Syntax — Mata language grammar and syntax

Description

Mata is a C-like compiled-into-pseudocode language with matrix extensions and run-time linking.

Syntax

The basic language syntax is

\[ istmt \]

where

\[ istmt := stmt \]

\[ function \ name(farglist) \ fstmt \]

\[ ftype \ name(farglist) \ fstmt \]

\[ ftype \ function \ name(farglist) \ fstmt \]

\[ stmt := nothing \]

\[ version \ number \ { \ stmt \ . . . } \]

\[ exp \]

\[ pragma \ pstmt \]

\[ if \ (exp) \ stmt \]

\[ if \ (exp) \ stmt \ else \ stmt \]

\[ for \ (exp; \ exp; \ exp) \ stmt \]

\[ while \ (exp) \ stmt \]

\[ do \ stmt \ while \ (exp) \]

\[ break \]

\[ continue \]

\[ label: \]

\[ goto \ label \]

\[ return \]

\[ return(exp) \]

\[ fstmt := stmt \]

\[ type \ arglist \]

\[ external \ type \ arglist \]

\[ arglist := name \]

\[ name() \]

\[ name(), \ arglist \]

\[ name(), \ arglist \]

\[ farglist := nothing \]

\[ efarglist \]
efarglist :=
  felement
  felement, efarglist
  \ felement
  \ felement, efarglist

felement :=
  name
  type name
  name()
  type name()

ftype :=
  type
  void

type :=
  eltype
  orgtype
  eltype orgtype

eltype :=
  transmorphic
  string
  numeric
  real
  complex
  pointer
  pointer(ptrtype)

orgtype :=
  matrix
  vector
  rowvector
  colvector
  scalar

ptrtype :=
  nothing
  type
  type function
  function

pstmt :=
  unset name
  unused name

name :=
  identifier up to 32 characters long

label :=
  identifier up to 8 characters long

exp :=
  expression as defined in [M-2] exp
Remarks and examples

Remarks are presented under the following headings:

- Treatment of semicolons
- Types and declarations
- Void matrices
- Void functions
- Operators
- Subscripts
- Implied input tokens
- Function argument-passing convention
- Passing functions to functions
- Optional arguments

After reading [M-2] Syntax, see [M-2] Intro for a list of entries that give more explanation of what is discussed here.

Treatment of semicolons

Semicolon (;) is treated as a line separator. It is not required, but it may be used to place two statements on the same physical line:

\[
x = 1 \ ; \ y = 2 \ ;
\]

The last semicolon in the above example is unnecessary but allowed.

Single statements may continue onto more than one line if the continuation is obvious. Take “obvious” to mean that there is a hanging open parenthesis or a hanging dyadic operator; for example,

\[
x = ( \\
3 \\
x = x + \\
2
\]

See [M-2] Semicolons for more information.

Types and declarations

The type of a variable or function is described by

\[
eltype \ orgtype
\]

where \( eltype \) and \( orgtype \) are each one of

\[
\begin{array}{ll}
\text{eltype} & \text{orgtype} \\
\text{transmorphic} & \text{matrix} \\
\text{numeric} & \text{vector} \\
\text{real} & \text{rowvector} \\
\text{complex} & \text{colvector} \\
\text{string} & \text{scalar} \\
\text{pointer} & \\
\end{array}
\]
For example, a variable might be real scalar, or complex matrix, or string vector.

Mata also has structures—the eltype is struct name—but these are not discussed here. For a discussion of structures, see [M-2] struct.

Mata also has classes—the eltype is class name—but these are not discussed here. For a discussion of classes, see [M-2] class.

Declarations are optional. When the type of a variable or function is not declared, it is assumed to be a transmorphic matrix. In particular:

1. eltype specifies the type of the elements. When eltype is not specified, transmorphic is assumed.

2. orgtype specifies the organization of the elements. When orgtype is not specified, matrix is assumed.

All types are special cases of transmorphic matrix.

