
    asStatus, iLagMode, iLagDefault, aReturn);
```

asSpecials	in:	array of strings, list of special variables, see Modelbase::SendSpecials
asStatus	in:	array, see Modelbase::SendVarStatus
iLagMode	in:	(optional) int, -1: no lags allowed; ≥ 0: default for first lags drop down box: 0=None, 1=Lag, 2=Lags 0 to)
iLagDefault	in:	(optional) int, ≥ 0: default for lag value box
aReturn	in:	address of variable
	out:	unused, some of the output can be obtained using OxPackGetData, but normally it is obtained through ReceiveModel and ReceiveData when the OP_ESTIMATE menu command is selected.

When accepted, OxPack will call SetModelSettings with the previous model's settings (if any). This allows a model to be recalled from history.

Example:

```
fok = "OxPackSpecialDialog"("OP_FORMULATE", 0, SendSpecials(),
    SendVarStatus(), 2, 1, &dlgout);
```

"OP_FORMULATE_CODE"

```
"OxPackSpecialDialog"("OP_FORMULATE_CODE", sTitle, sMsg,
    sCode, aReturn);
```

sMsg	in:	string, message (e.g. brief explanation)
sCode	in:	string, initial code
aReturn	in:	address of variable
	out:	string, the new code

When accepted, OxPack will call SetModelSettings with the previous model's settings (if any). This allows a model to be recalled from history.

"OP_FORMULATE_NODB"

```
"OxPackSpecialDialog"("OP_FORMULATE_NODB", sTitle, asSpecials,
    asStatus, iLagMode, iLagDefault, asDb, m, aReturn);
```

`asSpecials`	in:	array of strings, list of special variables, see `Modelbase::SendSpecials`
`asStatus`	in:	array$[s]$, see `Modelbase::SendVarStatus`
`iLagMode`	in:	(optional) int, -1: no lags allowed; ≥ 0: default for first lags drop down box: 0=None, 1=Lag, 2=Lags 0 to)
`iLagDefault`	in:	(optional) int, ≥ 0: default for lag value box
`asDb`	in:	array of strings, database variables,
`iFreq`	in:	(optional) int, ≥ 1: database frequency
`m`	in:	(optional) matrix, current formulation, see under `aReturn`
`aReturn`	in:	address of variable
	out:	$(3 + s) \times k$ matrix, where k is the number of selected variables: $[0][i]$: -1 or index in database $[1][i]$: index in specials or -1 $[2][i]$: lag length $[3 + j][i]$: 1 if variable i has status j

Formulation dialog which does not use the OxMetrics database.

When accepted, OxPack will call `SetModelSettings` with the previous model's settings (if any). This allows a model to be recalled from history.

"OP_FUNCTIONS"

```
"OxPackSpecialDialog"("OP_FUNCTIONS", sTitle, asX, aasFunc,
    aReturn);
```

`asX`	in:	array of strings, list of k X variables (the current database selection is used if this list is empty),
`aasFunc`	in:	array of array of strings, see `Modelbase::SendFunctions`
`aReturn`	in:	address of variable
	out:	array of strings with function calls, each of format `"func(name,arg1,arg2)"`, where `func` is the function, `name` is a string and `arg1`, `arg2` are integers.

"OP_MATRIX"

```
"OxPackSpecialDialog"("OP_MATRIX", sTitle, sMsg, mMat,
    iRmin, iRmax, iCmin, iCmax, iType, asRow, asCol,
    sComment, aReturn);
```

sMsg	in:	string, message (e.g. brief explanation)
mMat	in:	$n \times m$ matrix
iRmin	in:	int, minimum row count
iRmax	in:	int, maximum row count
iCmin	in:	int, minimum column count
iCmax	in:	int, maximum column count
iType	in:	(optional) int, type, currently unused (use 0 if required)
asRow	in:	(optional) array of strings with row labels, or string with row format
asCol	in:	(optional) array of strings with columns labels, or string with column format
sComment	in:	(optional) string, additional comment
aReturn	in:	address of variable
	out:	$p \times q$ matrix

"OP_MATRIX_CTL"

```
"OxPackSpecialDialog"("OP_MATRIX_CTL", sTitle, sMsg, mMat,
    iRmin, iRmax, asRow, asCol, aTypes, aReturn);
```

sMsg	in:	string, message (e.g. brief explanation)
mMat	in:	$n \times m$ matrix
iRmin	in:	int, minimum row count
iRmax	in:	int, maximum row count
asRow	in:	array of strings with row labels, or string with row format
asCol	in:	array of strings with columns labels
aTypes	in:	array$[m]$, column types (boolean, integer or double)
aReturn	in:	address of variable
	out:	$p \times m$ matrix

Example:

```
"OxPackSpecialDialog"("OP_MATRIX_CTL", "Test",
    "Message", m, 0, 100, "R %d",
    {"check","int","range","dbl", "choice", "sampleindex", "date"},
    {CTL_CHECK, CTL_INT, CTL_INTRANGE, 0, 10, CTL_DOUBLE,
        CTL_SELECT, "outlier|irregular|slope",
        CTL_SAMPLEINDEX, selsam, CTL_DATE},
        &m);
```

"OP_MESSAGE"

```
"OxPackSpecialDialog"("OP_MESSAGE", sTitle, sMsg, sLine, aReturn);
```

sMsg	in:	string, message test
sLine	in:	(optional) string, additional short message
aReturn	in:	address of variable
	out:	unused

"OP_PROGRESS"

```
"OxPackSpecialDialog"("OP_PROGRESS", sTitle, sMsg, aReturn);
```

sMsg	in:	string, message (e.g. brief explanation), use 0 for none
aReturn	in:	address of variable
	out:	unused, progress is printed when OK is clicked.

Example:

```
"OxPackSpecialDialog"("OP_PROGRESS", 0, 0, &dlgout);
```

"OP_SELECTVAR"

```
"OxPackSpecialDialog"("OP_SELECTVAR", sTitle, iDbChangeAllowed,
    iLagAllowed, aReturn);
```

iDbChangeAllowed	in:	int, set to one if the user can change OxMetrics database
iLagAllowed	in:	int, set to one if user can specify a (single) lag length
aReturn	in:	address of variable
	out:	array[5]: [0]: $k \times T$ data matrix, k variables, T observations, [1]: array with k names, [2]: int, specified lag length (or zero) [3]: array[5], start year, start period, end year, end period, frequency [4]: string, database name

"OP_TEXT"

```
"OxPackSpecialDialog"("OP_TEXT", sTitle, sMsg, sCode, iShowDb,
    sDesc, aReturn);
"OxPackSpecialDialog"("OP_TEXT", sTitle, sMsg, sCode, iShowDb,
    sDesc, sExt, sFileType, aReturn);
```

sMsg	in:	string, message (e.g. brief explanation)
sCode	in:	string, initial code
iShowDb	in:	int, 1: show current database
sDesc	in:	string, description
sExt	in:	string, extension, e.g. ".txt"
sFileType	in:	string, file type, e.g. "Text"
aReturn	in:	address of variable
	out:	string, the new code

"OP_YESNO"

```
"OxPackSpecialDialog"("OP_YESNO", sTitle, sMsg, sLine, aReturn);
```

sMsg	in:	string, message test
sLine	in:	(optional) string, additional short query
aReturn	in:	address of variable
	out:	unused

"OP_VARIABLE"

```
"OxPackSpecialDialog"("OP_VARIABLE", sTitle, sMsg, aX, aReturn);
"OxPackSpecialDialog"("OP_VARIABLE", sTitle, sMsg, aX, asX, aReturn);
```

sMsg	in:	string, message test
aX	in:	address of variable to edit
	out:	variable, possibly modified
asX	in:	array of strings with names of variables
aReturn	in:	address of variable
	out:	int, 1 if variable was changed, 0 otherwise

OxPackStore

```
"OxPackStore"(const vX, const iT1, const iT2, const sX);
"OxPackStore"(const vX, const iT1, const iT2, const sX, const bQuery);
```

vX	in:	$T \times 1$ data vector to store in database
iT1	in:	int, offset (observation index) in database of start of data
iT2	in:	int, $T+$ `iT1` -1
sX	in:	string, variable name
bQuery	in:	int, if `TRUE`: confirm name in OxMetrics

Return value

A string with the name of the stored variable (if successful).

Description

Stores a variable in the database.

OxPackWriteProfile...

```
"OxPackWriteProfileInt"(const sKey, const sLabel, int iValue);
"OxPackWriteProfileDouble"(const sKey, const sLabel, int dValue);
"OxPackWriteProfileString"(const sKey, const sLabel, int sValue);
```

sKey	in:	string, key name, or 0 to use package name
sLabel	in:	string, label name
iValue	in:	int, value to set
dValue	in:	double, value to set
sValue	in:	string, value to set

No return value.

Description

Writes persistent settings to the registry. See `Modelbase::SaveOptions` for an example.

D5.5 Modelbase virtual functions for OxPack

The default menu structure in Modelbase is defined through SendMenu:

```
Modelbase::SendMenu(const sMenu)
{
    if (sMenu == "Model")
    {
        return
        {   { "&Formulate...\tAlt+Y",       "OP_FORMULATE"},
            { "Model &Settings...\tAlt+S",  "OP_SETTINGS"},
            { "&Estimate...\tAlt+L",        "OP_ESTIMATE"},
            0,
            { "&Progress...",               "OP_PROGRESS"},
            0,
            { "&Options...\tAlt+O",         "OP_OPTIONS"}
        };
    }
    else if (sMenu == "Test")
    {
        return
        {   { "&Exclusion Restrictions...", "OP_TEST_SUBSET"},
            { "&Linear Restrictions...",    "OP_TEST_LINRES"},
            { "&General Restrictions...",   "OP_TEST_GENRES"}
        };
    }
    return 0;
}
```

This default does not use model classes to distinguish between different types of sub-models.

Running a Modelbase package from OxPack involves the following calls:

1. OxPack starts package, calling:
   — constructor
   — `LoadOptions()` load persistent settings
   — `SendMenu("ModelClass")` Model class items on Model menu
   — `SendMenu("Model")` Model menu items (below model class items)
   — `SendMenu("Test")` Test menu items
   — `BatchCommands()` Query for batch commands

2. User selects new model class (if possible):
   — `ReceiveMenuChoice(id_string)`
   — `SendMenu("ModelClass")`
   — `SendMenu("Model")`
   — `SendMenu("Test")`

3. User selects a model or test menu item:
   — `ReceiveMenuChoice(id_string)`

4. User selects the `"OP_FORMULATE"` item:
   — `ReceiveMenuChoice("OP_FORMULATE")` call `DoFormulateDlg(2)`, if accepted:

— SetModelSettings() with previous settings

5. User selects the "OP_SETTINGS" item:
   — ReceiveMenuChoice("OP_SETTINGS") calling DoSettingsDlg()

6. User selects the "OP_ESTIMATE" item:
   — OxPack loads the selected data from OxMetrics
   — ReceiveData()
   — ReceiveModel()
   — ReceiveMenuChoice("OP_ESTIMATE") calling DoEstimateDlg()
   — Estimate() if this is successful:
   — GetLogLik()
   — GetFreeParCount()
   — GetcT()
   — GetcDfLoss()
   — GetMethodLabel()
   — GetModelLabel()
   — GetModelDescription()
   — GetBatchModelSettings()
   — GetBatchEstimate()
   — GetOxCode()
   — GetModelSettings()

7. Running batch code from OxMetrics, calling:
   to prepare to receive the model formulation:
   — SendSpecials()
   — SendVarStatus()
   — IsCrossSection()
   to receive the batch command:
   — Batch()
   to receive the estimate command:
   — SetSelSample() or SetSelSampleByDates()
   — SetForecasts()
   — SetRecursive()
   — BatchMethod()

8. OxPack closes package, calling:
   — SaveOptions() save persistent settings
   — destructor

Modelbase::DoEstimateDlg

```
virtual DoEstimateDlg(const iFirstMethod, const cMethods,
    const sMethods, const bForcAllowed, const bRecAllowed,
    const bMaxDlgAllowed);
```

`iFirstMethod`	in:	int, index of first method (often 0),
`cMethods`	in:	int, number of estimation methods (use zero to skip method selection),
`sMethods`	in:	string, estimation methods, separated by `|`,
`bForcAllowed`	in:	int, `TRUE` if observations can be withheld at this stage for forecasting,
`bRecAllowed`	in:	int, `TRUE` if recursive estimation is allowed,
`bMaxDlgAllowed`	in:	int, `TRUE` if the maximization dialog (i.e. non-automatic) is allowed.

Return value

Returns `TRUE` if the users accepts the dialog.

Description

Creates and shows a sample selection dialog for estimation.

Example:

```
if (Modelbase::DoEstimateDlg(0, 2, "Newton's method|BFGS method",
    FALSE, FALSE, FALSE))
{
    if (m_iMethod == 0)
        m_fnMax = MaxNewton, m_sMax = "Newton";
    else
        m_fnMax = MaxBFGS, m_sMax = "BFGS";
    return TRUE;
}
return FALSE;
```

Modelbase::DoFormulateDlg

```
virtual DoFormulateDlg(const iLagMode);
virtual DoFormulateDlg(const iLagMode, const iLagDefault);
```

`iLagMode`	in:	int, -1: no lags allowed; ≥ 0: default for first lags drop down box: 0=None, 1=Lag, 2=Lags 0 to)
`iLagDefault`	in:	int, ≥ 0: default for lag value box

Return value

Returns `TRUE` if the users accepts the dialog.

Description

Calls the `OP_FORMULATE` dialog using `SendSpecials` and `SendVarStatus`.

Modelbase::DoOption, Modelbase::DoOptionsDlg

```
virtual DoOption(const sOpt, const val);
virtual DoOptionsDlg(const aMoreOptions);
```

`sOpt`	in:	string, label of option
`val`	in:	value of option
`aMoreOptions`	in:	array, dialog options that are to be appended to the Modelbase default.

Return value

`DoOptionsDlg` returns `TRUE` if the users accepts the dialog.

Description

Creates and shows an options dialog. Options that are appended using the `aMoreOptions` argument are processed by calls to `DoOption`, which therefore must be overridden in that case.

Modelbase::DoSettingsDlg

```
virtual DoSettingsDlg();
```

Return value

Returns `TRUE` if the users accepts the dialog.

Description

The settings usually relate to the model settings, such as ARMA or GARCH order, etc. The Modelbase default does not display a dialog, but just returns `TRUE`.

Modelbase::ForceYlag

```
ForceYlag(const iYgroup);
```

`iYgroup`	in:	int, identifier of group to adjust, or: array[2], identifier of group to adjust, followed by group to change from

No return value.

Description

By default, lagged dependent variables in modelbase are not classified as `Y_VAR` but as the default regressor type. Use `ForceYlag(Y_VAR)` to change lags to `Y_VAR`, which is the convention used in most Modelbase derived packages to facilitate dynamic analysis.

Or use (e.g.) `ForceYlag( {Y_VAR, X_VAR} )` to only change lagged Y's that are `X_VAR` to `Y_VAR`.

Modelbase::GetModelSettings

