

Matlab Programming Guidelines

Joan Solà
LAAS-CNRS

July 8, 2009

Contents

1	Matlab Help	1
2	Code readability	3
2.1	Aligned code reads well!	3
2.2	Line grouping and commenting	4
2.3	Line breaking “...”	5
2.4	Function APIs	5
3	Names of variables	6
4	Jacobians and the chain rule	7
5	Vectorizing structure arrays	8
6	Error messages	10

1 Matlab Help

Prepare your help headers to look really Matlab-like!

```
% FUN One line description with one space between % and FUN.  
%     FUN(X,Y) Longer description, with explanation of function  
%     inputs X and Y and the output. There are 4 spaces between  
%     % and FUN(). The function name is in CAPITAL LETTERS.  
%     Preferably, the input variables X and Y are also in  
%     capital letters.  
%  
%     If the paragraph above is too complex, break it into
```

```

% different paragraphs.
%
% If the list of input arguments is too complex, make a
% list here. Explain ALL input arguments. The list is
% indented another 4 spaces:
%     X:   one Bourbon
%     Y:   one Scotch
%
% FUN(X,Y,Z) explain extra inputs Z here and what they do.
% Explain if they have a default value. If you need to
% make a new list, remember the 4 spaces!
%     Z:   one beer.
%
% [out, OUT_x, OUT_y] = FUN(...) returns the Jacobians
% wrt X and Y. Maybe you have to explain something else.
% You do not need to repeat the input parameters so you
% can use the form [out, OUT_x] = FUN(...), with the (...).
%
% Before saving, select entire paragraphs and do RIGHT
% CLICK, "Wrap selected comments". This equals all line
% lengths to approximately the page width.
%
% See also FUN2, FUN3. Use it exactly like this, "See also "
% + function names in CAPITAL LETTERS. Matlab parses this line
% and will create links to the functions' helps ONLY IF YOU
% FOLLOW THESE GUIDELINE STRICTLY.
%
% (c) 2009 You @ LAAS-CNRS. Make yourself famous. See that
% this comment line is disconnected from the Help body (the
% previous line has no % sign).

```

Here is an example of the use of **'Warp selected comments'**:

BEFORE:

```

% FUN this is not really a function.
% FUN(X,Y) is a function that does not do anything special. It is here just to show
% how it is to
% use 'Warp selected comments'. Just select all the
% paragraph starting at FUN(X,Y). Then do RIGHT CLICK
% and select 'Warp selected comments'.

```

AFTER:

```

% FUN this is not really a function.
% FUN(X,Y) is a function that does not do anything special.
% It is here just to show how it is to use 'Warp selected
% comments'. Just select all the paragraph starting at FUN(X,Y).
% Then do RIGHT CLICK and select 'Warp selected comments'.

```

2 Code readability

2.1 Aligned code reads well!

1. Regularly do CNTRL+A, CNTRL+I to make all the indents look nice.
Example:

```
% BEFORE:
    if a == 1
        b = 4;
    end

% AFTER CTRL+A CTRL+I:
if a == 1
    b = 4;
end
```

2. When using consecutive lines of code, try to vertically align all EQUAL signs. Examples:

```
% GOOD: code reads easy
x          = f(y);
variable = fun(z);
JAC_x      = JAC_y*Y_x;

% BAD: code is a pack
x = f(y);
variable = fun(z);
JAC_x = JAC_y*Y_x;
```

3. Similarly, when commenting multiple lines on the right margin, align comments. Examples:

```
% GOOD: comments read well
x          = f(y);           % these lines
variable = fun(z);           % are all easy
JAC_x      = JAC_y*Y_x;      % to read

% BAD: comments are packed within the code
x          = f(y); %these lines
variable = fun(z); % are not easy
JAC_x      = JAC_y*Y_x; % to read
```

- Exceptions are accepted, but use common sense. Examples

```
% GOOD: all possible alignments coincide
x      = f(y);           % these comments are aligned
variable = g(z);         % with the fourth line.
JAC_x   = JAC_y*Y_x + JAC_a*A_variable*VARIABLE_x; % Oops!
output  = JAC_x*P*JAC_x'; % this defines the alignment above.
extra   = I*dont*know;    % over all it is easy to read.

% NOT SO GOOD, BUT OK: alignments come in groups
x      = f(y);           % these comments are NOT aligned
variable = g(z);         % with the fourth and fifth lines.
JAC_x   = JAC_y*Y_x + Z_a*A_variable*VARIABLE_x; % Oops!
output  = JAC_x*P*JAC_x'; % this margin is new
extra   = I*dont*know;    % over all it is easy to read.
```