The nesting of eltypes is

```
transmorphic
  numeric
    real
  string
  pointer
    complex
```

orgtypes amount to nothing more than a constraint on the number of rows and columns of a matrix:

<table>
<thead>
<tr>
<th>orgtype</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>matrix</td>
<td>$r \geq 0$ and $c \geq 0$</td>
</tr>
<tr>
<td>vector</td>
<td>$r = 1$ and $c \geq 0$ or $r \geq 0$ and $c = 1$</td>
</tr>
<tr>
<td>rowvector</td>
<td>$r = 1$ and $c \geq 0$</td>
</tr>
<tr>
<td>colvector</td>
<td>$r \geq 0$ and $c = 1$</td>
</tr>
<tr>
<td>scalar</td>
<td>$r = 1$ and $c = 1$</td>
</tr>
</tbody>
</table>

See [M-2] Declarations.

**Void matrices**

A matrix (vector, row vector, or column vector) that is $0 \times 0$, $r \times 0$, or $0 \times c$ is said to be void; see [M-2] void.

The function $J(r, c, val)$ returns an $r \times c$ matrix with each element containing $val$; see [M-5] J(). $J()$ can be used to create void matrices.

See [M-2] void.
Void functions

Rather than `eltype orgtype`, a function can be declared to return nothing by being declared to return `void`:

```mata
void function example(matrix A)
{
    real scalar i
    for (i=1; i<=rows(A); i++) A[i,i] = 1
}
```

A function that returns nothing (does not include a `return(exp)` statement), in fact returns $J(0, 0, .)$, and the above function could equally well be coded as

```mata
void function example(matrix A)
{
    real scalar i
    for (i=1; i<=rows(A); i++) A[i,i] = 1
    return(J(0, 0, .))
}
```

or

```mata
void function example(matrix A)
{
    real scalar i
    for (i=1; i<=rows(A); i++) A[i,i] = 1
    return(J(0, 0,.))
}
```

Therefore, `void` also is a special case of transmorphic matrix (it is in fact a $0 \times 0$ real matrix). Because declarations are optional (but recommended both for reasons of style and for reasons of efficiency), the above function could also be coded as

```mata
function example(A)
{
    for (i=1; i<=rows(A); i++) A[i,i] = 1
}
```

See [M-2] Declarations.

Operators

Mata provides the usual assortment of operators; see [M-2] exp.

The monadic prefix operators are

```mata
- ! ++ -- & *
```

Prefix operators `&` and `*` have to do with pointers; see [M-2] pointers.
The monadic postfix operators are

```
', ++ --
```

Note the inclusion of postfix operator ' for transposition. Also, for Z complex, Z' returns the conjugate transpose. If you want the transposition without conjugation, see [M-5] `transposeonly()`. 

The dyadic operators are

```
= ? \ :: , .. | & == >= <= < > != + - * # ^
```

Also, && and || are included as synonyms for & and |.

The operators == and != do not require conformability, nor do they require that the matrices be of the same type. In such cases, the matrices are unequal (== is false and != is true). For complex arguments, <, <=, >, and >= refer to length of the complex vector. == and !=, however, refer not to length but to actual components. See [M-2] `op_logical`.

The operators , and \ are the row-join and column-join operators. (1,2,3) constructs the row vector (1,2,3)′. (1\2\3) constructs the column vector (1,2,3)′. (1,2\3,4) constructs the matrix with first row (1,2) and second row (3,4). a\b joins two scalars, vectors, or matrices rowwise. a\b joins two scalars, vectors, or matrices columnwise. See [M-2] `op_join`.

.. and :: refer to the row-to and column-to operators. 1..5 is (1,2,3,4,5). 1::5 is (1\2\3\4\5). 5..1 is (5,4,3,2,1). 5:1 is (5\4\3\2\1). See [M-2] `op_range`.

For |, &:, ==, <=, >, !=, +, -, *, /, and ^, there is :op at precedence just below op. These operators perform the elementwise operation. For instance, A*B refers to matrix multiplication; A:*B refers to elementwise multiplication. Moreover, elementwise is generalized to cases where A and B do not have the same number of rows and the same number of columns. For instance, if A is a 1 × c row vector and B is a r × c matrix, then ||C_{ij}|| = ||A_j|| * ||B_{ij}|| is returned. See [M-2] `op_colon`.

Subscripts

A[i,j] returns the i,j element of A.