```
virtual GetModelSettings();
```

Return value

Returns a $c \times 2$ array with labels (`aValues[i][1]`) and values (`aValues[i][0]`).

Description

Called by OxPack after successful estimation, to get model settings for the model history. This allows model parameters to be recalled together with the model specification.

Modelbase::LoadOptions

```
virtual LoadOptions();
```

No return value.

Description

Called by OxPack to load persistent settings when a package is activated. For example, in `Modelbase`:

```
decl deps1, deps2, iprint, iitmax, bcompact;
[iitmax, iprint, bcompact] = GetMaxControl();
[deps1, deps2] = GetMaxControlEps();

iitmax  = "OxPackReadProfileInt"("ModelBase", "itmax", iitmax);
iprint  = "OxPackReadProfileInt"("ModelBase", "iprint", iprint);
bcompact= "OxPackReadProfileInt"("ModelBase", "bcompact", bcompact);
deps1   = "OxPackReadProfileDouble"("ModelBase", "deps1", deps1);
deps2   = "OxPackReadProfileDouble"("ModelBase", "deps2", deps2);

MaxControl(iitmax, iprint, bcompact);
MaxControlEps(deps1, deps2);
```

Modelbase::ReceiveData

`virtual ReceiveData();`

No return value.

Description

Called by OxPack as part of estimation, prior to `ReceiveModel()`. The default implementation creates the database, and stores the model data in the database, also see `OxPackGetData()`.

Modelbase::ReceiveMenuChoice

`virtual ReceiveMenuChoice(const sDialog);`

`sDialog`	in:	string, menu command identifier

Return value

Returns 1 if successful, 0 otherwise.

Description

Called by OxPack when the user selects a menu item.

Modelbase::ReceiveModel

`virtual ReceiveModel();`

Description

Called by OxPack as part of estimation, after `ReciveData` and prior to `Estimate()`. The default implementation extracts the model formulation from OxPack, also see `OxPackGetData()`.

Modelbase::SaveOptions

`virtual SaveOptions()`

No return value.

Description

Called by OxPack to save persistent settings when a package is closed (to load a different package, or when OxPack is exiting). For example, in `Modelbase`:

```
decl deps1, deps2, iprint, iitmax, bcompact;
[iitmax, iprint, bcompact] = GetMaxControl();
[deps1, deps2] = GetMaxControlEps();
"OxPackWriteProfileInt"("ModelBase", "itmax", iitmax);
"OxPackWriteProfileInt"("ModelBase", "iprint", iprint);
"OxPackWriteProfileInt"("ModelBase", "bcompact", bcompact);
"OxPackWriteProfileDouble"("ModelBase", "deps1", deps1);
"OxPackWriteProfileDouble"("ModelBase", "deps2", deps2);
```

Modelbase::SendFunctions

`virtual SendFunctions();`

Return value

Returns an array of which each item is an array of three strings: function name, label of first argument, label of second argument. Returns 0 if functions are not implemented.

Description

Could be used by derived class as part of model formulation, after `SendSpecials`, to determine if additional functions are used as part of the model formulation process. For example, the DPD class uses:

```
return
    { {"Gmm", "Lag1", "Lag2"},
      {"GmmLevel", "Lag length", "1=Diff 0=Lag"}
    };
```

In this case, the value received from a call to `"OxPackGetData"("Functions")` could be:

```
    { {"Gmm",      "n", 1, 2},
      {"GmmLevel", "y", 1, 0},
      {"GmmLevel", "w", 1, 0}
    }
```

Modelbase::SendMenu

`virtual SendMenu(const sMenu);`

`sMenu` in: name of menu, `"Package"`, `"ModelClass"`, `"Model"`, or `"Test"`

Return value

Returns an array of which each item is an array of two strings: menu command text, followed by the menu command identifier. Returns 0 if the menu is not implemented.

Description

Called by OxPack to determine the content of the menus. The command identifiers can be any string, or an empty string to indicate that the menu item is inactive. For example, the Arfima class uses for the Test menu:

```
if (sMenu == "Test")
{   return
        {{ "&Graphic Analysis", "OP_TEST_GRAPHICS"},
         { "&Forecast...", "OP_TEST_FORECAST"},
         0,
         { "&Test Summary", "OP_TEST_SUMMARY"},
         0,
```

```
        { "Exclusion Restrictions...", "OP_TEST_SUBSET"},
        { "Linear Restrictions...",    "OP_TEST_LINRES"}
        };
}
```

The ampersand in the command text indicates a short-cut character (will be underscored in the menu). The ellipse is used to indicate to the user that a dialog will follow. The entry of 0 paints a separator between menu items.
The menu identifier is passed to `ReceiveMenuChoice()` by OxPack to allow the package to execute the action.
`"OP_SETTINGS"`, `"OP_ESTIMATE"` and `"OP_PROGRESS"` have a special meaning for OxPack. These Model menu items are only active when a model has been estimated. Test menu items are only active when a model has been estimated. Some `OP_TEST...` identifiers are predefined to allow a connection to the toolbar buttons (however, other identifiers may also be used, which are then not linked to the toolbar):

`"OP_TEST_GRAPHICS"`	Graphic Analysis
`"OP_TEST_GRAPHREC"`	Recursive Graphics
`"OP_TEST_FORECAST"`	Forecasts
`"OP_TEST_SUMMARY"`	Test Summary
`"OP_TEST_DYNAMICS"`	Dynamic Analysis

When `sMenu` equals `"ModelClass"`, OxPack allows setting of model classes at the top of the Model menu. Up to 16 are allowed, and their identifiers are `"modelclass0"`, `"modelclass1"`, etc.. An additional entry specifies which model class is active. For example:

```
if (sMenu == "ModelClass")
{
    return
        {{ "&1: Binary", "modelclass0", m_iModelClass == MC_BINARY},
         { "&2: Count",  "modelclass1", m_iModelClass == MC_COUNT}
         };
}
else if (sMenu == "Test")
{   // ...
}
```

Modelbase::SendSpecials

```
virtual SendSpecials();
```

Return value

Returns 0 if there are no special variables. Returns an array of strings listing the special variables otherwise.

Description

Used by Modelbase as part of model formulation, after `SendVarStatus`, to determine the content of the special variables listbox in the model formulation dialog. The default implementation returns {`"Constant", "Trend", "Seasonal"`}.

Modelbase::SendVarStatus

```
virtual SendVarStatus();
```

Return value

Returns an array, where each item is an array defining the type of variable:

1. string: status text,
2. character: status letter,
3. integer: status flags,
4. integer: status group.

Description

Called by Modelbase as part of model formulation, to determine the variable types which are available in the model formulation dialog. For example, the Modelbase default is:

```
return
    {{ "&Y variable", 'Y', STATUS_GROUP + STATUS_ENDOGENOUS, Y_VAR},
     { "&X variable", 'X', STATUS_GROUP, X_VAR}};
```

The status text, and is used on the data selection dialog button. The status letter used to indicate the presence of the status. The status flags can be:

- STATUS_DEFAULT: is default: no status letter displayed;
- STATUS_ENDOGENOUS: apply to first (non-special) variable at lag 0;
- STATUS_GROUP : is a group (each variable is in only one group);
- STATUS_GROUP2: is a second group (each variable is only in one of each group);
- STATUS_GROUP3: is a third group (each variable is only in one of each group);
- STATUS_GROUP4: is a fourth group (each variable is only in one of each group);
- STATUS_GROUP5: is a fifth group (each variable is only in one of each group);
- STATUS_MULTIPLE: multiple instances of a variable are allowed
- STATUS_MULTIVARIATE: apply to all (non-special) variables at lag 0;
- STATUS_ONEONLY: only one variable can have this status.
- STATUS_SPECIAL: apply to all special variables;
- STATUS_TRANSFORM: is a transformation;

Some flags can be combined by adding the values together.

As a second example, consider the status definitions of the DPD class:

```
return
  {{ "&Y variable", 'Y', STATUS_GROUP + STATUS_ENDOGENOUS, Y_VAR},
   { "&X variable", 'X', STATUS_GROUP, X_VAR},
   { "&Instrument", 'I', STATUS_GROUP2, I_VAR},
   { "&Level instr",'L', STATUS_GROUP2, IL_VAR},
   { "Yea&r",       'r', STATUS_GROUP + STATUS_ONEONLY, YEAR_VAR},
   { "I&ndex",      'n', STATUS_GROUP + STATUS_ONEONLY, IDX_VAR}
  };
```

Modelbase::SetModelSettings

```
virtual SetModelSettings(const aValues)
```

aValues in: if array: $c \times 2$ array with labels (aValues[i][1]) and values (aValues[i][0]).

No return value.

Description

Called by OxPack to set model settings. This is called immediately after model formulation, before model settings, to inherit default settings from the previous model, or the model that was recalled from history.

Table D5.1 Batch commands (partially) handled by OxPack

`estimate("`*METHOD*`"="OLS",`*YEAR1*`=-1,`*PER1*`=0,` *YEAR2*`=-1,`*PER2*`=0,`*FORC*`=0,`*INIT*`=0) ;`
`model { ... }`
`nonlinear { ... }`
`progress;`
`system { ... }`

D5.6 Adding support for a Batch language

Modelbase::Batch

`virtual Batch(const sBatch, ...);`

`sBatch`	in:	a string with name of the batch command
`...`	in:	zero or more batch arguments

Return value

Should return `TRUE` if the batch command was correct, `FALSE` if there was a syntax error.

Description

All Batch commands are directly passed to the Ox class, with the exception of those listed in Table D5.1.

The arguments of the batch command are passed separately. For example, when the batch call is

```
test("ar", 1, 2);
```

this function is called as

```
Batch("test", "ar", 1, 2);
```

Note that batch commands can have a variable number of arguments, so

```
test("ar", 1);
```

is a valid call, and the Ox class should use default values for the missing arguments.

estimate Involves the following steps:

- Load data from OxMetrics.
- Calls to `ReceiveData` and `ReceiveModel`.
- Calls to `SetSelSample(` *YEAR1*, *PER1*, *YEAR2*, *PER2*`)`, `SetForecasts(`*FORC*`)`, `SetRecursive(`*INIT*>0, *INIT*`)`, `BatchMethod(`*METHOD*`)`.
- Call to `Estimate`, following interactive OxPack from here.

nonlinear Stored in OxPack, before passed on in the call to `Batch("nonlinear",` code`)`.

progress Activates the `"OP_PROGRESS"` item on the model menu.

system Calls to `SendSpecials`, `SendVarStatus` and `IsCrossSection` to determine the special variables, variable statuses, and whether lags are allowed (not if `IsCrossSection` exists and returns a positive integer) for model formulation.

testres Calls `TestRestrictions` with an array of strings as argument.

testlinres Calls `TestRestrictions` with two arguments: the matrix R' and the column vector r.

Modelbase::BatchCommands

```
virtual BatchCommands();
```

Return value

Should return an array of strings with batch commands.

Description

If this function does not exist, only a few predefined commands will work (`system`, `estimate`, `progress`; `estimate` will also require `BatchMethod` if there is more than one method).

Here is an example from PcGive:

```
PcGive::BatchCommands()
{
    return
    {   "adftest(\"VAR\", LAG, DETERMINISTIC=1, SUMMARY=1);",
        "arorder(AR1, AR2);",
        "comfac;",
        "cointcommon { };",
        "cointknown { };",
        "constraints { };",
        "derived { };",
        "dynamics;",
        "encompassing;",
        "forecast(NFORC, HSTEP=0, SETYPE=1);",
        "option(\"OPTION\", ARGUMENT);",
        "output(\"OPTION\", VALUE=1);",
        "rank(RANK);",
        "store(\"WHAT\", \"RENAME\"=\"\");",
        "test(\"TYPE\"=\"\", LAG0=0, LAG1=0);",
        "testlinres { }",
        "testgenres { }",
        "testres { }",
        "testsummary"
    };
}
```

Modelbase::BatchMethod

```
virtual BatchMethod(const sMethod);
```

`sMethod`	in:	a string with the first argument of the `estimate` batch command

Return value

Should return the index of the method type.

Description

This function is called immediately after processing the `estimate` batch command. When writing batch code, OxPack uses the return value from GetMethodLabel() to determine the first argument of `estimate`. Therefore, the input argument should match the possible return values of `GetMethodLabel()`, and the return value the index.

Modelbase::GetBatchEstimate, Modelbase::GetBatchModelSettings

```
virtual GetBatchEstimate();
```

`virtual GetBatchModelSettings();`

Return value

The required batch code as a string.

Description

When the Batch editor is opened, it will show the batch code for the estimated model. OxPack writes the `package`, `usedata` and `system` (or `nonlinear`) parts, then calls `GetBatchModelSettings` and `GetBatchEstimate` for the rest.

D5.7 Adding support for Help

Help is implemented through HTML files. When the user presses F1 in a dialog, an anchor in the html file is launched.

The anchor (or help string) is based on the title of the dialog (without the model class specific component). The title is modified as follows:

1. the first letter is made uppercase,
2. all remaining letters lowercase,
3. spaces are replaced with an underscore,
4. the result is prefixed with a # symbol.
5. If there is more than one model class, and the current model class is not zero (i.e. not the first), then $.n$ is appended, where n equals one plus the model class.
6. If there is more than one package embedded (this can only happen with OxModel packages such as PcGive and STAMP), and the current class is not zero, then the model class name is inserted immediately after the # symbol, followed by a dot.

The HTML file is searched for as follows. Let `package_path` be the path of the oxo file, and `package_name` the name without extension. then:

1. drop `\bin` from `package_path`, then
2. drop trailing digits from `package_name`
3. try path `package_path\doc`
4. try path `package_path\doc\package_name`
5. try path `package_path\package_name`
6. try path `package_path\package_name\doc`
7. try file `path\package_name.html`

The BprobitEx example in `samples/oxpack` contains a help file, `BprobitEx.html`.

Chapter D6

Using OxGauss

D6.1 Introduction

Ox has the capability of running a wide range of Gauss[1] programs (compatible with versions up to 3.2.x). Gauss code can be called from Ox programs, or run on its own. The formal syntax of OxGauss is described in Chapter D7. Section D6.7 lists some of the limitations of OxGauss. The remainder of this chapter gives some examples on its use, as well as a comparison between Ox and Gauss syntax.

Additional information can be found in Laurent and Urbain (2005), 'Bridging the gap between Ox and Gauss using OxGauss', *Journal of Applied Econometrics*, **20**, 131–139. They provide additional examples, and tested a range of Gauss codes that were found on the web in OxGauss.

The M@ximize library, `www.core.ucl.ac.be/~laurent/M@ximize`, bridges the gap between cml, maxlik, optmum and Ox.

D6.2 Running OxGauss programs from the command line

As an example we consider a small project, consisting of a code file that contains a procedure and an external variable, together with a code file that includes the former and calls the function. We shall always use the `.src` extension for the OxGauss programs.

samples/oxgauss/gaussfunc.src