- Still, you can try to align consecutive groups of lines. Example

```
x      = f(y);           % these comments aligned,
variable = g(z);         % and the alignment
output  = JAC_x*P*JAC_x'; % continues in next group

y      = 4;              % this follows the same alignment
extra   = 5*eye(3);      % over all it is easy to read.
```

2.2 Line grouping and commenting

- Comment every group of lines performing a coherent action before the group. Example:

```
% get idps to delete
used      = [Lmk.used];
idps      = strcmp({Lmk.type}, 'idpPnt');
drawn     = (strcmp((get([MapFig.estLmk.ellipse], 'visible')), 'on'))';
delIdps   = drawn & idps & ~used;
```

- Comment individual lines on the right if more info is needed. Example:

```
% get idps to delete
used      = [Lmk.used];           % used lmks
idps      = strcmp({Lmk.type}, 'idpPnt'); % inverse-depth landmks
delIdps   = drawn & idps & ~used;  % to be deleted
```

3. Separate small groups of lines with an empty line so that the code does not look packed. As a rule, no more than 4 lines should go together.

2.3 Line breaking “...”

Make exceptional use of line breaking “...”, particularly when functions have long names or many long parameters:

```
[out, OUT_x, OUT_y, OUT_z, OUT_par, OUT_calibration] = ...  
  functionNameThatMightBeVeryLong(...  
    Lmk.state.x,...           % you can put  
    Sen(4).par.y,...          % comments here  
    Obs(sen,lmk).nom.N,...    % if necessary  
    Sen(4).par.k,...          % to explain the  
    Sen(4).par.cal);          % input data
```

See `userData.m`, `createMapFig.m` to see examples of this.

2.4 Function APIs

Matlab functions accept multiple input, multiple output arguments. Please follow these simple rules:

1. Order the input and output arguments according to this list:

```
Rob, Sen, Raw, Lmk, Obs, Tim, ...  
SimRob, SimSen, SimObs, ...  
MapFig, SenFig, ...  
Opt, SimOpt, FigOpt, ...  
other.
```

Remember that **Map** is global and it does not need to be given as argument.

2. Use the same input and output names and scopes when calling functions that update fields:

```
[Rob(rob), Sen(sen), Lmk, Obs(sen,:)] = ...  
  myFunction(Rob(rob), Sen(sen), Lmk, Obs(sen,:), Opt)
```

3 Names of variables

For convention, we are going to do the following:

1. Variables inside functions have short names in small letters normally.
2. Robot, sensor, landmark etc INDICES are always **rob**, **sen**, **lmk**: For example,

```
Rob(rob).rob      = rob;  
Obs(sen, lmk).sen = sen;
```

3. Robot, sensor, landmark etc IDENTIFIERS are **rid**, **sid**, **lid**. For example,

```
rid = Rob(rob).id;  
sid = Sen(sen).id;  
  
Obs(sen, lmk).sid = sid;
```

4. Jacobians are **BIG.small**, where $\mathbf{Y.x} = d\mathbf{y}/d\mathbf{x}$.
Jacobians are not \mathbf{Yx} , better $\mathbf{Y.x}$.
5. Gaussian variables have mean and covariances matrix. As a general rule, we use **small** for the mean and **BIG** for the covariances. Examples

```
e      % expectation  
E      % expectation covariance  
  
z      % innovation  
Z      % Innovation covariance  
  
idp    % inverse depth point  
IDP    % inverse depth point covariance
```

6. Known exceptions to the previous rule correspond to classic EKF notations:

```
x      % state vector  
P      % state covariance
```

```

y      % measurement
R      % measurement covariance

```

7. Cross-variances depend on two variables and cannot follow the previous rule. We switch then to this other $\{\mathbf{x}, \mathbf{P}\}$ notation:

```

a      % mean of a
idp     % mean of idp
P_AA   % covariance of a
P_IDPIDP % covariance of idp
P_AIDP % cross-variance of a and idp

```

4 Jacobians and the chain rule

Systematically make use of the chain rule when constructing Jacobians. While MAPLE code may be faster to compute in some cases, the chain rule permits a modular organization and a better comprehension of the code. Both features are crucial in a toolbox because they allow us to modify parts of the code without compromising the rest.