A[k] returns A[1,k] if A is 1 × c and A[k,1] if A is r × 1. That is, in addition to declared vectors, any 1 × c matrix or r × 1 matrix may be subscripted by one index. Similarly, any vector can be subscripted by two indices.

i, j, and k may be vectors as well as scalars. For instance, A[(3\4\5), 4] returns a 3 × 1 column vector containing rows 3 to 5 of the 4th column.

i, j, and k may be missing value. A[., 4] returns a column vector of the 4th column of A.

The above subscripts are called list-style subscripts. Mata provides a second format called range-style subscripts that is especially useful for selecting submatrices. A[13,3\5,5] returns the 3 × 3 submatrix of A starting at A[3,3].

See [M-2] Subscripts.
Implied input tokens

Before interpreting and compiling a line, Mata makes the following substitutions to what it sees:

<table>
<thead>
<tr>
<th>Input sequence</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>'name'</td>
<td>'*name'</td>
</tr>
<tr>
<td>[ , ]</td>
<td>[ , ]</td>
</tr>
</tbody>
</table>

Hence, coding $X'Z$ is equivalent to coding $X'*Z$, and coding $x = z[1,]$ is equivalent to coding $x = z[1,\,]$.

Function argument-passing convention

Arguments are passed to functions by address, also known as by name or by reference. They are not passed by value. When you code

```plaintext
... f(A) ...
```

it is the address of $A$ that is passed to $f()$, not a copy of the values in $A$. $f()$ can modify $A$.

Most functions do not modify their arguments, but some do. `lud(A, L, U, p)`, for instance, calculates the LU decomposition of $A$. The function replaces the contents of $L$, $U$, and $p$ with matrices such that $L[p,]*U = A$.

Oldtimers will have heard of the FORTRAN programmer who called a subroutine and passed to it a second argument of 1. Unbeknownst to him, the subroutine changed its second argument, with the result that the constant 1 was changed throughout the rest of his code. That cannot happen in Mata. When an expression is passed as an argument (and constants are expressions), a temporary variable containing the evaluation is passed to the function. Modifications to the temporary variable are irrelevant because the temporary variable is discarded once the function returns. Thus if $f()$ modifies its second argument and you call it by coding $f(A, 2)$, because 2 is copied to a temporary variable, the value of the literal 2 will remain unchanged on the next call.

If you call a function with an expression that includes the assignment operator, it is the left-hand side of the expression that is passed. That is, coding

```plaintext
f(a, b=c)
```

has the same result as coding

```plaintext
b = c  
f(a, b)
```

If function $f()$ changes its second argument, it will be $b$ and not $c$ that is modified.

Also, Mata attempts not to create unnecessary copies of matrices. For instance, consider

```plaintext
function changearg(x) x[1,1] = 1  
changearg(mymat)
```

changes the 1,1 element of mymat to 1. Now let us define

```plaintext
function cp(x) return(x)
```
Coding `changearg(cp(mymat))` would still change `mymat` because `cp()` returned `x` itself. On the other hand, if we defined `cp()` as

```plaintext
function cp(x)
{
    matrix t
    t = x
    return(t)
}
```

then coding `changearg(cp(mymat))` would not change `mymat`. It would change a temporary matrix which would be discarded once `changearg()` returned.

### Passing functions to functions

One function may receive another function as an argument using pointers. One codes

```plaintext
function myfunc(pointer(function) f, a, b)
{
    ... (*f)(a) ... (*f)(b) ...
}
```

although the `pointer(function)` declaration, like all declarations, is optional. To call `myfunc()` and tell it to use function `prima()` for `f()`, and 2 and 3 for `a` and `b`, one codes

```plaintext
myfunc(&prima(), 2, 3)
```


### Optional arguments

Functions may be coded to allow receiving a variable number of arguments. This is done by placing a vertical or bar (`|`) in front of the first argument that is optional. For instance,

```plaintext
function mynorm(matrix A, |scalar power)
{
    ...
}
```

The above function may be called with one matrix or with a matrix followed by a scalar.

The function `args()` (see [M-5] `args()`) can be used to determine the number of arguments received and to set defaults:

```plaintext
function mynorm(matrix A, |scalar power)
{
    ...
    (args()==1) power = 2
    ...
}
```

See [M-2] `optargs`.
Reference


Also see

[M-2] Intro — Language definition