```
declare matrix _g_base = 1;

proc(0)=gaussfunc(a,b);
    "calling gaussfunc";
    retp(a+_g_base*eye(b));
endp;
```

[1] GAUSS is a trademark of Aptech Systems, Inc., Maple Valley, WA, USA

samples/oxgauss/gausscall.src

```
#include gaussfunc.src;

_g_base = 20;
z = gaussfunc(10,2);
"result from gaussfunc" z;
```

To run this program on the command line, enter

```
oxl -g gausscall.src
```

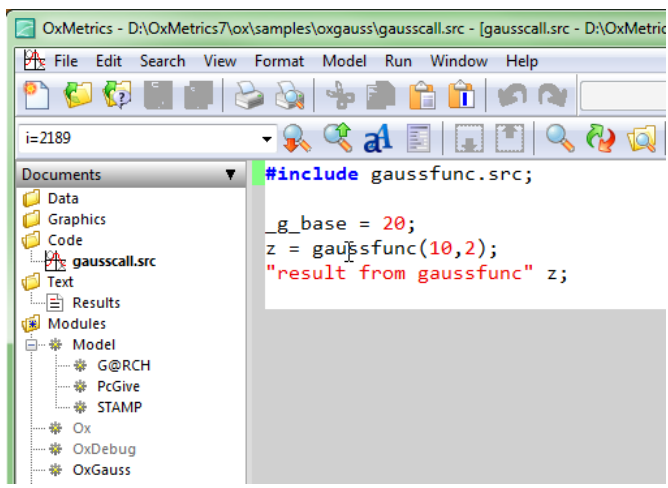
Which produces the output:

```
Ox version 3.00 (Windows) (C) J.A. Doornik, 1994-2001
calling gaussfunc
result from gaussfunc
       30.000000         10.000000
       10.000000         30.000000
```

If there are problems at this stage, we suggest to start by reading the first chapter of the 'Introduction to Ox'.

D6.3 Running OxGauss programs from OxMetrics

Using Ox Professional, the OxGauss program can be loaded into OxMetrics. The syntax highlighting makes understanding the program easier:



Click on Run (the running person) to execute the program. This runs the program using the *OxGauss* application, with the output in a window entitled OxGauss Session. OxMetrics will treat the file as an OxGauss file if it has the `.src`, `.g` or `.oxgauss` extension. If not, the file can still be run by launching *OxGauss* from the OxMetrics workspace window.

D6.4 Calling OxGauss from Ox

The main objective of creating OxGauss was to allow Gauss code to be called from Ox. This helps in the transition to Ox, and increases the amount of code that is available to users of Ox.

The main point to note is that the *OxGauss code lives inside the* `gauss` *namespace*. In this way, the Ox and OxGauss code can never conflict.

Returning to the earlier example, the first requirement is to make an Ox header file for `gaussfunc.src`. This must declare the external variables and procedures explicitly in the `gauss` namespace:

samples/oxgauss/gaussfunc.h

```
namespace gauss
{
    extern decl _g_base;
    gaussfunc(const a, const b);
}
```

Next, the OxGauss code must be imported into the Ox program. The `#import` command has been extended to recognize OxGauss imports by prefixing the file name with `gauss::`, as in the following program:

samples/oxgauss/gausscall.ox

```
#include <oxstd.h>
#import "gauss::gaussfunc"
main()
{
    gauss::_g_base = 20;
    decl z = gauss::gaussfunc(10,2);
    println("result from gaussfunc", z);
}
```

When the OxGauss functions or variables are accessed, they must also be prefixed with the namespace identifier `gauss::`. The output is:

```
calling gaussfunc
result from gaussfunc
       30.000       10.000
       10.000       30.000
```

D6.5 How does it work?

When an OxGauss program is run, it automatically includes the `ox/include/oxgauss.ox` file. This itself imports the required files:

```
#define OX_GAUSS
#import <g2ox>
#import <gauss::oxgauss>
```

These import statements lead to `g2ox.h` and `oxgauss.h` being included. The majority of the OxGauss run-time system is in `g2ox.ox`. The keywords are largely in

oxgauss.src, because they cannot be defined in Ox (however keyword functions can be declared by prefixing them with extern "keyword", see oxgauss.h) .

D6.6 Some large projects

The objective now is to give several serious examples, discussing some of the issues that can be encountered. The code for these is available on the internet.[2]

D6.6.1 DPD98 for Gauss

Download and install DPD from www.cemfi.es/~arellano/#dpd (for example in ox/packages/DPD98 for Gauss).[3] DPD stands for dynamic panel data.

Rename file The main file is dpd98.run, so rename that to dpd98.oxgauss to get syntax highlighting and the OxMetrics Run button. Windows users using Ox Professional may note that now it can be run directly from the Explorer window by clicking on the file.

Fix for OxGauss syntax There are several warnings that 'dot part of number, not dot operator', which happens when writing for example: 1.*x. It is safer to insert some spacing or a 0. There are also two errors:

```
dpd98.prg (411): 'gauss::fms' undeclared identifier
dpd98.prg (412): 'gauss::obs' undeclared identifier
```

If you are in OxMetrics or OxEdit, jump to these errors by double-clicking on the first. The lines

```
fms=fms+mul;
obs=obs+n;
```

are problematic because fms and obs are used on the right-hand side before they exist. This is quickly fixed by inserting:

```
fms=0;
obs=0;
```

at the top of dpd98.oxgauss.

Convert data files Running the modified program gives twice the 'Invalid .FMT or .DAT file' error message, before falling over an array indexing problem (note that indexing errors are always reported with element 0 the first element, which is the Ox convention). The reason is that old style data sets (v89 .dht/.dat) must be converted to the new format (v96 .dat). The program to do this conversion is ox/lib/dht2dat. The conversion can be run from the command line as:

[2] Note that more comprehensive tests can be found in Laurent and Urbain (2005), 'Bridging the gap between Ox and Gauss using OxGauss', *Journal of Applied Econometrics*, **20**, 131–139.

[3] PcGive also incorporates DPD for panel data estimation. And there a DPD package for Ox, which can also be used interactively with Ox Professional. Therefore, there is no reason to attempt to call DPD98 from Ox.

```
oxl lib/dht2dat auxdata.dht auxdata1.dat
oxl lib/dht2dat xdata.dht xdata1.dat
```

Now `dpd98.oxgauss` must be adjusted to use `auxdata1` and `xdata1` (in the `open` commands).

Running the program As a final change set *bat* to one:

```
@ Set bat=1 to use in batch mode @      bat=1;
```

and the program, which is more than 2000 lines, will run successfully.

D6.6.2 BACC2001

BACC stands for Bayesian Analysis, Computation, and Communication, see `www2.cirano.qc.ca/~bacc/`.

We only tested this on the 2001 version of BACC. The most recent version is BAC2003. The GAUSS version of BACC can be found as `baccWinGauss.zip` at `www2.cirano.qc.ca/~bacc/bacc2003` .

Installation BACC is library based, and the files need to be copied to their correct location:

- `ox/oxgauss/lib`
  Copy `libPCBACC.lcg` to this folder.
- `ox/oxgauss/src`
  Copy all `.src` files to `ox/oxgauss/src/bacc`.
- `ox/oxgauss/dlib`
  Copy `libBACC.dll` to this folder.

Next, load `libPCBACC.lcg` in your editor, and change all instances of `c:\gauss\src\` to `bacc/`, for example:

```
bacc/initPCBACC.src
    initPCBACC:proc
```

Running the program A test program is supplied in the `test` folder of the zip file. Rename `BACCTEST` to `BACCTEST.src`, and run the file.

As it stands, the test program will bomb when trying to print the error message 'k less than or equal to 1.'[4] This happen in the first call to `robust`. Since the error message would abort the program anyway, it is better to comment out this line, so that the test program can run to completion.

D6.7 Known limitations

- `printfm` ignores the format argument.
- Character arrays cannot be transposed.

[4] It seems that error messages crash the DLL. If you wish to avoid this, recompile BACC replacing `fprintf(stderr,` with `printf(` in `error.c`.

- Obsolete v89 data sets must be converted to v96; `lib/dht2dat.ox` can be used for this. Obsolete v92 data sets are not supported.
- Dataloop commands are not supported.
- Complex numbers are not supported.
- Indexing error messages always use base zero.
- An argument cannot be called `fn`, because that is a reserved word. Change to `func` (e.g.).
- The pgraph library has only been partially implemented.

D6.8 OxGauss Function Summary

abs(a);
    returns absolute value of a
arccos(a);
    returns arccosine of a
arcsin(a);
    returns arcsine of a
arctan,arctan2
    see atan,atan2
atan(a);
    returns arctangent of a
atan2(y,x);
    returns arctangent of y ./ x
{x,s}=balance(a);
    returns balanced matrix x and diagonal scale matrix s
band(a,n);
    returns banded matrix with bandwidth n (diagonal + n)
bandchol(b);
    returns Choleski decomposition of banded matrix
bandcholsol(b,r);
    solves system where b is output from bandchol, and r is right-hand side
bandltsol(mb,ma);
    as bandsolpd
bandrv(mx);
    undoes band()
bandsolpd(mb,ma);
    solves system where b band matrix, and r is right-hand side
{mantissa,power}=base10(x);
    writes x as $m * 10^p, -10 < m < 10$
besselj(n,x);
    returns Bessel function $J_n(x)$ for integer n
bessely(n,x);
    returns Bessel function $Y_n(x)$ for integer n
cdfbeta(x,df1,df2);
    returns $P(X \leq x)$ for $X \sim Beta(a, b)$

cdfbvn(h,k,r);
    returns $P(X \leq h, Y \leq k)$ for $X, Y \sim BVN(r)$
cdfbvn2(h,dh,k,dk,r);
    unsupported
cdfbvn2e(h,dh,k,dk,r);
    unsupported
cdfchic(x,nu);
    returns $P(X \geq x)$ for $X \sim \chi^2(nu)$
cdfchii(p,nu);
    returns x for $P(X \leq x) = p$ for $X \sim \chi^2(nu)$
cdfchinc(x,nu,k);
    returns $P(X \leq x)$ for $X \sim \chi^2_d(nu)$ with non-centrality $d = k^2$
cdffc(x,m,n);
    returns $P(X \geq x)$ for $X \sim F(m, n)$
cdffnc(x,m,n,d);
    returns $P(X \leq x)$ for $X \sim F_k(m, n)$ with non-centrality $d = k^2$
cdfgam(r,x);
    returns $P(X \leq x)$ for $X \sim \Gamma(x; r, 1)$
cdfmvn(x,r);
    unsupported
cdfn(ma);
    returns $P(X \leq x)$ for $X \sim N(0, 1)$
cdfn2(x,d);
    returns $P(X \leq x + d) - P(X \leq x)$ for $X \sim N(0, 1)$
cdfnc(x);
    returns $P(X \geq x)$ for $X \sim N(0, 1)$
cdfni(p);
    returns x for $P(X \leq x) = p$ for $X \sim N(0, 1)$
cdftc(x,n);
    returns $P(X \geq x)$ for $X \sim t(n)$
cdftci(p,n);
    returns x for $P(X \geq x) = p$ for $X \sim t(n)$
cdftnc(x,v,k);
    returns $P(X \leq x)$ for $X \sim t_k(n)$ with non-centrality k
cdftvn(x1,x2,x3,rho12,rho23,rho31);
    unsupported
cdir(s);
    get current working directory (s is 0, "" or string with drive letter)
ceil(a);
    returns the ceiling of a
changedir(s);
    change directory, returns current directory
chdir s;
    keyword version of changedir
chol(x);
    returns the Choleski decomposition of x