Follow these guidelines:

1. Name all Jacobians as specified in the previous section, that is, if $\mathbf{y} = \mathbf{f}(\mathbf{x})$ then $\mathbf{Y}_\mathbf{x} = \mathbf{dy}/\mathbf{dx}$
2. Build functions returning output variable and optional Jacobians. Here is an example:

```

function [z, Z_x, Z_y] = f(x, y)

z = sin(x-y);          % this is the output value
if nargin > 1          % Jacobians requested
    Z_x = cos(x-y);    % this is dz/dx
    Z_y = -cos(x-y);   % this is dz/dy
end

```

3. Use the chain rule for functions using other functions. Keep the Jacobians optional. Example:

```

function [q, Q_a, Q_b, Q_c] = g(a, b, c)

```

```

if nargout == 1      % No Jacobians requested
    q = h(a, f(b,c)); % compose functions f() and h().
else                % Jacobians requested
    [p, P_b, P_c] = f(b, c); % This uses function f() above.
    [q, Q_a, Q_p] = h(a, p); % This uses function h().

    Q_b = Q_p*P_b;      % This is the chain rule
    Q_c = Q_p*P_c;      % to compose Jacobians.
end

```

4. Observe how the chain rule ‘chains’ Jacobians by matching leading and trailing name parts. The leading and trailing parts of the whole chain define the resulting Jacobian name. Examples:

```

LEAD_trail    = LEAD_x * X_trail ;

FOURTH_first  = FOURTH_third * THIRD_first ;
FOURTH_second = FOURTH_third * THIRD_second ;

```

5. Long chains and multi-path chains are possible (multi-path chains are seldom):

```

Z_w = Z_y * Y_x * X_w;      % a chain of three elements
D_a = D_b * B_a + D_c * C_a; % a chain with two paths

```

5 Vectorizing structure arrays

In the toolbox code it is usual to check different flags on the structure arrays as a whole. Here is a typical example:

```

% this code clears all landmarks in Lmk()
for lmk = find([Lmk.used])
    Lmk(lmk).used = false;
end

```

In the code above, the expression `[Lmk.used]` collects in a vector all the `.used` flags in each member of the structure array `Lmk()`. For example:

```

% if Lmk() is such that

```



```

Lmk(1).used = true;
Lmk(2).used = false;
Lmk(3).used = true;
% then we have
[Lmk.used]
ans =
     1     0     1
% and
find([Lmk.used])
ans =
     1     3
% so that the loop
for lmk = find([Lmk.used])
    lmk
    Lmk(lmk) = something();
end
% prints the indices of the landmarks in Lmk()
% that are being affected by something()
lmk =
     1
lmk =
     3
% See also FOR.

```

Use the following guidelines for vectorizing structure array fields:

1. Use vectorization to obtain arrays. Examples:

```

% 3 logical vectors
used = [Lmk.used];
vis = [Obs(sen,:).vis];
drawn = (strcmp(get([MapFig.estLmk.ellipse], 'visible')), 'on'))';

% a numeric vector of IDs
lmkIds = [Lmk.id];

```

2. If the field you want to access is a string, try this

```

idps = strcmp({Lmk.type}, 'idpPnt') % a logical vector

```

3. Operate with the logicals to get new logicals. Example:

```

erase = ~vis & drawn;
usedIdps = used & idps;

```

4. When setting logicals individually, always use **true/false**, not **1/0**:

```
Obs(1).vis = true;    % Do not use 1 instead of true, otherwise
Obs(2).vis = false;  % you turn the whole vector to numeric.
```

5. You can access an array directly with the logical vector

```
Lmk(used)    % all the Lmk's that are used
```

6. You can get the indices with **FIND**

```
usedIdx = find(used);
```

7. You can also access an array with indices, of course:

```
Lmk(usedIdx)    % this is equivalent to Lmk(used)
```

8. If you want the first N unused **Lmk**'s, do for example

```
Lmk(find(~used,N,'first'))
```

or, easier to read:

```
notUsed = find(~[Lmk.used]);
Lmk(notUsed(1:N));
```

6 Error messages

Be kind to your fellows and stick to Matlab standards. The line:

```
error('??? Unknown sensor type','%s'.',Sen(sen).type)
```

gives a 'nice' Matlab error message (the second line is ours!):

```
??? Error using ==> createSensors at 46
```

```
??? Unknown sensor type 'pinPole'.
```

```
Error in ==> createSLAMstructures at 10  
Sen = createSensors(Sensor);
```

```
Error in ==> slamtb at 38  
[Rob,Sen,Lmk,Obs,Tim] = createSLAMstructures(...
```