```
choldn(p,x);
    returns the Choleski decomposition of p'p-x'x
cholsol(b,a);
    solves ax=b using the Choleski decomposition
cholup(p,x);
    returns the Choleski decomposition of p'p+x'x
chrs(mx);
    converts numbers into characters (32 to a space, etc.), returns a string
clear
    sets variables to 0, creates them if in main section
clearg
    sets global variables to 0, creates them if in main section
close(fileno);
    closes the file
closeall fileno1,fileno2,...;
    closes all files and sets specified variables to 0
cls();
    does nothing
{zr,zi} = cmadd(xr,xi,yr,yi);
    returns result from complex addition (not in complex mode)
{zr,zi} = cmcplx(x);
    returns x,0 (not in complex mode)
{yr,yi,zr,zi} = cmcplx2(x1,x2);
    returns x1,0,x2,0 (not in complex mode)
{zr,zi} = cmdiv(xr,xi,yr,yi);
    returns result from complex dot division (not in complex mode)
{zr,zi} = cmemult(xr,xi,yr,yi);
    returns result from complex dot multiplication (not in complex mode)
cmimag(xr,xi);
    returns xi (not in complex mode)
{zr,zi} = cminv(xr,xi);
    returns result from complex inversion (not in complex mode)
{zr,zi} = cmmult(xr,xi,yr,yi);
    returns result from complex multiplication (not in complex mode)
cmreal(xr,xi);
    returns xr (not in complex mode)
{zr,zi} = cmsoln(br,bi,ar,ai);
    returns result from complex solution to (ar,ai)z=(br,bi) (not in complex mode)
{zr,zi} = cmsub(xr,xi,yr,yi);
    returns result from complex subtraction (not in complex mode)
{zr,zi} = cmtrans(xr,xi);
    returns result from complex transpose (not in complex mode)
code(me,v);
    returns recoded version of v, according to rows in me
color(s);
    does nothing
```

cols(a);
    returns number of columns in a
colsf(fh);
    returns number of columns in matrix file fh
comlog;
    keyword, does nothing
compile;
    keyword, does nothing
complex(xr,xi);
    unsupported, creates a complex matrix (only in complex mode)
con(r,c);
    enter a matrix from the keyboard (interactive mode)
cond(a);
    returns condition number of a (using SVD)
conj(z);
    unsupported, returns complex conjugate of z (only in complex mode)
cons();
    enter a string from the keyboard (interactive mode)
conv(a,b,first,last);
    returns the convolution of a and b from first to last
coreleft();
    returns $2^3 1$
corrm(m);
    returns correlation matrix when m=x'x and first column of x is 1
corrvc(vc);
    returns correlation matrix from variance-covariance matrix
corrx(mx);
    returns correlation matrix from data matrix
cos(a);
    returns cosine
cosh(a);
    returns hyperbolic cosine
counts(x,v);
    return counts of elements in x that fall between values in v
countwts(x,v,w);
    return weighted counts of x that fall between values in v
create [complex] fh=fname with vnames,col,typ;
    creates a file
create [complex] fh=fname using comfile;
    creates a file
crossprd(x,y);
    returns cross product of x,y (both 3 x m)
crout(x);
    returns LU decomposition of x in one matrix, U has diagonal of ones.
croutp(x);
    as crout, but with pivoting, pivots are appended as extra row.

csrcol();
    unsupported
csrlin();
    unsupported
csrtype(mx);
    returns 1
cumprodc(mx);
    returns in a column: cumulative product of each column
cumsumc(mx);
    returns in a column: cumulative sum of each column
cvtos(mas);
    returns a string representing the vector of character data
datalist dataset var1 var2 ...;
    unsupported
date(d);
    returns 4×1 vector: year, month, day, 100th of seconds after midnight
datestr(vt);
    returns "mm/dd/yy", vt is 0 for today or vector with y,m,d,...
datestring(vt);
    returns "mm/dd/yyyy", vt is 0 for today or vector with y,m,d,...
datestrymd(vt);
    returns "yyyymmdd", vt is 0 for today or vector with y,m,d,...
dayinyr(vt);
    returns day of the year, vt is 0 for today or vector with y,m,d,...
debug filename;
    keyword, does nothing
delete [/flags] [symbol1,symbol2,...];
    unsupported
delif(x,vif);
    deletes rows of x if there is a 1 in the corresponding row of vif
design(x);
    returns a 0-1 matrix with a 1 in the columns specified by x
det(ma);
    returns determinant of x
detl(mx);
    returns determinant from last chol,crout,croutp,det,inv,invpd,solpd,y/x
{zr,zi}=dfft(xr,xi);
    returns the discrete FFT of (xr,xi)
{zr,zi}=dffti(xr,xi);
    returns the reverse discrete FFT of (xr,xi)
dfree(drive);
    returns 2^31
diag(a);
    returns the diagonal of a as a column vector
diagrv(a,mdiag);
    returns a with its diagonal replaced by mdiag

disable
    ignored: is always on (invalid floating point operations return NaN or Inf)
dlibrary
    lists dynamic link libraries to search for calls
dllcall
    calls a function from a dynamic link libraries
dos
    keyword which issues an operating system call
dotfeq(ma,mb);
    returns 0-1 matrix with result of dot-fuzzy-equal
dotfge(ma,mb);
    returns 0-1 matrix with result of dot-fuzzy-greater-or-equal
dotfgt(ma,mb);
    returns 0-1 matrix with result of dot-fuzzy-greater
dotfle(ma,mb);
    returns 0-1 matrix with result of dot-fuzzy-less-or-equal
dotflt(ma,mb);
    returns 0-1 matrix with result of dot-fuzzy-less
dotfne(ma,mb);
    returns 0-1 matrix with result of dot-fuzzy-not-equal
draw();
    not supported
dstat(dataset,vars);
    prints and returns summary statistics of a dataset
dummy(mx,v);
    creates a 0-1 matrix from mx according to v
dummybr(mx,v);
    creates a 0-1 matrix from mx according to v, closed on right
dummydn(mx,v, p);
    as dummy, but drops column p
ed
    unsupported
edit
    unsupported
editm(mx);
    unsupported
eig(mx);
    returns the eigenvalues of a general matrix
eigcg(mr,mi);
    unsupported
eigcg2(mr,mi);
    unsupported
eigch(mr,mi);
    unsupported
eigch2(mr,mi);
    unsupported

eigh(mx);
    returns the eigenvalues of a symmetric matrix
{e,v}=eighv(mx);
    returns the eigenvalues e and vectors v of a symmetric matrix
{er,ei}=eigrg(mx);
    returns the eigenvalues of a general matrix
{er,ei,vr,vi}=eigrg2(mx);
    returns the eigenvalues e and vectors v of a general matrix
eigrs(mx);
    same as eigh
{e,v}=eigrs2(mx);
    same as eighv
{e,v}=eigv(mx);
    returns the eigenvalues e and vectors v of a general matrix
enable
    ignored (see disable)
end();
    closes all open files and stops the current run
envget(s);
    returns the value of a environment variable
eof(fileno)
    returns 1 if at end of file, 0 otherwise
eqsolve(func,start);
    unsupported
erf(x);
    returns erf(x), where erf is the error function
erfc(x);
    returns 1 - erf(x)
error(i);
    returns a missing value with embedded error code i, 0¡=i¡=65535
errorlog str;
    prints the text s
etdays(vt1,vt2);
    returns the difference in days between two dates
ethsec(vt1,vt2);
    returns the difference in hundreds of seconds beween two dates
etstr(hsecs);
    returns the text representing the hundreds of seconds hsecs
exctsmpl(infile,outfile,percent);
    unsupported
exec(program,cmdline);
    operating system call to run program with arguments cmdline
exp(x);
    returns exponential of x
export(x,fname,namelist);
    unsupported

exportf(dataset,fname,namelist);
    unsupported
eye(r);
    returns r by r identity matrix
fcheckerr(ifileno);
    returns 1 if a read/write error occurred, 0 otherwise
fclearerr(ifileno);
    clears the error status of the file
feq(a1,a2);
    returns 1 if fuzzy-equal to, 0 otherwise
fflush(ifileno);
    flushes the file buffer
fft(x);
    returns FFT of x
ffti(f);
    returns inverse FFT of f
fftm(mx,dim);
    unsupported
fftmi(mx,dim);
    unsupported
fftn(mx,dim);
    currently identical to fft
fge(ma,mb);
    returns 1 if fuzzy-greater-equal to, 0 otherwise
fgets(ifileno,n);
    reads upto n characters or end-of-line (whichever comes first)
fgetsa(ifileno,n);
    reads upto n lines (or end-of-file), returns an array of strings
fgetsat(ifileno,n);
    as fgetsa, but drops newline character
fgetst(ifileno,n);
    as fgets, but drops newline character
fgt(ma,mb);
    returns 1 if fuzzy-greater than, 0 otherwise
fileinfo(fspec);
    unsupported
files(mx);
    unsupported
filesa(fspec);
    unsupported
fle(ma,mb);
    returns 1 if fuzzy-less-equal to, 0 otherwise
floor(ma);
    returns the floor of a ma (floor(x): largest integer ¡= x)
flt(ma,mb);
    returns 1 if fuzzy-less than, 0 otherwise

fmod(ma,mb);
    Returns the floating point remainder of ma / mb
fne(ma,mb);
    returns 1 if fuzzy-not-equal to, 0 otherwise
fopen(sfilename,smode);
    opens a file, smode is read ("r"), write ("w"), or append ("a")
format [/type] [/onoff] [/rowsep] [/fmt] widt,precision;
    sets format for print
formatcv(mch);
    sets character format for printfm
formatnv(s);
    sets numeric format for printfm
fputs(ifileno,sa);
    writes a string or string array, returns number of lines written
fputst(ifileno,sa);
    as fputs, but adds newline after each line
fseek(fileno,offset,base);
    moves the file pointer to offset+base, returns the new position
fstrerror();
    returns the current error text
ftell(f);
    returns the current position of the file pointer
ftocv(x, wid, prec);
    returns the character-matrix representation of x
ftos(x,fmt,wid,prec);
    return the value of x as a string
gamma(mx);
    returns the result of the gamma function
gammaii(r,p);
    returns quantiles from the Gamma(p,r,1) (incomplete gamma function)
gausset();
    resets the defaults
getf(filename,mode);
    returns the contents of the specified file in a single string
getname(dset);
    returns the names in a data set
getnr(nset,ncols);
    unsupported
getpath(pfname);
    unsupported
gradp(f,x);
    return gradient of function f at x, $f : n \rightarrow k$, return value is $k \times n$
graph(x,y);
    unsupported
graphprt(str);
    ignored

hardcopy(str);
skipped
hasimag(x);
unsupported
header(procname,dataset,ver);
unsupported
hess(x);
unsupported
hessp(f,vp);
return Hessian of function f at x, $f : n \rightarrow 1$, return value is $n \times n$
hsec();
returns the current time in 100th of seconds
imag(x);
unsupported
import(fname,range,sheet);
unsupported
importf(fname,dataset,range,sheet);
unsupported
indcv(what,where);
returns indices in where of strings matching what (case insensitive)
indexcat(x,v);
returns indices of elements in x equal to v (v scalar) or v[1]¡x¡=v[2]
indices(dataset,vars);
unsupported
indices2(dataset,var1,var2);
unsupported
indnv(what,where);
returns the indices of the numeric values from what in where
int(x)
see floor
intgrat2(f,xl,gl);
unsupported
intgrat3(f,xl,gl,hl);
unsupported
intquad1(f,xl);
unsupported
intquad2(f,xl,yl);
unsupported
intquad3(f,xl,yl,zl);
unsupported
intrleav(infile1,infile2,outfile,keyvar,keytyp);
unsupported
intrsect(v1,v2,flag);
returns the intersection of v1 and v2 (numerical if flag=1, character otherwise)
intsimp(f,xl,tol);
unsupported

inv(ma);
    returns inverse of ma (using LU decomposition with pivoting)
invertpd(ma);
    returns the inverse of ma (ma symmetrix p.d., using Choleski decomposition)
invswp(x);
    returns the generalized inverse of ma
iscplx(x);
    unsupported
iscplxf(x);
    unsupported
ismiss(a);
    returns 1 if a has any missing values, 0 otherwise
key();
    unsupported
keyw();
    unsupported
lag1(x);
    returns x with each column one observation lagged (so first is missing)
lagn(x,n);
    returns x with each column n observations lagged (so first is missing)
lib
    not supported
library [lib1,lib2,...];
    specifies an OxGauss library
ln(ma);
    returns the natural logarithm of a
lncdfbvn(x1,x2,r);
    returns ln(cdfbvn(...))
lncdfbvn2(h,dh,k,dk,r);
    unsupported
lncdfmvn(x,r);
    unsupported
lncdfn(x);
    returns ln(cdfn(...))
lncdfn2(x,dx);
    returns ln(cdfn2(...))
lncdfnc(x);
    returns ln(cdfnc(...))
lnfact(mx);
    returns $\Gamma(x+1)$ (log-factorial)
lnpdfmvn(x,s);
    returns multivariate normal log-density
lnpdfn(x);
    returns normal log-density
load x;
load y[]=filename;

load z=filename;
    loads a file
loadd(sdataname);
    loads a data set
loadf f;
loadf f=filename;
    unsupported
loadk k;
loadk k=filename;
    unsupported
loadm x;
loadm y[]=filename;
loadm z=filename;
    loads a matrix file
loadp p;
loadp p=filename;
    unsupported
loads s;
loads s=filename;
    loads a string file
locate m,n;
    unsupported
loess(y,x);
    unsupported
log(ma);
    returns the base 10 logarithm of a (use ln for natural logarithm!)
lower(s);
    returns s in lower case (s can be a string or character matrix
lowmat(x);
    returns the lower diagonal of x, upper diagonal is set to 0
lowmat1(x);
    as lowmat, but diagonal is set to 1
lpos();
    unsupported
lprint
    unsupported
lpwidth
    unsupported
lshow
    unsupported
ltrisol(b,L);
    returns x from Lx=b, where L is lower diagonal
{ml,mu}=lu(x);
    returns LU decomp. of x, rows of L are reordered to reflect the pivoting.
lusol(b,L,U);
    returns x from LUx=b, where L,U are from lu() (L may be row-reordered)

makevars(x,vnames,xnames);
unsupported
maxc(x);
returns the maximum value in each column as a column vector
maxindc(x);
returns the index of the maximum value in each column as a column vector
maxvec();
returns 2^31
mbesselei(x,n,alpha);
returns $e^{-x}I_\alpha(x), \ldots, e^{-x}I_{n-1+\alpha}(x)$
mbesselei0(x);
returns $e^{-x}I_0(x)$
mbesselei1(x);
returns $e^{-x}I_1(x)$
mbesseli(x,n,alpha);
returns $I_\alpha(x), I_{1+\alpha}(x), \ldots, I_{n-1+\alpha}(x)$
mbesseli0(x);
returns $I_0(x)$
mbesseli1(x);
returns $I_0(x)$
meanc(x);
returns the mean of each column of x as a column vector
median(ma);
returns the median of each column of x as a column vector
medit(x,xv,xfmt);
unsupported
mergeby(infile1,infile2,outfile,keytyp);
unsupported
mergevar(vnames);
unsupported
minc(x);
returns the minimum value in each column as a column vector
minindc(x);
returns the index of the minimum value in each column as a column vector
miss(x,v);
returns x with values equal to v replaced by the missing value
missex(x,e);
returns x with a missing value in positions where e is not 0
missrv(x,v);
returns x with values that are misisng replaced by v
moment(a,b);
returns a'a; if b=1 rows with missing values are deleted,
if b=2 missing values are set to 0
momentd(dataset,vars);
unsupported
msym str;

```
    unsupported
nametype(vname,vtype);
    unsupported
ndpchk(x);
    unsupported
ndpclex();
    unsupported
ndpcntrl(x);
    unsupported
new [nos[,mps]];
nextn(n0);
    unsupported
nextnevn(n0);
    unsupported
null(x);
    returns the null space of x'
null1(x,dataset);
    unsupported
{...}=ols(dataset,depvar,indvars);
    unsupported
olsqr(y,x);
    returns estimated coefficients from regressing y on x
{bhat,res,yhat}=olsqr2(y,x);
    returns estimated coefficients, residuals and fitted values
ones(r,c);
    returns a r x c matrix of ones
open fh=filename [for mode];
    opens a file
optn(n0);
    unsupported
optnevn(n0);
    unsupported
orth(x);
    returns an orthonormal base for x
output [file=filename] [on or reset or off];
    switches output logging on or off
outwidth n;
    sets the output line length (default is 256)
packr(x);
    returns x with rows containing missing values deleted
parse(str,chmdelim);
    returns a character matrix with the tokens in str, delimited by chmdelim
pause(isec);
    pauses fo isec seconds
pdfn(a);
    returns the normal PDF at a
```

pi();
    returns π
pinv(x);
    returns generalized inverse off x
plot x,y;
    unsupported
plotsym n;
    unsupported
polychar(x);
    returns the characterstic polynomial of x
polyeval(x,c);
    returns the polynomial evaluated at x
polyint(xa,ya,x);
    returns $y = P(x)$, where P is the polynomial of degree $n - 1$ such that $P(xa_i) = ya_i, i = 1, \ldots, n$.
polymake(roots);
    returns the polynomial coefficients
polymat(x,p);
    returns `x^1 ~ ... ~ x^p`
polymult(c1,c2);
    multiplies two polynomials
polyroot(poly);
    returns the roots of the polynomial
pqgwin
    ignored
prcsn n;
    ignored
print [/type] [/onoff] [/rowsep] [/fmt] [expression-list][;];
    print
printdos str;
    prints a string
printfm(x,mask,fmt);
    prints a mixed character/numeric matrix
printfmt(x,mask);
    prints a mixed character/numeric matrix
prodc(x);
    returns a row vector with the products of the elements in each column
putf(f,str,start,len,mode,append);
    unsupported
QProg(start,q,r,a,b,c,d,bnds);
    unsupported
{q,r}=qqr(x);
    QR decomposition without pivoting
{q,r,p}=qqre(x);
    QR decomposition with pivoting, p holds permutation indices
{q,r,p}=qqrep(x,pvt);

as qqre (pvt is ignored)
r=qr(x);
QR decomposition without pivoting
{r,p}=qre(x);
QR decomposition with pivoting, p holds permutation indices
{r,p}=qrep(x,pvt);
as qre (pvt is ignored)
qrsol(b,U);
returns x from Ux=B where U is upper triangular
qrtsol(b,L);
returns x from Lx=B where L is lower triangular
{qty,r}=qtyr(y,x);
QR decomposition without pivoting, returning Q'Y and R
{qty,r,p}=qtyre(y,x);
QR decomposition without pivoting, returning Q'Y, R, and P
qtyrep(y,x,pvt);
as qtyre (pvt is ignored)
quantile(x,e);
returns e'th quantiles of columns of x
quantiled(dataset,x,e);
unsupported
{qy,r}=qyr(y,x);
returns QY and R from QR decomposition
{qy,r,piv}=qyre(y,x);
returns QY and R from QR decomposition with pivoting
qyrep(y,x,pvt);
same as qyre
rank(x);
returns the rank of x
rankindx(x,flag);
returns the rank index of columsn elements of x
readr(f,r);
reads r rows from file f
real(x);
returns x;
recode(x,e,v);
recodes elements in x as indicated by e using v
recserar(x,y0,a);
returns the cumulated autoregressive sum of x, with starting values x0 and coeff. a
recsercp(x,z);
returns the cumulated autoregressive product of x, with starting values x0 and coeff. a
recserrc(x,z);
returns the cumulated autoregressive division of x
reshape(ma,r,c);
returns an r by c matrix, filled by row from vecr(ma).
rev(ma);

```
    returns ma with elements of each row in reverse order
rfft(x);
    returns the real FFT of x
rffti(x);
    returns the inverse real FFT of x
rfftip(x);
    same as rffti
rfftn(x);
    same as rfft
rfftnp(x);
    same as rfft
rfftp(x);
    same as rfft
rndbeta(r,c,a,b);
    returns r x c matrix with Beta(a,b) random numbers
rndcon c;
    ignored
rndgam(r,c,alpha);
    returns r x c matrix with Gamma(alpha,1) random numbers
rndmod m;
    ignored
rndmult a;
    ignored
rndn(r,c);
    returns r x c matrix with N(0,1) random numbers
rndnb(r,c,n,p);
    returns r x c matrix with NegBin(n,p) random numbers
rndns(r,c,s);
    sets seed to s, and returns r x c matrix with N(0,1) random numbers
rndp(r,c,mu);
    returns r x c matrix with Poisson(mu) random numbers
rndseed s;
    sets seed to s
rndu(r,c);
    returns r x c matrix with uniform random numbers
rndus(r,c,s);
    sets seed to s, and returns r x c matrix with uniform random numbers
rndvm(r,c,mu,kappa);
    returns r x c matrix with VonMises(mu,kappa) random numbers
rotater(x,c);
    returns x with row elements rotated according to c
round(x);
    returns rounded valuess of x
rows(x);
    returns the number of rows of x
rowsf(f);
```

returns the number of rows in .fmt or .dht file f
rref(x);
returns the reduced row echelon form of x
run filename;
save [option][path=dpath]x,[lpath=]y;
saves as .fmt or .fst file (default is extended v89 unless option is -v96)
saveall
unsupported
saved(x,dataset,vnames);
unsupported
scalerr(x);
returns the error code embedded in the missing value
scalmiss(x);
returns 1 if x is scalar and a missing value
schtoc(sch,trans);
unsupported
schur(x);
unsupported
screen [on or off or out];
ignored
scroll
ignored
seekr(fh,r);
moves to row r in file fh
selif(x,e);
returns those rows of x where e has a 1
seqa(start,inc,m);
returns a column vector with start, start+inc, start+(m-1)*inc
seqm(start,inc,m);
returns a column vector with start, start*inc, start*inc$^(m-1)$
setcnvrt(type,ans);
ignored
setdif(v1,v2,flag);
returns the sorted unique elements of v1 which are not in v2 as a column vector
(flag=0: character matrix, 1: numerical, 2: character matrix, converted to upper case)
setvars(dataset);
unsupported
setvmode(x);
obsolete
shell cmd;
same as dos
shiftr(x,c,d);
returns x with row elements rotated according to r, vacated positions are set to d
show [/flags][symbol];
unsupported
sin(ma);

returns sine of ma
sinh(ma);
returns sine hyperbolic of ma
sleep(secs);
same as pause
solpd(b,a);
returns x from ax=b where a is symmetric positive definite
sortc(x,c);
returns x sorted by column c
sortcc(x,c);
returns x sorted by column c, where x is a character matrix or string array
sortd(infile,outfile,keyvar,keytyp);
unsupported
sorthc(x,c);
same as sortc
sorthcc(x,c);
same as sortcc
sortind(x);
returns the index corresponding to sorted x
sortindc(x);
returns the index corresponding to sorted x, where x is a character matrix
sortmc(x,vc);
returns x sorted by the columns specified by vc
spline1d(x,y,d,s,sigma,g);
unsupported
spline2d(x,y,z,sigma,g);
unsupported
sqpsolve(func,start);
unsupported
sqrt(ma);
returns the square root of ma (. if ma ¡ 0)
stdc(x);
returns the standard deviation ox x
stocv(s);
returns s as a character vector
stof(x);
converts x to numerical values, where x is a string or character matrix
stop();
stops the current run
strindx(where,what,start);
returns the index of what in where[start:,.] or 0 if not found
strlen(s);
returns the length of s, or matrix of lenngths if s is a character matrix
strput(substr,str,pos);
returns a string str with substr insert at pos
strrindx(where,what,start);

reverse version of strindx
strsect(string,pos,len);
returns a substring of length len from string at pos (or empty string)
submat(x,r,c);
returns the r x c leading sub matrix of x (r=0 all rows, c=0 all columns)
subscat(x,v,s);
replaces values in x by s according to category v
substute(x,v,s);
replaces values in x by s according to logical values in v
sumc(x);
returns sum of columns of x as a column vector
svd(x);
returns the singular values of x in a column vector
svd1(x);
as svd2, but u is r x r if r ¡ c.
{u,w,v}=svd2(x);
returns SVD of r x c matrix x, w is a diagonal matrix
svdcusv(mx);
as svd2, but does not use trapchk
svds(mx);
as svd, but does not use trapchk
svdusv(mx);
as svd1, but does not use trapchk
{...}=sysstate(vcase,y);
system;
exits
tab(col);
unsupported
tan(x);
returns tangent of x
tanh(x);
returns hyperbolic tangent of x
tempname(path,pre,ext);
returns a temporary file name
time(x);
returns the time as a 4 x 1 vector: hour, min, sec, 0
timestr(x);
prints the time as a string (x=0: current time)
tocart(x);
unsupported
toeplitz(x);
returns a toeplitz matrix constructed from x
{tok,str}=token(str);
returns the leading token and the remainder of str
topolar(xy);
unsupported

```
trace new[,mask];
    unsupported
trap new[,mask];
    sets or clears the trap value
trapchk(m);
    returns the trap value masked by m
trim
    same as trimr
trimr(x,top,bot);
    returns x[top + 1 : rows(x) - bot,.]
trunc(ma);
    truncates fractional part
type(x);
    returns the type of x
typecv(x);
    returns the type of the named global variable
typef(x);
    unsupported
union(v1,v2,flag);
    returns the union of v1 and v2 (v1,v2 are numerical if flag=1)
uniqindx(v1,flag);
    returns index of the unique elements in v1 (v1 is numerical if flag=1)
unique(v1,flag);
    returns the unique elements in v1 (v1 is numerical if flag=1)
upmat(x);
    returns the upper diagonal of x, lower diagonal 0
upmat1(x);
    returns the strict upper diagonal of x, diagonal is 1, lower diagonal 0
upper(s);
    returns s converted to uppercase
utrisol(b,u);
    returns x from Ux=B where U is upper triangular
vals(s);
    returns a column vector with the character values of the string s
varget(s);
    returns the named variable from the global stack
vargetl(s);
    unsupported
varput(x,n);
    sets the named variable on the global stack
varputl(x,n);
    unsupported
vartypef(names);
    unsupported
vartypef(names);
    returns the type of the named global variable
```

vcm(m);
    returns a correlation matrix from moments m=x'x, first column of x must be 1's
vcx(x);
    returns a correlation matrix from data matrix x
vec(x);
    returns the stacked columns of x
vech(x);
    returns vec of the lower diagonal of x
vecr(x);
    returns the stacked rows of x as a column vector
vget(dbuf,name);
    unsupported
vlist(dbuf);
    unsupported
vnamecv(dbuf);
    unsupported
vput(dbuf,x,name);
    unsupported
vread(dbuf,xname);
    unsupported
vtypecv(dbuf);
    unsupported
wait();
    waits for an integer to be entered
waitc();
    unsupported
writer(fh,x);
    writes x to fh
xpnd(ma);
    creates a symmetrix matrix
zeros(r,c);
    returns an r x c matrix of zeros.

D6.9 Comparing OxGauss and Ox syntax

In the following two column format, OxGauss is discussed on the left, and Ox in the right-hand column. The aim is to aid OxGauss users in understanding Ox. Elements of Ox syntax which are not needed for that purpose (such as classes) are not discussed here.

D6.9.1 Comment

The `@ ... @` style of comment does not exist in Ox.	Ox comment style is `/* ... */` (as in OxGauss) or `//` which indicates a comment up to the end of the line.

D6.9.2 Program entry

A OxGauss program starts execution at the first executable statement (which is not a procedure/function/keyword etc.).

An Ox program starts execution at the function `main`.

D6.9.3 Case and symbol names

OxGauss is not case sensitive, except inside strings. Symbol names may be up to 60 characters.

Ox is case sensitive. Symbol names may be up to 60 and strings up to 2048 characters.

D6.9.4 Types

OxGauss primarily has a matrix type.

Ox is implicitly typed, and has the following types: integer, double, matrix, string, array, file, function, class. Type is determined at run time (and can change at run time). E.g. `a=1;` creates an integer, `a=1.0;` a double and `a=<1>;` a matrix.

D6.9.5 Matrix indexing

Indexing starts at 1, so `m[1,1]` is the first element in a matrix. Vectors only need one index. A matrix can be indexed by a single index, a list of numbers, or an expression evaluating to a vector or matrix (in which case no spaces are allowed). A dot indicates all elements, for example:

```
w[1,1]
w[2:5,3:6]
w[1 3:4,.]
w[a+b,c]
```

Indexing starts at 0, so `m[0][0]` is the first element in a matrix. Ox can be made to start indexing at 1; this will lead to a somewhat slower program. Vectors only need one index. A matrix can be indexed by a single index, a list of numbers, or an expression evaluating to a vector or matrix (including matrix constants) or a range. The upper or lower index in a range may be omitted. A empty index indicates all elements, for example:

```
w[0][0]
w[1:4][2:5]
w[<0,2:3>][]
w[a + b][c]
w[:4][2:]
```

D6.9.6 Arrays

OxGauss implements arrays using the varput and varget function.

The array is a type in Ox, e.g. `{"one", "two", <1,2>}` is an array constant, where the first two elements are a string, and the last a matrix. To print these: `print(a[0], a[1], a[2])`. A new array is created with the new operator.

D6.9.7 Declaration and constants

In OxGauss, a variable can be assigned a value with a `let` or implicit `let` statement. If the variable doesn't exist yet, it is declared, otherwise it is redeclared. A variable can be declared explicitly with the `declare` statement. Assignment in a let statement may consist of a number, a sequence of numbers (or strings) separated by spaces, or numbers in closed in curly brackets. The latter specifies a matrix, with a comma separating rows, and a space between elements in a row (these are not proper matrix constants, because they cannot be used in expressions). A variable outside a function is also created if a value is assigned to it (and it doesn't exist yet).

```
let w = { 1 1 1 };
let y0 = 1 2;
let y1[2,2] = 1 1 2 2;
y2[2,2] = {1 1, 2 2}; /*(1)*/
let w[2,2] = 1;
let w[2,2];
w = zeros(2,2);
```

The line labelled `(1)` is an implicit let which creates a 2×2 matrix. A statement like `y2[2,2] = 1;` on the other hand puts the value one in the 2,2 position of `y`, which therefore must already exist.

Ox has explicit declaration of variables. A value can be assigned to a variable at the same time as it is declared. If the variable has external scope (i.e. is assigned outside any function), you can use constants only, (matrix or other constants). Such constants can also be used in expressions.

```
decl w  = < 1,1,1 >;
decl y0 = <1,2>;
decl y1 = <1,1; 2,2>;
decl y2 = <1,1; 2,2>;
decl w[2][2] = 1;
decl w[2][2];
decl w = zeros(2, 2);
     /* only inside function */
```

If all statements would be used together, the compiler would complain about the last three declarations: `w` was already declared earlier (no redeclaration is possible, but re-assignment is, of course). The last declaration involves code, and can only be made inside a function.

D6.9.8 Expressions

Assignment statements are quite similar, e.g. `y = a .* b + 3 - d;` works in both OxGauss and Ox, whether the variables are matrices or scalars.

Ox allows multiple assigments, e.g. `i = j = 0;`. In addition there are conditional and dot-conditional expressions.

D6.9.9 Operators

The following have a different symbol:

OxGauss	Ox
`.*.`	`**`
`/=`	`!=`
`not`	`!`
`and`	`&&`
`or`	`||`

The following OxGauss operators are not supported in Ox: `%` (Ox has the `idiv` function) `! *~ .'`.
For $x!$ use `exp(loggamma(x+1))` or `gammafact(x+1)` in Ox.

The text form of the relational operators are not available in Ox, so e.g. use `.<` instead of `.LT`.
There are no special string versions of operators in Ox.
The `^` operator is matrix power, not element by element power.
And finally, `x=A/b` (with `A` and `b` conformable) does not solve a linear system, but is executed as `x=A*(1/b)`. This fails, because intended is `x=(1/A)*b`. The `1/A` part in Ox computes the generalized inverse if the normal inverse does not work.

D6.9.10 Loop statements

OxGauss has the `do while` and `do until` loop:

```
i = 1;
do while (i <= 10);
    /* something */
    i = i + 1;
endo;

i = 10;
do until (i < 1);
    /* something */
    i = i - 1;
endo;
```

Recently a for loop statement has been added to OxGauss.

Ox has the for, while and do while loop statements (note the difference in the use of the semi-colon).

```
for (i = 0; i < 10; ++i)
{
    /* something */
}

i = 10;
while (i >= 1)
{
    /* something */
    --i;
}

i = 1;
do
{   /* something */
    ++i;
} while (i <= 10);
```

D6.9.11 Conditional statements

```
if i == 1;
    /* statements */
elseif i = 2;
    /* statements */
else;
    /* statements */
endif;
```

Again notice the difference in usage of parenthesis and semi-colons.

```
if (i == 1)
{   /* statements */
}
else if (i = 2)
{   /* statements */
}
else
{   /* statements */
}
```

D6.9.12 Printing

In OxGauss, a `print` statement consists of a list of items to print. A space separates the items, unless they are in parenthesis. An expression without an equal sign is also treated as a print statement.

Ox has a `print` and `println` function, which gives the expressions to print, separated by a comma. Strings which contain a format are not printed but apply to the next expression.

D6.9.13 Functions

OxGauss has procedures (`proc`), keywords and single-line functions (`fn`). Procedures may return many values; no values can be returned in arguments. Local variables are declared with the `local` statement.

```
proc(2) = foo(x, y);
    local a,b;
    /* code */
    retp (a,b);
endp;

{c, d} = foo(1, 2);
```

Ox only has functions which may return zero, one or more values. Values can be also returned in arguments. Variables are declared using `decl`. Variables have a lifetime restricted to the brace level at which they are declared.

```
foo(const x, const y,
            const retb)
{   decl a,b;
    /* code */
    retb[0] = b;
    return a;
}
c = foo(1, 2, &d);
```

Multiple returns are implemented as:

```
bar(const x)
{   decl a,b;
    /* code */
    return {a, b};
}
[c, d[0] ] = bar(1);
```

D6.9.14 String manipulation

OxGauss allows storing of strings in a matrix, and provides special operators to manipulate matrices which consists of strings.

A string is an inbuilt data type in Ox and arrays of strings can be created. It is possible to store a string which is 8 characters or shorter in a matrix or double as e.g. `d = double("aap")`, and extract the string as `string(d)`

D6.9.15 Input and Output

OxGauss `.fmt` files are different between the MS-DOS/Windows versions (little endian) and the Unix versions (big endian).

Ox can read and write `.fmt` files, and read `.dht/.dat` files. These are always written/read in little-endian mode (the Windows/MS-DOS way of storing doubles on disk; Unix systems use big-endian mode). So a `.fmt` file can be written on a PC, transferred (binary mode!) to a Sun, and read there. Ox can also read Excel files, see under `loadmat`.

Chapter D7

OxGauss Language Reference

D7.1 Lexical conventions

D7.1.1 Tokens

The first action of a compiler is to divide the source code into units it can understand, so-called tokens. There are four kinds of tokens: identifiers, keywords, constants (also called literals) and operators. White space (newlines, formfeeds, tabs, comments) is ignored except when indexing or in the `print` statement.

D7.1.2 Comment

Anything between `/*` and `*/` is considered comment; this comment *can* be nested (unlike C and C++). Anything between `@` and `@` is also comment; this *cannot* be nested.

Everything following `//` up to the end of the line is comment, but is ignored inside other comment types.*[1]
Note that code can also be removed using preprocessor statements, see §D7.9.2.

D7.1.3 Space

A space (including newline, formfeed, tab, and comments) is used to separate items when indexing a matrix, or in the `print` statement.

D7.2 Identifiers

Identifiers are made up of letters and digits. The first character must be a letter. Underscores (_) count as a letter. Valid names are `CONS`, `cons`, `cons_1`, `_a_1_b`, etc. Invalid are `#CONS`, `1_CONS`, `log(X)`, etc. OxGauss is *not* case sensitive, so `CONS` and `cons` are the same identifiers. It is better not to use identifiers with a leading underscore, as

[1] Extensions are marked with a *.

several compilers use these for internal names. The maximum length of an identifier is 60 characters[2]; additional characters are ignored.

D7.2.1 Keywords

The following keywords are reserved:*[3]

keyword: one of

`and`	`delete`	`endp`	`goto`	`matrix`	`string`
`break`	`do`	`eq`	`gt`	`ne`	`until`
`call`	`else`	`eqv`	`if`	`not`	`while`
`clear`	`elseif`	`external`	`keyword`	`or`	`xor`
`clearg`	`endata`	`fn`	`le`	`pop`	
`continue`	`endfor`	`for`	`let`	`proc`	
`dataloop`	`endif`	`ge`	`local`	`retp`	
`declare`	`endo`	`gosub`	`lt`	`return`	

D7.3 Constants

Arithmetic types and string type have corresponding constants.

constant:
- *scalar-constant*
- *matrix-constant*
- *vector-constant*
- *string-constant*

scalar-constant:
- *int-constant*
- *double-constant*

D7.3.1 Integer constants

A sequence of digits is an integer constant. A hexadecimal constant is a sequence of digits and the letters `A` to `F` or `a` to `f`, prefixed by `0x` or `0X`.

D7.3.2 Character constants*

Character constants are interpreted as an integer constant. A character constant is an integer constant consisting of a single character enclosed in single quotes (e.g. `'a'` and `'0'`) or an escape sequence (see §D7.3.5) enclosed in single quotes.

[2] Up to 32 characters in GAUSS

[3] This is different from GAUSS, where all variables and functions in the namespace become reserved words.

D7.3.3 Double constants

A double constant consists of an integer part, a decimal point, a fraction part, an `e`, `E`, `d` or `D` and an optionally signed integer exponent. Either the integer or the fraction part may be missing (not both); either the decimal point or the full exponent may be missing (not both). A hexadecimal double constant is written as `0v`*hhhhhhhhhhhhhhhh*. The format used is an 8 byte IEEE real. The hexadecimal string is written with the most significant byte first (the sign and exponent are on the left). If any hexadecimal digits are missing, the string is left padded with 0's.

Note that most numbers which can be expressed exactly in decimal notation, cannot be represented exactly on the computer, which uses binary notation.

D7.3.4 Matrix constants

A matrix constant lists within `{` and `}` the elements of the matrix, row by row. Each row is delimited by a comma, successive elements in a row are separated by a space. For example:

```
{ 11  12  13, 21  22  23 }
```

which is a 2×3 matrix:

$$\begin{pmatrix} 11 & 12 & 13 \\ 21 & 22 & 23 \end{pmatrix}$$

Elements in a matrix constant can only be an integer or double constant. No expressions are allowed. To indicate complex numbers, write:

complex-constant:
    sign$_{opt}$ *real-part sign complex-part* `i`
    sign$_{opt}$ *real-part sign complex-part*
    sign$_{opt}$ *complex-part*`i`
sign one of:
    `+ -`

without spaces.

A dot may be used in a matrix constant to indicate a missing value. This has a double value NaN (Not a Number).

In some contexts (`declare`, `let`), the braces surrounding the matrix constant are optional. This is indicated as: *vector-constant*, because the result is always a columnn vector (so a comma does not separate rows).

D7.3.5 String constants

A string constant is a text enclosed in double quotes. To extend a string across a second line, put a backslash between adjacent string constants. This backslash is optional: adjacent string constants are concatenated*. (In non-interactive mode a string constant is also allowed to span multiple lines.) A null character is always appended to indicate the end of a string. The maximum length of a string constant is 2048 characters.

Escape sequences can be used to represent special characters:

escape-sequence: one of

`\"`	double quote (")	`\'`	single quote (')
`\0`	null character	`\\`	backslash (\)
`\a` or `\g`	alert (bel)	`\b`	backspace
`\f`	formfeed	`\n` or `\l`	newline
`\r`	carriage return	`\t`	horizontal tab
`\v`	vertical tab	`\e`	escape (ASCII 27)
`\x`*hh*	hexadecimal number (*hh*)		
`\`*ooo*	decimal number		

At least one and at most two hexadecimal digits must be given for the hexadecimal escape sequence. A single quote need not be escaped.

D7.3.6 Constant expression

A *constant-expression*[*4] is an expression which involves scalar constants and the following operators: `+ - * /`.

An *int-constant-expression* is a constant expression which evaluates to an integer.

Constant expressions are evaluated when the code is compiled.

D7.4 Objects

D7.4.1 Types

Variables in OxGauss are implicitly typed, and can change type during their lifetime. The life of a variable corresponds to the level of its declaration. Its scope is the section of the program in which it can be seen. Scope and life do not have to coincide.

There are three basic types and four derived types. The integer type *int* is a signed integer. The double precision floating point type is called *double*. A *matrix* is a two-dimensional array of doubles which can be manipulated as a whole. A *string*-type holds a string, while an *array*-type is an array of references. A function is also recognized as a type.

arithmetic-type:	int, double, matrix
string-type:	string
scalar-type:	int, double
vector-type:	string, matrix
derived-type:	string-array, character-matrix
other-type:	function

At the programming level, the following types are used in external declarations:

type: one of
`fn`, `keyword`, `matrix`, `proc`, `string`
function-type: one of
`fn`, `keyword`, `proc`

[4]Where OxGauss allows constant-expressions, Gauss only allows constants.

A character matrix is a matrix where the elements holds strings rather than numeric data. Since the underlying storage type is a double, the strings cannot be longer than 8 characters.

A string array is a vector or matrix of strings. For this type, there is no restriction on the length of the strings stored in the array.

D7.4.1.1 Type conversion

When a double is converted to an int, the fractional part is discarded. For example, conversion to int of 1.3 and 1.7 will be 1 on both occasions. When an int is converted to a double, the nearest representation will be used.

A single element of a string (a character) is of type int. An int or double can be assigned to a string element, which first results in conversion to int, and then to a single byte character.

D7.4.2 Lvalue

An lvalue is an object to which an assignment can be made.

D7.5 OxGauss Program

program:
external-statement-list
external-declaration-list

A OxGauss program consists of a sequence of statements and external declarations. These either reserve storage for an object, or serve to inform of the existence of objects created elsewhere. All statements at the external level make up the main section of the program.

D7.6 External declarations

external-declaration-list:
external-declaration
external-declaration-list external-declaration
external-declaration:
declare-statement
external-statement
function-statement

An Ox program consists of a sequence of external declarations. These either reserve storage for an object, or serve to inform of the existence of objects created elsewhere.

D7.6.1 External statement

external-statement:
    `external` *type variable-list* `;`
variable-list:
    identifier
    variable-list `,` *identifier*

The external variable declaration list makes externally created variables available to the remainder of the source file. Such variables are not created through the `external` statement, but just pulled into the current scope. The *type* is defined in §D7.4.1.

D7.6.2 Declare statement

declare-statement:
    `declare` *declare-ident-list* `;`
    `declare matrix` *declare-ident-list* `;`
    `declare string` *declare-ident-list* `;`

declare-ident-list:
    identifier initialisation$_{opt}$
    declare-ident-list `,` *identifier initialisation*$_{opt}$

initialisation:
    dimension$_{opt}$ *initial-value*
dimension:
    `[` *int-constant-expression* `,` *int-constant-expression* `]`
    `[` *int-constant-expression*`]`
initial-value:
    assign scalar-constant
    assign matrix-constant
    assign vector-constant
    assign string-constant
assign one of:
    `= != := ?=`

The `declare` statement creates storage space for a variable. If no type is specified, the type is matrix. If no initialisation is specified, the variable is set to zero (or an empty string if the type is `string`). Constants and constant expressions are explained in §D7.3.

The dimension can only be specified for `matrix` type. If a dimension is specified as well as a matrix constant for initialization, they must match in dimension (this is not enforced: the constant takes precedence*). If a dimension is specified together with a scalar initial value, all elements are set to that value. If an external variable is created without explicit value and without dimensions, it will default to an int with value 0. The type of assignment symbol only matters when the variable already has a value: `=` and `!=` reassign, `:=` results in an error, and `?=` leaves the old value.

The variable is within the scope of the remainder of the source file. The `external` statement makes the variable available elsewhere.

D7.6.3 Function (procedure, fn, keyword) definitions

function-statement:
`proc` *return-count*$_{opt}$ *identifier* `(`*variable-list*$_{opt}$`);` *proc-statement-list* `endp;`
`fn` *identifier* `(`*variable-list*$_{opt}$`) =` *expression* `;`
`keyword` *identifier* `(`*argument-identifier*`);` *proc-statement-list* `endp;`

return-count:
`(` *int-constant-expression* `)`
int-constant-expression

proc-statement-list:
proc-statement
proc-statement-list proc-statement

proc-statement:
statement
local-statement
retp-statement

local-statement:
`local` *typed-list*`;`

typed-list:
typed-identifier
typed-list`,` *typed-identifier*

typed-identifier:
identifier
identifier`:`*function-type*

retp-statement:
`retp;`
`retp(`*expression-list*`);`

A function definition specifies the function header and body, and declares the function so that it can be used in the remainder of the file. A function can be declared many times, but defined only once. An empty argument list indicates that the function takes no arguments at all. Such a function can be called by the name only (or, which is better coding practice, with `()` after the name).

```
proc(2) = test2(a1, a2);        /* definition of test2 */
{
    local b1;
    b1 = test1(a2);    /* call external function test1 */
    a2 = 1;                        /* a2 may be changed */
    /* ... */
    retp(a2,b1);
    endp;
}
{x1, x2} = test2(2,3);
```

The example shows that external functions need not be declared before they are called (although it would be good programming practice): if `test1` is not found at the link stage, an error will be reported.

All functions may have a return value, but this return value need not be used by the caller. *If a function does not return a value, its actual return value is undefined.* Use `call` to call a function and discard the return values. A function has only one return value when the number of returns is left unspecified.

If a function is redefined, it automatically replaces the function which existed earlier (without printing a warning).

The `local` statement allocates a local variable. If the local variable has the same name as a global variable, the local will hide the global variable. Multiple declarations result in a warning, unless it is a type change (such as from a matrix to a function, see the `genfunc` example below).

The `retp` statement returns one or more values from the function, *and also exits the function*. So, when the program flow reaches a `retp` statement, control returns to the caller, without executing the remainder of the function. If a function fa returns p values, and is in a call function *fb*, then the return from *fa* counts for p arguments in the call to *fb*.

A `fn` function is a function with one return value. So the following two are equivalent:

```
fn func(arg) = expr;
proc(1) func(arg); retp(expr); endp;
```

A `keyword` function differs from a `proc` in two ways: there is no return value, and only one argument which is always a string. When a keyword is called, the argument text up to the semicolon is passed as one string to the keyword function, unless the argument starts with a `^`, in which case it is interpreted as a variable name.

Functions can be passed as arguments, and an array of functions can be created. As an example of the first:

```
proc(0)= func(a);
    print("\nfunc:", a);
endp;

proc(0)= func3(&fnc);  /* takes a function as argument */
    local fnc:proc;        /* tell compiler about this */
    print("\nin func3:");
    call fnc(100);     /* and call the passed function */
endp;

call func3(&func); /* call func3 with func as argument */
```

And an example of an array of functions:

```
proc(0)= genfunc(flist,x,i);
    local f;
    f = flist[i];              /* f holds ith function */
    local f:proc;    /* indicate that it is a function */
    f(x);                                  /* call f */
endp;

genfunc(&func0 ~ &func1, 100, 1);
```

D7.6.4 external-statement-list

external-statement-list:
statement-list

External statements are like normal statements, except that they are issued outside a procedure (so in the main code). When undeclared variables are assigned to, these are automatically created. So no explicit declaration is required at the external level.

D7.7 Statements

statement-list:
statement
statement-list statement

statement:
labelled-statement
assignment-statement
expression$_{opt}$;
selection-statement
iteration-statement
jump-statement
pop-statement
call-statement
dataloop-statement
delete-statement
command-statement
declare-statement
external-statement

assignment-statement:
lvalue = *expression* ;
{ *identifier-list* } = *expression* ;
`let` *identifier initialisation* ;
`clear` *identifier-list*;
`clearg` *identifier-list*;

labelled-statement:
label: *statement*

Labels are the targets of `goto` statements (see §D7.7.5); labels are local to a function and have separate name spaces (which means that variables and labels may have the same name).

D7.7.1 Assignment statements

An assignment statement assigns the result of an expression to a variable (or an element in a variable). If a function has multiple returns, the result can be assigned to multiple

destinations, by listing the destinations within curly braces, separated by a comma (see the example in §D7.6.3).

If an assignment is made at the external level (outside any function), then the variable is automatically created if it does not exist yet. Inside a function, a left-hand variable must exist, either externally, or after creation with the `local` statement.

The `let` statement is similar to `declare`, see §D7.6.2, except that there is no type component, and only = for the assignment.

The `clear` statement is followed by a comma-separated list of identifiers. This is the same as issuing a `let` *identifier* tt = 0; statement for each variable (so inside a function, the variable must be declared with `local` first). The `clearg` command only works on global variables, so, even if a local with the same name exists inside a function, the global is set to 0, and the local left untouched.

If an expression is executed without assignment, the result is printed.

D7.7.2 Selection statements

selection-statement:
`if` *expression* `;` *statement-list*$_{opt}$ `endif ;`
`if` *expression* `;` *statement-list*$_{opt}$ *elseif-statement*$_{opt}$ *else-statement*$_{opt}$ `endif ;`

elseif-statement:
`elseif` *expression* `;` *statement-list*$_{opt}$

else-statement:
`else ;` *statement-list*$_{opt}$

The conditional expression in an `if` statement is evaluated, and if it is nonzero (`TRUE` (*for a matrix: no element is zero*)*, the statement is executed. If the expression is zero (`FALSE`) the `if` part is not executed. The conditional expression may not be a declaration statement.

D7.7.3 Iteration statements

iteration-statement:
`do while` *expression* `;` *statement-list* `endo;`
`do until` *expression* `;` *statement-list* `endo;`
`for` *identifier* `(` *init-expr*`,` *test-expr*`,` *increment-expr*`);` *statement-list* `endfor;`

The `do while` statement excutes the statement-list as long as the test expression is nonzero (for a matrix: at least one element is nonzero). The test is performed before the statement-list is executed. Note that `endo` has only one d.

The `do until` statement excutes the statement-list as long as the test expression is nonzero (for a matrix: at least one element is nonzero). The test is performed before the statement-list is executed. so `do until` *expr* corresponds to `do while not` *expr*.

The `for` expression corresponds to:

identifier = *init-expr*;
do while *identifier* <= *test-expr*;
    statement-list
    identifier = *identifier* + *increment-expr*;
endo;

The main feature is that *identifier* is local to the loop, so cannot be accessed after the loop is finished. If another variable with the same name already exists, that variable is hidden during the loop. The value of *test-expr* and *increment-expr* is evaluated when the loop is entered, and cannot be changed during the loop. If *increment-expr* is zero, the loop is not executed; it is allowed to be negative. The values of *init-expr*, *test-expr* and *increment-expr* are truncated to integers.

D7.7.4 Call statements

Use `call` to call a function and discard the return values, see §D7.6.3.

D7.7.5 Jump and pop statements

jump-statement:
    break ;
    continue ;
    goto *label*;
    goto *label*(*parameter-list*);
    gosub *label*;
    gosub *label*(*parameter-list*);
    return *label*;
    return *label*(*parameter-list*);

pop-statement:
    pop *identifier* ;

A `continue` statement may only appear within an iteration statement and causes control to pass to the loop-continuation portion of the smallest enclosing iteration statement.

A `break` statement may only appear within an iteration statement and terminates the smallest enclosing iteration statement.

The use of `goto` should be kept to a minimum, but could be useful to jump out of a nested loop, jump to the end of a routine or when converting Fortran code. It is always possible to rewrite the code such that no `goto`s are required. The target of a goto is a label.

A `gosub` is similar to a `goto`, with the exception that a subsequent `return` jumps to the point immediately after the `gosub` statement.

The `pop` commands is used to handle the arguments of `gosub`, `goto`, and `return`. If a `goto` or `gosub` has arguments, then the first statement(s) after the target label must be as many `pop` statements as there are arguments (note that the arguments are popped in reverse order). Similarly, if a `return` has arguments, there must be as many `pop`s immediately after the `gosub` statement. This way, `gosub` is similar to a function call where the local variables are shared. Usage of `gosub` is not recommended.

D7.7.6 Command statements

D7.7.6.1 `print` and `format` command

print-command:
`print` *options*$_{opt}$ *expression-list*$_{opt}$ `;`$_{opt}$ `;`
format-command:
`format` *options* `;`
`format` *options*$_{opt}$ *width* `,` *precision* `;`
options: one or more of:
/type /onoff /rowsep /fmt

The `print` and `format` commands share the same set of options, see Table D7.1. Options used with `print` are local to that command, the `format` options are in force until changed with the next `format` command, or locally within a `print`. The expression list in print is separated by a space (except for expressions in parenthese or square brackets). Use two semicolons after `print` to suppress the newline character. The default width is 16, and default precision 8. Note that `format 16,8` is the same as `format /rd 16,8`.

An expression without assignment is an *implicit print* statement. If it is preceded by a dollar symbol, the result is printed as a character matrix. A double semicolon after an implicit print suppresses the newline character.

D7.7.6.2 `output` command

output-command:
`output` *file-spec*$_{opt}$ *action*$_{opt}$ `;`
file-spec:
`file =` *string-constant*
`file = ^`*string-variable*
action: one of
`on of reset`

D7.8 Expressions

Table D7.2 gives a summary if the operators available in OxGauss, together with their precedence (in order of decreasing precedence) and associativity. The precedence is in decreasing order. Operators on the same line have the same precedence, in which case the associativity gives the order of the operators.

Subsections below give a more comprehensive discussion. Several operators require an *lvalue*, which is a region of memory to which an assignment can be made. Many operators require operands of arithmetic type, that is int, double or matrix.

The most common operators are *dot-operators* (operating element-by-element) and relational operators (element by element, but returning a single boolean value). The resulting value is given Tables D7.3 and D7.4 respectively. In addition, there are special matrix operations, such as matrix multiplication and division; the result from these operators is explained below. A scalar consists of: int, double or 1×1 matrix.

Table D7.1 Options for `print` and `format` commands

		/type	
`/mat`	options applies to matrix type		
`/str`	options applies to string type		
`/sa`	options applies to string-array type		
		/onoff	
`/on`	string only: switch formatting on		
`/off`	string only: switch formatting off (default)		
	/rowsep indicates what is printed before or after each matrix row		
	condition	before row	after row
`/m0`			
`/mb1` or `/m1`	$r > 1$	`\n`	
`/mb2` or `/m2`	$r > 1$	`\n\n`	
`/mb3` or `/m3`	$r > 1$	Row #	
`/ma1`	$r > 1$		`\n`
`/ma2`	$r > 1$		`\n\n`
`/b1`		`\n`	
`/b2`		`\n\n`	
`/b3`		Row #	
`/a1`			`\n`
`/a2`			`\n\n`
	/fmt format for matrix elements		
`/rd`*C*	right adjusted, fixed format (`%`*f*.*p*`f`)		
`/re`*C*	right adjusted, scientific format (`%`*f*.*p*`e`)		
`/ro`*C*	right adjusted, general format with trailing zeros (default, `%#`*f*.*p*`g`)		
`/rz`*C*	right adjusted, general format (`%`*f*.*p*`g`)		
`/ld`*C*	left adjusted, fixed format (`%-` *f*.*p*`f`)		
`/le`*C*	left adjusted, scientific format (`%-` *f*.*p*`e`)		
`/lo`*C*	left adjusted, general format with trailing zeros (`%#-` *f*.*p*`g`)		
`/lz`*C*	left adjusted, general format (`%-` *f*.*p*`g`)		
	C optional character after each matrix element		
`s`	space (default), assumed when *C* omitted		
`t`	tab		
`c`	comma		
`n`	nothing		

D7.8.1 Primary expressions

An expression in parenthesis is a primary expression. Its main use is to change the order of evaluation, or clarify the expression. Other forms of primary expressions are: an identifier, or an identifier prefixed by the address operator `&` (the address can only be taken of functions, see §D7.6.3).

All types of constants discussed in §D7.3 form a primary expression. This includes a matrix constant inside curly braces.*

Table D7.2 OxGauss operator precedence

Category	operators	associativity
primary	*ident* *ident*() *constant* ()	
postfix	[] ' .' !	left to right
power	^ .^	left to right
unary	+ -	right to left
multiplicative	.*. * .* *~ / ./	left to right
modulo	%	
additive	+ -	left to right
horizontal concatenation	~	
vertical concatenation	|	
dot relational	.$< .$> .$<= .$>= .$>= .$/=	
	.< .> .<= .>= .== ./=	left to right
dot not	.not	
dot and	.and	
dot or	.or	
dot xor	.xor	
dot eqv	.eqv	
relational	$< $> $<= $>= $>= $/=	
	< > <= >= == /=	left to right
not	not	
and	and	
or	or	
xor	xor	
eqv	eqv	
assignment*	=	

A function call is a function name followed in parenthesis by a possibly empty, comma-separated list of assignment expressions. All argument passing is by value, but when an array is passed, its contents may be changed by the function (unless they are `const`). The order of evaluation of the arguments is unspecified; all arguments are evaluated before the function is entered. Recursive function calls are allowed. Also see §D7.6.3.

D7.8.2 Postfix expressions

D7.8.2.1 Indexing vector and array types

Vector types (that is, string or matrix) are indexed by postfixing square brackets. A matrix can have one or two indices, a string only one. In the case of two indices, they are separated by a comma. If a matrix has more than one row or more than one column, two indices must be used.

Note that indexing always starts at one. So a 2×3 matrix has elements:

[1,1] [1,2] [1,3]
[2,1] [2,2] [2,3]

Table D7.3 Result from dot operators

left a	operator	right b	result	computes
int	*op*	int	int	a *op* b
int/double	*op*	double	double	a *op* b
double	*op*	int/double	double	a *op* b
scalar	*op*	matrix $m \times n$	matrix $m \times n$	a *op* b_{ij}
matrix $m \times n$	*op*	scalar	matrix $m \times n$	a_{ij} *op* b
matrix $m \times n$	*op*	matrix $m \times n$	matrix $m \times n$	a_{ij} *op* b_{ij}
matrix $m \times n$	*op*	matrix $m \times 1$	matrix $m \times n$	a_{ij} *op* b_{i0}
matrix $m \times n$	*op*	matrix $1 \times n$	matrix $m \times n$	a_{ij} *op* b_{0j}
matrix $m \times 1$	*op*	matrix $m \times n$	matrix $m \times n$	a_{i0} *op* b_{ij}
matrix $1 \times n$	*op*	matrix $m \times n$	matrix $m \times n$	a_{0j} *op* b_{ij}
matrix $m \times 1$	*op*	matrix $1 \times n$	matrix $m \times n$	a_{i0} *op* b_{0j}
matrix $1 \times n$	*op*	matrix $m \times 1$	matrix $m \times n$	a_{0j} *op* b_{i0}

Table D7.4 Result from relational operators

left a	operator	right b	result	computes
int	*op*	int	int	a *op* b
int/double	*op*	double	int	a *op* b
double	*op*	int/double	int	a *op* b
scalar	*op*	matrix $m \times n$	int	a *op* b_{ij}
matrix $m \times n$	*op*	scalar	int	a_{ij} *op* b
matrix $m \times n$	*op*	matrix $m \times n$	int	a_{ij} *op* b_{ij}
matrix $m \times n$	*op*	matrix $m \times 1$	int	a_{ij} *op* b_{i0}
matrix $m \times n$	*op*	matrix $1 \times n$	int	a_{ij} *op* b_{0j}
matrix $m \times 1$	*op*	matrix $m \times n$	int	a_{i0} *op* b_{ij}
matrix $1 \times n$	*op*	matrix $m \times n$	int	a_{0j} *op* b_{ij}
string	*op*	string	int	a *op* b

Four ways of indexing are distinguished:

indexing type	example
all elements	`m[.,.]`
scalar	`m[1,1]`
expression	`z = {1 2}; m[1,z]`
element-list	`m[1,1:2]`

- A dot selects all elements (all rows for the first index, all columns for the second).
- In the scalar indexing case (allowed for all non-scalar types), the expression inside square brackets must have scalar type, whereby double is converted to integer by discarding the fractional part.

Table D7.5 Result from operators involving an empty matrix as argument

operator	either argument empty	both arguments empty
==	FALSE	TRUE
!=	TRUE	FALSE
>=	FALSE	TRUE
>	FALSE	FALSE
<=	FALSE	TRUE
<	FALSE	FALSE
other	<>	<>

If the index is scalar 0, all rows (first index) or columns (second index) are used; all elements if one index is used on a vector.

- An expression can be used for the index. If the expression evaluates to a a scalar, it is identical to scalar indexing. If it evaluates to a matrix, all elements will be used for indexing.
  A matrix in the first index selects rows, a matrix in the second index selects columns. The resulting matrix is the intersection of those rows and columns.
- An index can be written as a *space* separated list of elements. Such elements must either be scalars, or a range. A range has the form *start-index* : *end-index*. A space inside a parenthesized expression is not a separator.

D7.8.2.2 Transpose

The postfix operators ' and .' take the transpose of a matrix. It has no effect on other arithmetic types of operands. There is only a difference if the operand is a complex matrix.

The following translations are made when parsing OxGauss code:

' *identifier*	into	' * *identifier*
' (	into	' * (
.' *identifier*	into	.' * *identifier*
.' (	into	.' * (

A single quote is also used in a character constant; the context avoids ambiguity.*.

D7.8.2.3 Factorial

The postfix operator ! takes the factorial of the operand (if it is a matrix: of each element). Elements are rounded to the nearest integer before the factorial is applied.

D7.8.3 Power expressions

The operands of the power operator must have arithmetic type, and the result is given in the table. Note that .^ and ^ are always the same. A scalar consists of: int, double or 1×1 matrix.

left a	operator	right b	result	computes
int	^ .^	int or double	int	a^b
int/double	^ .^	double	double	a^b
double	^ .^	scalar	double	a^b
scalar	^ .^	matrix $m \times n$	matrix $m \times n$	$a^{b_{ij}}$
matrix $m \times n$	^ .^	scalar	matrix $m \times n$	a_{ij}^{b}
matrix $m \times n$	^ .^	matrix $m \times n$	matrix $m \times n$	$a_{ij}^{b_{ij}}$

When a and b are integers, then `a ^ b` is an integer if $b \geq 0$ and if the result can be represented as a 32 bit signed integer. If $b < 0$ and $a \neq 0$ or the integer result would lead to overflow, the return type is double, giving the outcome of the floating point power operation.

D7.8.4 Unary expressions

The operand of the unary minus operator must have arithmetic type, and the result is the negative of the operand. For a matrix each element is set to its negative. Unary plus is ignored.

D7.8.5 Multiplicative expressions

The operators `.*.`, `*`, `.*`, `* `, `/`, and `./` group left-to-right and require operands of arithmetic type. A scalar consists of: int, double or 1×1 matrix. These operators conform to Table D7.3, except for:

left a	operator	right b	result	computes
matrix $m \times n$	*	matrix $n \times p$	matrix $m \times p$	$a_{i.}b_{.k}$
matrix $m \times n$	.*.	matrix $p \times q$	matrix $mp \times nq$	$a_{ij}b$
scalar	*	matrix $n \times p$	matrix $n \times p$	ab_{ij}
matrix $m \times n$	*	scalar	matrix $m \times n$	$a_{ij}b$
matrix $m \times n$	*~	matrix $m \times p$	matrix $m \times np$	$a_{1.}b \ldots a_{m.}b$
matrix $m \times n$	/	matrix $m \times p \geq m$	matrix $p \times n$	solve $bx = a$
scalar	/	matrix $m \times n$	matrix $m \times n$	a/b_{ij}
matrix $m \times n$	/	scalar	matrix $m \times n$	a_{ij}/b
scalar	* .*	scalar	double	$a * b$
scalar	/ ./	scalar	double	a/b

This implies that `* .*. *~` are the same as `.*` when one or both arguments are scalar, and similarly for `/` and verb./ when the right-hand operand is not a matrix.

Kronecker product is denoted by `.*.`. If neither operand is a matrix, this is identical to normal multiplication. Direct (horizontal) multiplication is denoted by `* `. The operands must have the same number of rows.

The binary `*` operator denotes multiplication. If both operands are a matrix and neither is scalar, this is matrix multiplication and the number of columns of the first operand has to be identical to the number of rows of the second operand.

The `.*` operator defines element by element multiplication. It is only different from `*` if both operands are a matrix (these must have identical dimensions, however, if one or both of the arguments is a 1×1 matrix, `*` is equal to `.*`).

The binary `/` operator denotes division. If either operand is a scalar, this is identical to the element-by-element division performed by the `./` operator. If both operands are matrices, then the result of a/b is x, where x solves the linear system $bx = a$; a must have the same number of rows as a. (Note the potential for confusion: more logical would be to solve $xb = a$ by a/b.) If b has the same number of columns as a, the system is solved by a LU decomposition with pivoting; if b has more columns, it is equivalent to a least squares problem ($b'bx = b'a$ which is solved by the Choleski decomposition of $b'b$ (rather than the QR decomposition of b).

The `./` operator defines element by element division. If either argument is not a matrix, this is identical to normal division. It is only different from `/` if both operands are a non-scalar matrix, then both matrices must have identical dimensions.

Note that the result of dividing two integers is a double (3 / 2 gives 1.5). Multiplication of two integers also returns a double.

Notice the difference between `2./ m2` and `2 ./ m2`. In the first case, the dot is interpreted as part of the real number `2.`, whereas in the second case it is part of the `./` dot-division operator. The same applies for dot-multiplication, but note that `2.0*m2` and `2.0.*m2` give the same result.

D7.8.6 Additive expressions

The additive operators `+` and `-` are dot-operators, conforming to Table D7.3. They respectively return the sum and the difference of the operands, which must both have arithmetic type. Matrices must be conformant in both dimensions, and the operator is applied element by element. For example:

```
decl m1 = <1,2; 2,1>, m2 = <2,3; 3,2>;

r = 2 - m2;                                    // <0,-1; -1,0>
r = m1 - m2;                                  // <-1,-1; -1,-1>
```

D7.8.7 Modulo expressions

The module operators `%` is a dot-operators, conforming to Table D7.3. It returns the integer remainder remainder when the first operand is divided by the second. Matrices must be conformant in both dimensions, and the operator is applied element by element. Non-integer values are rounded to the nearest integer before applying the operator.

D7.8.8 Concatenation expressions

left	operator	right	result
int/double	~	int/double	matrix 1×2
int/double	~	matrix $m \times n$	matrix $m \times (1+n)$
matrix $m \times n$	~	int/double	matrix $m \times (n+1)$
matrix $m \times n$	~	matrix $p \times q$	matrix $\max(m,p) \times (n+q)$
int/double	|	int/double	matrix 2×1
int/double	|	matrix $m \times n$	matrix $(1+m) \times n$
matrix $m \times n$	|	int/double	matrix $(m+1) \times n$
matrix $m \times n$	|	matrix $p \times q$	matrix $(m+p) \times \max(n,q)$
int	~ |	string	string
string	~ |	int	string
string	~ |	string	string
array	~ |	array	array
array	~ |	any basic type	array

Horizontal concatenation is denoted by `~` while `|` is denoted by vertical concatenation.

If both operands have arithmetic type, the concatenation operators are used to create a larger matrix out of the operands. If both operands are scalar the result is a row vector (for `~`) or a column vector (for `|`). If one operand is scalar, and the other a matrix, an extra column (`~`) or row (`|`) is pre/appended. If both operands are a matrix, the matrices are joined. Note that the dimensions need not match: missing elements are set to zero (however, a warning is printed of non-matching matrices are concatenated). Horizontal concatenation has higher precedence than vertical concatenation.

Two strings or an integer and a string can be concatenated, resulting in a longer string. Both horizontal and vertical concatenation yield the same result.

The result is most easily demonstrated by examples:

```
print(1 ~ 2 ~ 3 | 4 ~ 5 ~ 6);                 // <1,2,3; 4,5,6>
print("tinker" ~ '&' ~ "tailor" );           // "tinker&tailor"
print(<1,0; 0,1> ~ 2);                       // <1,0,2; 0,1,2>
print(2 | <1,0; 0,1>);                       // <2,2; 1,0; 0,1>
print(<2> ~ <1,0; 0,1>);                     // <2,1,0; 0,0,1>
```

When the operands are an address of a function, the result is an array of functions, see §D7.6.3.

D7.8.9 Dot-relational expressions

The dot relational operators are `.<`, `.<=`, `.>`, `.>=`, `.==`, `./=`, standing for 'dot less', 'dot less or equal', 'dot greater', 'dot greater or equal', 'is dot equal to', 'is dot not equal to'.

They conform to Table D7.3, except when both arguments are a string, in which case the result is as for the non-dotted versions.

If both arguments are scalar, the result type inherits the higher type, so `1 >= 1.5` yields a double with value `0.0`. If both operands are a matrix the return value is a matrix with a 1 in each position where the relation is true and zero where it is false. If one of

the operands is of scalar-type, and the other of matrix-type, each element in the matrix is compared to the scalar returning a matrix with 1 at each position where the relation holds.

String-type operands can be compared in a similar way. If both operands are a string, the results is int with value 1 or 0, depending on the case sensitive string comparison.
In `if` statements, it is possible to use matrix values. Remember that a matrix is true if all elements are true (i.e. no element is zero).

D7.8.9.1 Logical dot-NOT expressions

The operand of the logical `.not` operator must have arithmetic type, and the result is 1 if the operand is equal to 0 and 0 otherwise. For a matrix, logical negation is applied to each element.

D7.8.10 Logical dot-AND expressions

The dot-or operator is written as `.\&\&` or `.and`. It returns 1 if both of its operands compare unequal to 0, 0 otherwise. Both operands must have arithmetic type. Handling of matrix-type is as for dot-relational operators: if one or both operands is a matrix, the result is a matrix of zeros and ones. Unlike the non-dotted version, both operands will always be executed. For example, in the expression `func1() .&& func2()` the second function is called, regardless of the return value of `func1()`.

D7.8.11 Logical dot-OR expressions

The dot-or operator is written as `.||` or `.or`. It returns 1 if either of its operands compares unequal to 0, 0 otherwise. Both operands must have arithmetic type. Handling of matrix-type is as for dot-relational operators: if one or both operands is a matrix, the result is a matrix of zeros and ones. Unlike the non-dotted version, both operands will always be executed. For example, in the expression `func1() .|| func2()` the second function is called, regardless of the return value of `func1()`.

D7.8.12 Logical dot-XOR expressions

The dot-or operator is written as `.xor`. It returns 1 if one and only one of the operands compares unequal to 0, 0 otherwise. Both operands must have arithmetic type. Handling of matrix-type is as for dot-relational operators: if one or both operands is a matrix, the expression is evaluated for each element, and the result is a matrix of zeros and ones.

D7.8.13 Logical dot-EQV expressions

The dot-eqv operator is written as `.eqv`. It returns 1 if both operands are unequal to 0 or if both are equal to 0, 0 otherwise. Both operands must have arithmetic type. Handling of matrix-type is as for dot-relational operators: if one or both operands is a matrix, the expression is evaluated for each element, and the result is a matrix of zeros and ones.

D7.8.14 Relational expressions

The relational operators are `<`, `<=`, `>`, `>=`, `==`, `/=`, standing for 'less', 'less or equal', 'greater', 'greater or equal', 'is equal to', 'is not equal to'. They yield 0 if the specified relation is false, and 1 if it is true.

The type of the result is always an integer, see Table D7.4. If both operands are a matrix, the return value is true if the relation holds for each element. If one of the operands is of scalar-type, and the other of matrix-type, each element in the matrix is compared to the scalar, and the result is true if each comparison is true.

String comparison is case sensitive.

D7.8.15 Logical-NOT expressions

The logical negation operator `not` precedes the operand which must be scalar and have arithmetic type. The result is 1 if the operand is equal to 0 and 0 otherwise.

D7.8.16 Logical-AND expressions

Logical and (`&&` or `and` returns the integer 1 if both of its operands compare unequal to 0, and the integer 0 otherwise. Both operands must be scalar and have arithmetic type.

First the left operand is evaluated, if it is false (for a matrix: there is at least one zero element), the result is false, and the right operand will not be evaluated. So in the expression `func1() && func2()` the second function will *not* be called if the first function returned false.*

D7.8.17 Logical-OR expressions

Logical or (`"|"|` or `or` returns the integer 1 if either of its operands compares unequal to 0, integer value 0 otherwise. Both operands must be scalar and have arithmetic type.

First the left operand is evaluated, if it is true, the result is true, and the right operand will not be evaluated. So in the expression `func1() .|| func2()` the second function will *not* be called if the first function returned true.*

D7.8.18 Logical-XOR expressions

Logical `xor` returns the integer 1 if one and only one of the operands compares unequal to 0, integer value 0 otherwise. Both operands must have arithmetic type.

D7.8.19 Logical-EQV expressions

Logical `eqv` returns the integer 1 if both operands are unequal to 0 or if both are equal to 0, integer value 0 otherwise. Both operands must be scalar and have arithmetic type.

D7.8.20 Assignment expressions*

The assignment operator is the = symbols; it is the operator with the lowest precedence. An lvalue is required as the left operand. The type of an assignment is that of its left operand.

D7.8.21 Constant expressions

An expression that evaluates to a constant is required in initializers and certain preprocessor expressions. A constant expression can have the operators `* / + -`, but only if the operands have scalar type.

D7.9 Preprocessing

Preprocessing in OxGauss is used for inclusion of files, conditional compilation of code, and definition of constants. The following preprocessor commands are ignored: `#lineson`, `#linesoff`, `#srcfile`, `#srcline`.*

D7.9.1 File inclusion

A line of the form

`#include "`*filename*`";`

will insert the contents of the specified file at that position. Escape sequences in strings names are *not* interpreted. The string constant does not have to be enclosed in double quotes (the string ends at the first space or semicolon, so use double quotes if the filename contains a space). The ending semicolon is optional. Both forward and backward slashes may be used in filenames.*

The file is searched for as follows:*

1. in the directory containing the source file (if just a filename, or a filename with a relative path is specified), or in the specified directory (if the filename has an absolute path);
2. the directories specified on the compiler command line (if any);
3. the directories specified in the `OX3PATH` environment string (or the default under Windows).
4. in the current directory.

D7.9.2 Conditional compilation

The first step in conditional compilation is to define (or undefine) identifiers:

`#define` *identifier*
`#definecs` *identifier*
`#undef` *identifier*

Identifiers so defined only exist during the scanning process of the input file, and can subsequently be used by `#ifdef` and `#ifndef` preprocessor statements:

`#ifdef` *identifier*
`#ifndef` *identifier*
`#else`
`#endif`

Use `#define` to make a case insensitive definition and `#definecs` for a case sensitive definition. Subsequently `#undef`, `#ifdef`, `#ifndef` will first search for a case sensitive match, if that is not found, it will try to find a case insensitive definition.

Also defined are:

`#ifDOS` TRUE when running under Windows

`#ifOS2WIN`	TRUE when running under Windows
`#ifUNIX`	TRUE when running under UNIX
`#ifLIGHT`	TRUE when running light version
`#ifCPLX`	TRUE if complex matrices supported
`#ifREAL`	TRUE if complex matrices not supported
`#ifDLLCALL`	TRUE if DLL calls supported

D7.9.3 Constant definition

If any text follows the defined constant, all matching occurrences of that text will be replaced by the specified text:

`#define` *identifier replacement_text*
`#definecs` *identifier replacement_text*

For example, after

```
#define MAXVAL 100
```

all instances of `MAXVAL` (including `Maxval`, `maxval`, etc.) will be replaced by 100. Another example is

```
#definecs MINVAL 100+12
```

where `MINVAL` is replaced by the expression `100+12`. Note that macro arguments are not supported, nor is reference to another defined replacement.

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